NATIONAL CERTIFICATE IV

Water Supply System Operation & Maintenance

Student
Learning
Materials

TVET Authority

Ministry of Environment

ACKNOWLEDGEMENT

TVET Authority wishes to thank Ministry of Environment for facilitating development of the Occupational Standard and Instructional Materials for Water & Sewerage Courses through the Green Climate Fund.

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INSTRUCTION TO TRAINERS

Competency Based Training (CBT) and assessment - An introduction for trainers
Learning Materials presented here can be used to deliver competency based training using the National Competency Standard developed for the respective occupation.

Competency
Competency refers to the ability to perform particular tasks and duties to the standard of performance expected in the workplace. It requires the application of specified knowledge, skills and attitudes relevant to effective participation, consistently over time and in the workplace environment. The essential skills and knowledge are either identified separately or combined.

Knowledge identifies what a person needs to know to perform the work in an informed and effective manner.

Skills describe the application of knowledge to situations where understanding is converted into a workplace outcome.

Attitude describes the founding reasons behind the need for certain knowledge or why skills are performed in a specified manner. Competency covers all aspects of workplace performance and involves:

- Performing individual tasks
- Managing a range of different tasks
- Responding to contingencies or breakdowns
- Dealing with the responsibilities of the workplace
- Working with others.

Unit of Competency
Like with any training qualification or program, a range of subject topics are identified that focus on the ability in a certain work area, responsibility or function. Each manual focuses on a specific unit of competency that applies in the hospitality workplace. In this manual a unit of competency is identified as a "unit‟. Each unit of competency identifies a discrete workplace requirement and includes:

- Knowledge and skills that underpin competency
- Language, literacy and numeracy
- Occupational health and safety requirements.

Each unit of competency must be adhered to in training and assessment to ensure consistency of outcomes.

Element of Competency
An element of competency describes the essential outcomes within a unit of competency. The elements of competency are the basic building blocks of the unit of competency. They describe in terms of outcomes the significant functions and tasks that make up the competency. In this manual elements of competency are identified as an "element‟.

Performance criteria
Performance criteria indicate the standard of performance that is required to demonstrate achievement within an element of competency. The standards reflect identified industry skill needs. Performance criteria will be made up of certain specified skills, knowledge and attitudes.

Learning
For the purpose of this manual learning incorporates two key activities:
- Training
- Assessment.

Both of these activities will be discussed in detail in this introduction.

Today training and assessment can be delivered in a variety of ways. It may be provided to participants:
- On-the-job – in the workplace
- Off-the-job – at an educational institution or dedicated training environment
- As a combination of these two options.

No longer is it necessary for learners to be absent from the workplace for long periods of time in order to obtain recognized and accredited qualifications.

Learning Approaches
Student learning materials developed here can support delivery of training and the expected learning can be facilitated through the following avenues:

Competency Based Training (CBT)
This is the strategy of developing a participant's competency. Educational institutions utilize a range of training strategies to ensure that participants are able to gain the knowledge and skills required for successful:
- Completion of the training program or qualification
- Implementation in the workplace.

The strategies selected should be chosen based on suitability and the learning styles of participants.

Competency Based Assessment (CBA)
This is the strategy of assessing competency of a participant. Educational institutions utilize a range of assessment strategies to ensure that participants are assessed in a manner that demonstrates validity, fairness, reliability, flexibility and fairness of assessment processes.

Flexibility in Learning
Even with the use of this book, it is important to note that flexibility in training and assessment strategies is required to meet the needs of participants who may have learning difficulties. The strategies used will vary, taking into account the needs of individual participants with learning difficulties. However they will be applied in a manner which does not discriminate against the participant or the participant body as a whole.

Catering for Participant Diversity
Participants have diverse backgrounds, needs and interests. When planning training and assessment activities to cater for individual differences, trainers and assessors should:
- Consider individuals' experiences, learning styles and interests
- Develop questions and activities that are aimed at different levels of ability
- Modify the expectations for some participants
- Provide opportunities for a variety of forms of participation, such as individual, pair and small group activities

- Assess participants based on individual progress and outcomes.

The diversity among participants also provides a good reason for building up a learning community in which participants support each other's learning.

Participant Centered Learning

This involves taking into account structuring training and assessment that:

- Builds on strengths – Training environments need to demonstrate the many positive features of local participants (such as the attribution of academic success to effort, and the social nature of achievement motivation) and of their trainers (such as a strong emphasis on subject disciplines and moral responsibility). These strengths and uniqueness of local participants and trainers should be acknowledged and treasured
- Acknowledges prior knowledge and experience – The learning activities should be planned with participants‟ prior knowledge and experience in mind
- Understands learning objectives – Each learning activity should have clear learning objectives and participants should be informed of them at the outset. Trainers should also be clear about the purpose of assignments and explain their significance to participants
- Teaches for understanding – The pedagogies chosen should aim at enabling participants to act and think flexibly with what they know
- Teaches for independent learning – Generic skills and reflection should be nurtured through learning activities in appropriate contexts of the curriculum. Participants should be encouraged to take responsibility for their own learning
- Enhances motivation – Learning is most effective when participants are motivated. Various strategies should be used to arouse the interest of participants
- Makes effective use of resources – A variety of teaching resources can be employed as tools for learning
- Maximizes engagement – In conducting learning activities, it is important for the minds of participants to be actively engaged
- Aligns assessment with learning and teaching – Feedback and assessment should be an integral part of learning and teaching
- Caters for learner diversity – Trainers should be aware that participants have different characteristics and strengths and try to nurture these rather than impose a standard set of expectations.

Active Learning

The goal of nurturing independent learning in participants does not imply that they always have to work in isolation or solely in a classroom. On the contrary, the construction of knowledge in tourism and hospitality studies can often best be carried out in collaboration with others in the field. Sharing experiences, insights and views on issues of common concern, and working together to collect information through conducting investigative studies in the field (active learning) can contribute a lot to their eventual success.

Active learning has an important part to play in fostering a sense of community in the class. First, to operate successfully, a learning community requires an ethos of acceptance and a sense of trust among participants, and between them and their trainers. Trainers can help to foster acceptance and trust through encouragement and personal example, and by allowing participants to take risks as they explore and articulate their views, however immature these may appear to be. Participants also come to realize that their classmates (and their trainers) are partners in learning and solving.
Trainers can also encourage cooperative learning by designing appropriate group learning tasks, which include, for example, collecting background information, conducting small-scale surveys, or

producing media presentations on certain issues and themes. Participants need to be reminded that, while they should work towards successful completion of the field tasks, developing positive peer relationships in the process is an important objective of all group work.

Competency Based Training (CBT)

Principle of Competency Based Training

Competency based training is aimed at developing the knowledge, skills and attitudes of participants, through a variety of training tools.

Training Strategies

The aims of this curriculum are to enable participants to:

- Undertake a variety of subject courses that are relevant to industry in the current environment
- Learn current industry skills, information and trends relevant to industry
- Learn through a range of practical and theoretical approaches Be able to identify, explore and solve issues in a productive manner
- Be able to become confident, equipped and flexible managers of the future
- Be „job ready‟ and a valuable employee in the industry upon graduation of any qualification level.
- To ensure participants are able to gain the knowledge and skills required to meet competency in each unit of competency in the qualification, a range of training delivery modes are used.

Types of Training

In choosing learning and teaching strategies, trainers should take into account the practical, complex and multi-disciplinary nature of the subject area, as well as their participant's prior knowledge, learning styles and abilities. Training outcomes can be attained by utilizing one or more delivery methods:

Lecture/Tutorial

This is a common method of training involving transfer of information from the trainer to the participants. It is an effective approach to introduce new concepts or information to the learners and also to build upon the existing knowledge. The listener is expected to reflect on the subject and seek clarifications on the doubts.

Demonstration

Demonstration is a very effective training method that involves a trainer showing a participant how to perform a task or activity. Through a visual demonstration, trainers may also explain reasoning behind certain actions or provide supplementary information to help facilitate understanding.

Group Discussions

Brainstorming in which all the members in a group express their ideas, views and opinions on a given topic. It is a free flow and exchange of knowledge among the participants and the trainer. The discussion is carried out by the group on the basis of their own experience, perceptions and values. This will facilitate acquiring new knowledge. When everybody is expected to participate in the group discussion, even the introverted persons will also get stimulated and try to articulate their feelings.

The ideas that emerge in the discussions should be noted down and presentations are to be made by the groups. Sometimes consensus needs to be arrived at on a given topic. Group discussions are to be held under the moderation of a leader guided by the trainer. Group discussion technique triggers thinking process, encourages interactions and enhances communication skills.

Role Play
This is a common and very effective method of bringing into the classroom real life situations, which may not otherwise be possible. Participants are made to enact a particular role so as to give a real feel of the roles they may be called upon to play. This enables participants to understand the behavior of others as well as their own emotions and feelings. The instructor must brief the role players on what is expected of them. The role player may either be given a ready-made script, which they can memorize and enact, or they may be required to develop their own scripts around a given situation. This technique is extremely useful in understanding creative selling techniques and human relations. It can be entertaining and energizing and it helps the reserved and less literate to express their feelings.

Simulation Games
When trainees need to become aware of something that they have not been conscious of, simulations can be a useful mechanism. Simulation games are a method based on "here and now" experience shared by all the participants. The games focus on the participation of the trainees and their willingness to share their ideas with others. A "near real life" situation is created providing an opportunity to which they apply themselves by adopting certain behaviour. They then experience the impact of their behaviour on the situation. It is carried out to generate responses and reactions based on the real feelings of the participants, which are subsequently analyzed by the trainer.

While use of simulation games can result in very effective learning, it needs considerable trainer competence to analyses the situations.

Individual /Group Exercises
Exercises are often introduced to find out how much the participant has assimilated. This method involves imparting instructions to participants on a particular subject through use of written exercises. In the group exercises, the entire class is divided into small groups, and members are asked to collaborate to arrive at a consensus or solution to a problem.

Case Study
This is a training method that enables the trainer and the participant to experience a real life situation. It may be on account of events in the past or situations in the present, in which there may be one or more problems to be solved and decisions to be taken. The basic objective of a case study is to help participants diagnose, analyses and/or solve a particular problem and to make them internalize the critical inputs delivered in the training. Questions are generally given at the end of the case study to direct the participants and to stimulate their thinking towards possible solutions. Studies may be presented in written or verbal form.

Field Visit
This involves a carefully planned visit or tour to a place of learning or interest. The idea is to give first-hand knowledge by personal observation of field situations, and to relate theory with practice. The emphasis is on observing, exploring, asking questions and understanding. The trainer should remember to brief the participants about what they should observe and about the customs and norms that need to be respected.

Group Presentation
The participants are asked to work in groups and produce the results and findings of their group work to the members of another sub-group. By this method participants get a good picture of each other's views and perceptions on the topic and they are able to compare them with their own point of view. The pooling and sharing of findings enriches the discussion and learning process.

Practice Sessions
This method is of paramount importance for skills training. Participants are provided with an opportunity to practice in a controlled situation what they have learnt. It could be real life or through a make-believe situation.

Games
This is a group process and includes those methods that involve usually fun-based activity, aimed at conveying feelings and experiences, which are everyday in nature, and applying them within the game being played. A game has set rules and regulations, and may or may not include a competitive element. After the game is played, it is essential that the participants be debriefed and their lessons and experiences consolidated by the trainer.

Research
Trainers may require learners to undertake research activities, including online research, to gather information or further understanding about a specific subject area.

As National Competency Standards require Competency Based Assessment, following paragraphs provide an overview of the Competency Based Assessment.

Competency Based Assessment (CBA)

Principle of Competency Based Assessment
Competency based assessment is aimed at compiling a list of evidence that shows that a person is competent in a particular unit of competency. Competencies are gained through a multitude of ways including:

- Training and development programs
- Formal education
- Life experience
- Apprenticeships
- On-the-job experience
- Self-help programs.

All of these together contribute to job competence in a person. Ultimately, assessors and participants work together, through the „collection of evidence‟ in determining overall competence. This evidence can be collected:

- Using different formats
- Using different people
- Collected over a period of time.

The assessor, who is ideally someone with considerable experience in the area being assessed, reviews the evidence and verifies the person as being competent or not.

INSTRUCTIONS TO CANDIDATE

Introduction to trainee manual

Congratulations on joining this course. The "Student Learning Materials" developed and compiled here is a complete resource book developed in alignment to the respective National Competency Standard and hence will support the students to learn and understand comprehensive theoretical aspects related to the standard. This "Student Learning Materials" will be used for student learning and the method of instruction is called Competency Based Skill Training (CBST).

Aim of the training is to enable trainees to perform tasks and duties at a standard expected by employers. CBT seeks to develop the skills, knowledge and attitudes (or recognize the ones the trainee already possesses) to achieve the required competency standard.

While progressing with the training, make sure you participate with ongoing sessions and systematically develop the required theoretical knowledge and make sure to develop the theoretical competencies in all the units prescribed in the relevant National Competency Standard. Once each competency unit is learnt or the full set of competency units are covered, you may register and undertake the assessment. Do note that, formal assessments related to the TVET programs of Maldives are done by the TVET Authority and the assessments are undertaken within the principles of Competency Based Assessment.

CBA (Competency Based Assessment) involves collecting evidence and making a judgment of the extent to which a worker can perform his/her duties at the required competency standard.

What is a competency standard?

Competency standards are descriptions of the skills and knowledge required to perform a task or activity at the level of a required standard. You will find a description of each competency at the beginning of each Unit. The unit descriptor describes the content of the unit you will be studying in the Manual and provides a table of contents which are divided up into 'Elements' and its 'Performance Criteria'

An element is a description of one aspect of what has to be achieved in the workplace. The 'Performance Criteria' details the level of performance that needs to be demonstrated to be declared competent. There are other components of the competency standard:

- Unit Title: statement about what is to be done in the workplace
- Unit Number: unique number identifying the particular competency
- Contact hours: number of classroom or practical hours usually needed to complete the competency. We call them 'nominal' hours because they can vary e.g. sometimes it will take an individual less time to complete a unit of competency because he/she has prior knowledge or work experience in that area.

Competency based assessment requires trainees to be assessed in at least 2 – 3 different ways, one of which must be practical. Assessments will be carried out and includes work projects, written questions and oral questions. Your trainer and/or assessor may also use other assessment methods including 'Observation Checklist' and 'Third Party Statement'. An observation checklist is a way of recording how you perform at work and a third party statement is a statement by a supervisor or employer about the degree of competence they believe you have achieved. This can be based on observing your workplace performance, inspecting your work or gaining feedback from fellow workers.

Your trainer and/or assessor may use other methods to assess you such as:

- Journals
- Oral presentations
- Role plays
- Log books
- Group projects
- Practical demonstrations.

Remember your trainer is there to help you succeed and become competent. Please feel free to ask them for more explanation of what you have just read and of what is expected from you and best wishes for your future studies and future career.

UNIT 01

WRITE TECHNICAL REPORTS

This unit covers the competence to identify and analyse requirements, to plan and conduct research, to evaluate information and findings, and to develop, document and present technical reports

PLAN RESEARCH AND WRITE PROPOSAL

With the planned engineering qualification, it is important that develop the knowledge and skills on undertaking small research projects that could be system of study, or an engineering part and follow the standard process of writing research or project proposal, conducting research and finally writing the report and presenting them.

Purposes of a Proposal

The project or research proposal:

- ✓ Allows the writer to clarify what it is he/she wants to do, why and how he/she wants to do it,
- ✓ Presents what she/he wants to do in the manner and timeframe proposed, and
- ✓ Once approved, provides a written contract between the student and the project supervisor

Components of a Project Proposal

1. **Title**

The title of the project is very significant. It will go on the spine of the published document when it is bound and becomes accessible in the University of Lethbridge Library. The title is one of the ways that people using the University of Lethbridge electronic search engine will locate the project in the holdings. The title must be clear, appropriate for the topic and less than 45 characters, including spaces and punctuation.

2. **Introduction (WHAT is this about?)**

The Introduction to the project provides a general introduction to the phenomena or issue of interest, and is usually contained in 2 pages. The issue or problem under investigation is described, and background and/or context for understanding the nature of the issue is provided. In writing this section, students should provide answers to two main questions:

What is the project all about?
Why is the project important or worthwhile?
The Introduction will also typically conclude with a brief description of the structure of the remainder of the document.

3. **Research Question (WHAT am I trying to find out? WHY?)**

Every project must state a research question or a statement on what is the intent of the project. It is not a "null-hypothesis statement" but rather you are stating the big, overarching question that is guiding your study. Several smaller questions may even be nested in the larger one.

The research question and the title are two required elements of all proposals. The connections between the two must be obvious. (Hopefully, they are obvious to the writer, but they may not be to the audience.)

Where the research question appears in the proposal is something each writer must decide. It could appear in the introduction; it could follow the introduction or the background or the literature review or it could appear within any of the above sections. Just don't leave it until the reference section!

4. **Method (HOW? WHO? WHERE?)**

(This section must make sense within the context of the document and be linked with the sections preceding it.) In this section provide a clear, explicit and thorough description of how you will complete your project and the timetable for completing each step. For example, what databases will you be using during your literature review? What search terms and exclusion criteria will you be using? When will you be starting your literature review and when will it be finished?

It is the writer's responsibility to ensure that the proposal is clear about what is being proposed, with whom, where and when. (WHY should already have been explained.) Approximately 1-2 paragraphs is suitable for this section.

A project does not involve interviewing people or collecting raw data as this type of collection of data would require ethics approval and a host of other documents would need to be created such as informed consent.

This section needs to include a statement that you will adhere to an approved code of ethics of your selection.

5. **Project (What do I do when I'm done doing what I said I would do?)**

Describe what the final product will look like. For example, if it is a manual, provide details about the manual's length, formatting style, number of lessons, etc. If the product is to be something creative and other than text, provide examples of what the final product might look like. If the proposal includes writing a series of fictionalized autobiographical accounts, a sample should be included in the proposal. If the proposal includes a website describe it.

Title Page
Acknowledgements Page
Abstract
Table of Contents
Chapter 1: Overview (proposed number of pages:)
Sub headings:
a.
b.
c.
Chapter 2: Review of Literature (proposed number of pages:)
Sub headings:
a.
b.
c.
Chapter 3: Methods (proposed number of pages:)
Chapter 4: Outcome
a.
b.
c.
Chapter 5: Synthesis
a. Strengths
b. Limitations
c. Recommended Future Research

References

6. **Timeline Include a draft timeline from start to finish.**

Start with the proposed convocation date and work backwards to revising the final draft of project (expect at least two to three rewrites). Availability of the supervisor is also very important to consider and factor in to your timeline.

7. **References**

References to anything cited in the text of the proposal must adhere to APA guidelines. (As a matter of fact the entire proposal needs to adhere to APA guidelines). APA formatting requires only those materials cited or referred to in the text be listed in the References. A separate section entitled "Bibliography" lists other materials (books, journal articles, etc.) related to the project but not specifically referred to in the document.

CONDUCT RESEARCH AND ANALYSE THE INFORMATION

The research plan shall detail completely the prosecution of the research, including the submission of an acceptable final report. The plan ultimately becomes a part of the contract by reference of the proposal; therefore, it should describe, in a specific and straightforward manner, the proposed approach to the solution of the problem described in the project statement. It should be concise, yet include sufficient detail to describe completely the approach to the solution of the problem. Research methodology shall be described in sufficient detail to permit evaluation of the probability of success in achieving the objectives.

The research plan shall be subdivided into the following sections:

Introduction

The introduction to the research plan should provide a concise overview of the proposer's approach to conducting research. It should describe the manner in which the expertise and experience of the proposed team will be used in the research, and the application of special data, facilities, contacts or equipment should be presented. The Introduction should highlight the linkages of the proposed team's capabilities to the project tasks and the manner by which the proposed plan will satisfy the objectives.

Research Approach

This section will be used to describe how the objectives will be achieved through a logical, innovative, and rational scientific plan. The plan shall describe each phase or task of the research to be undertaken.

Equipment and Facilities

This section shall include a description of the facilities available to undertake the research and an itemization of the equipment on hand considered necessary to complete the research. In the event that use of the facilities or equipment is conditional, the conditions should be described. In the event that certain facilities or equipment are considered necessary to undertake the research but are not on hand, that fact should be presented. The proposer should identify any arrangements that will be made to borrow or rent necessary equipment. In the case where it is contemplated that additional equipment will be purchased under project funds, be certain that the budget item "capital equipment" indicates this.

Time Requirements

The time required to complete the research project shall be specified. Proposals will not be rejected if the proposed time does not match the time specified in the project statement. However, the agency must justify any difference. In addition, a schedule shall be included that shows each phase or task of the work, when that phase or task will begin, how long it will continue, and when it should end. The timetable should clearly delineate the points in time where project deliverables and reports are planned

Research Work Plan

In the absence of specific requirements for the format and content of the research work plan, the following constitutes a useful outline:

- ✓ Title
- ✓ Introduction
- ✓ Objectives
- ✓ Research Approach
- ✓ Project Team
- ✓ Equipment and Facilities
- ✓ Budget
- ✓ Schedule
- ✓ Anticipated Results
- ✓ Implementation

The introduction provides background information taken from the Problem Statement or the Request for Proposals. It is included because the work plan should be a "stand-alone" document, i.e. the reader should not need to refer to other documents. The objectives also should be a re-statement of the objectives from the earlier documents. The 'Research Approach' is the largest section in the work plan. It should present the hypothesis, and describe and justify the strategy, which is being employed to satisfy the objectives. For instance it could be a desk study comprising literature review and analysis, laboratory studies, field studies, or a combination of approaches. It is usual to divide the work into tasks, each of which constitutes a milestone in the completion of the work. For example, if the study involves writing a state-of-the-art report, the tasks might be:

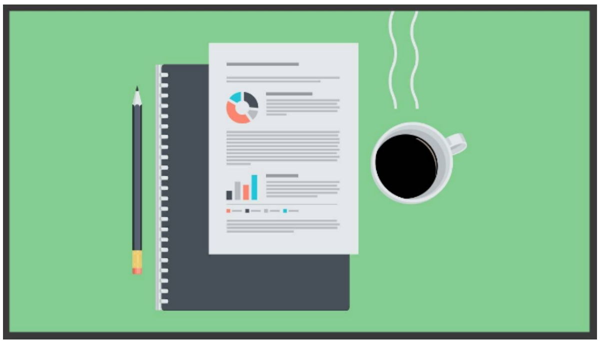
- ✓ Task 1 Literature Survey
- ✓ Task 2 Questionnaire
- ✓ Task 3 Field Visits
- ✓ Task 4 Preparation of First Draft
- ✓ Task 5 Preparation of Second Draft
- ✓ Task 6 Preparation of Final Draft

For each task the activities should be described in detail. In Task 1 the search strategy and the databases should be described. In Task 2 the recipients of the questionnaire should be identified. If it is known which agencies will be included in the field visits in Task 3, they should be identified, otherwise it should be made clear how the decision would be made. In Task 4, the scope and intended audience should be identified, and a tentative outline of the report provided. The work plan should also state who would review each of the drafts.

In the case of a project that involves experimental work and developing the plans for subsequent fieldwork, the tasks might be as follows:

- ✓ Task 1 Literature Survey
- ✓ Task 2 Laboratory Studies
- ✓ Task 3 Exposure Plot Studies
- ✓ Task 4 Development of Field Study Design
- ✓ Task 5 Preparation of Final Report

Task 1 would be described as in the previous example. Task 2 will probably consist of sub-tasks, each comprising a series of experiments. The experiments should be described in detail. This allows the principal investigator to ensure that the necessary people, equipment and laboratory facilities will be available to perform the work, and to calculate the cost of the work. This will usually be an iterative process that involves determining how many experiments can be performed within the available budget. It is essential that the principal investigator be confident that the experiments being performed will be sufficient to satisfy the objectives for the task. It is also good practice to identify a strategy to be followed if the experimental work is not completely successful, e.g. are there other test procedures that could be used? The work plan should describe clearly what would have been accomplished before Task 3 begins, the way in which the work in Task 3 will be influenced by the results obtained in Task 2, and the manner in which the results will be reported. The activities in Task 3 should be described in the same way as for Task 2, except that they will be more tentative because it is likely that many details cannot be finalized until results from Task 2 become available. Because it is a plan that is being written, it is inevitable that less detail can be provided for the later activities. One of the key roles of the principal investigator is to recognize when changes in the work plan are necessary, and to modify the plan accordingly. The good researcher will maintain flexibility in the work plan to deal with setbacks, and to seize opportunities, while planning in sufficient detail to estimate resources, and to make arrangements for activities which require a long lead time.



In the example given, Task 4 consists of developing a design for a field study to verify the results of Tasks 2 and 3 under real world conditions, not performing the field work itself. The specific details will depend on the results of Tasks 1 to 3, but the plan should contain the following sections:

- ✓ Hypothesis to be tested on field studies
- ✓ Criteria for selection of the study site
- ✓ Potential sites
- ✓ Equipment and other facilities required
- ✓ Data collection and analysis procedures
- ✓ Staffing plan
- ✓ Schedule
- ✓ Budget

The final report prepared in Task 5 should provide full documentation of the problem definition, experimental methods, results, conclusions and future activities, including implementation. Further information on the content and preparation of reports is given in Chapter Five.

In the section describing the project team, the team members should be listed, along with the responsibilities and time commitment for each person. This information is required to ensure that each person will be available to work on the project when required, and to establish costs. The key members of the team should be identified, but for junior positions where the work could be done by one of a number of technicians, it is sufficient to identify the person by rank, e.g. senior technician @ 200 hours, 3 junior technicians @ 300 hours each. The key members must be identified because if a substitution becomes necessary, management and the sponsor will need to satisfy themselves that the replacement has the necessary credentials and experience to perform the research. Curriculum vitae are not required in a work plan.

Equipment and facilities are listed for the same reason as personnel, i.e. to ensure that they will be available when needed and that all the costs are captured in the budget. This also forces the researcher to verify that all the equipment necessary to perform the planned experiments is available, or identify equipment and supplies that must be purchased.

If the research approach, project team, and the equipment are documented in sufficient detail, calculation of the budget for the project is relatively straightforward. Other items such as travel, overhead and profit must, of course, also be included.

A detailed schedule for the work is required to establish a completion date and to provide a mechanism for management to measure the progress of the work. It is also needed to identify when resources will be needed, and to calculate cash flow requirements. For projects that involve no more than about 10 tasks, and about an equal number of sub-tasks, a chart similar to that shown in Figure B-6 is perfectly adequate. Using the second study described above as an example, the chart shows the start and completion dates for each sub-task, and the anticipated progress of each sub-task, as a cumulative percentage. It also shows the interrelationship of the tasks and sub-tasks because it is clear which activities are underway concurrently, and which are sequential. The schedule allows one month for the review of the interim report, and two months to review the final report. The anticipated progress on the overall project can be calculated from a knowledge of the amount of effort required for each task and sub-task. The amount of effort required to complete each sub-task, expressed as a percentage of the effort required to complete the project, is shown in the third column. Taking the end of June 1996 as an example, the anticipated overall completion is:

Task 1 + 25% of sub-tasks 2a, 2b, and 2c
= 10% + 0.25 x (16% + 16% + 16%)
= 22%

By plotting the values from the row "Overall Completion" in Figure C-6 against duration of the project, a chart of anticipated progress is developed, as illustrated in Figure B-7. Using the same technique, planned expenditures can be plotted, as shown in Figure B-8, from knowledge of the budget and cash flow projections for each sub-task. Figures C-6 to C-8 are used to measure the progress of the research as described in the section "Execution of the Research".

The Gantt chart provides a powerful visual representation of the work schedule and quite large research projects, typically up to $1million budget, can be managed in this way. Larger projects, especially those involving many semi-autonomous contributors, or requiring access to expensive equipment that is used on many projects, may require a more sophisticated work schedule to be developed. This can be done by preparing a critical path analysis or using computer software designed for project management.

The final section of the work plan, Implementation, describes how the findings of the research will be implemented. This enables the researchers to involve those who will be responsible for implementation in the research, and to allow the plans for the implementation activities to be developed while the research is in progress so that there is no delay between completion of the research and implementation of the findings.

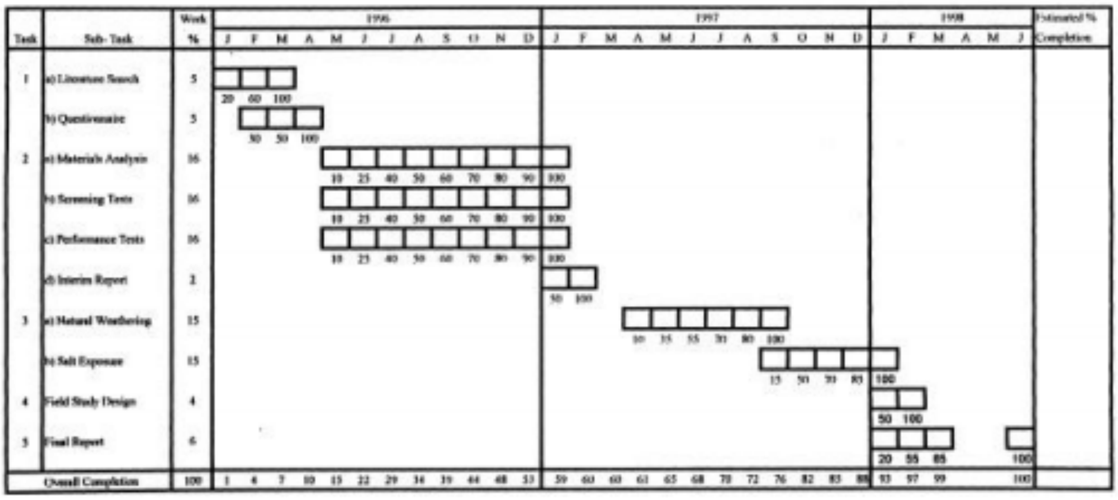


Figure B-6: Example of a Work Schedule Using a Gantt Chart

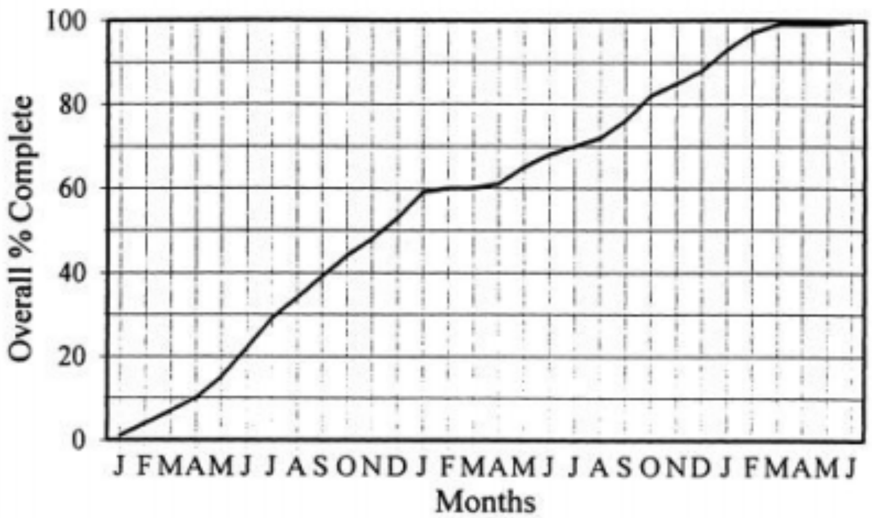


Figure B-7: Planned Progress

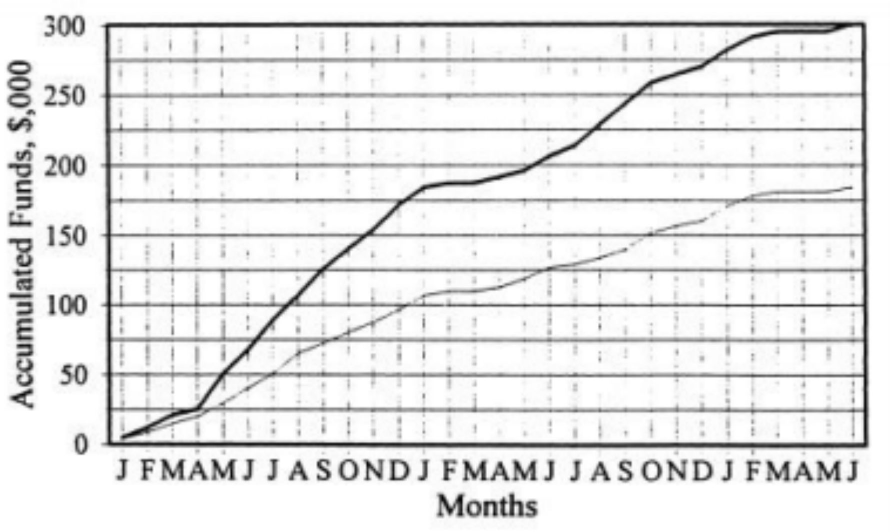


Figure B-8: Anticipated Expenses

Execution of the Research

Technical progress and financial expenditures must be tracked, and monitored, throughout the period of execution of the research. Charts similar to those illustrated in Figures B-6 to B-8 are suitable for this purpose. As an example, Figures B-9 to B-11 illustrate the status of the project described in the previous section as it might have been reported in December 1996. The data indicate that there were delays in beginning Task 2, but, except for work on the performance tests (Task 2c), the project was back on schedule.

Where a greater level of detail is required, as for example, where different budget codes must be reconciled, comparisons between planned and actual expenditures can be made by category, e.g. salaries, travel, and equipment. In this way, variations can be detected early in the process, and steps taken to bring the project under control.

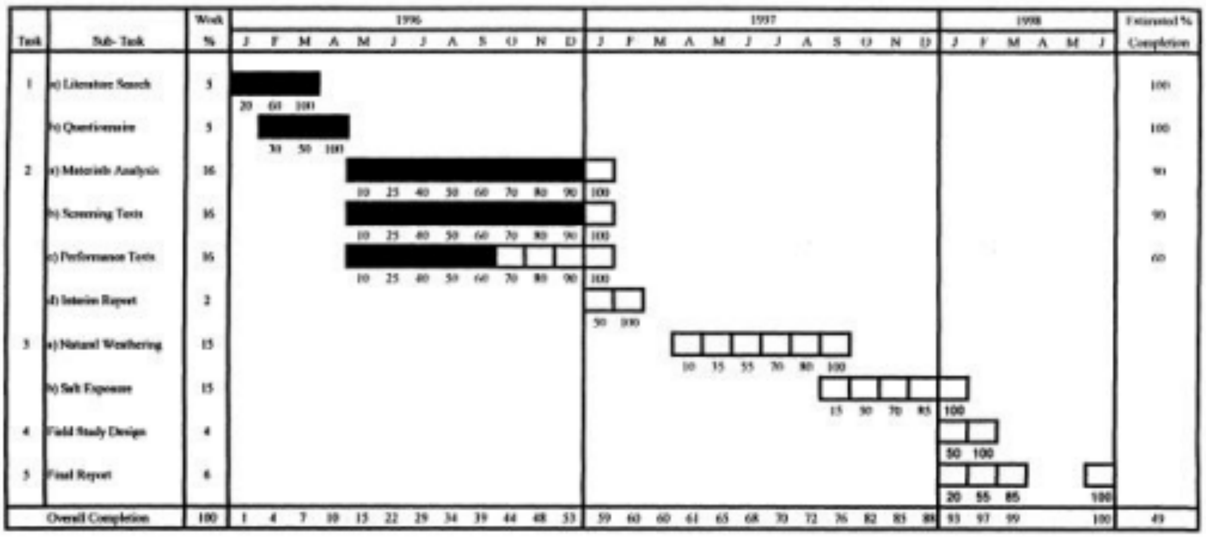


Figure B-9: Completed Progress Schedule for December, 1996

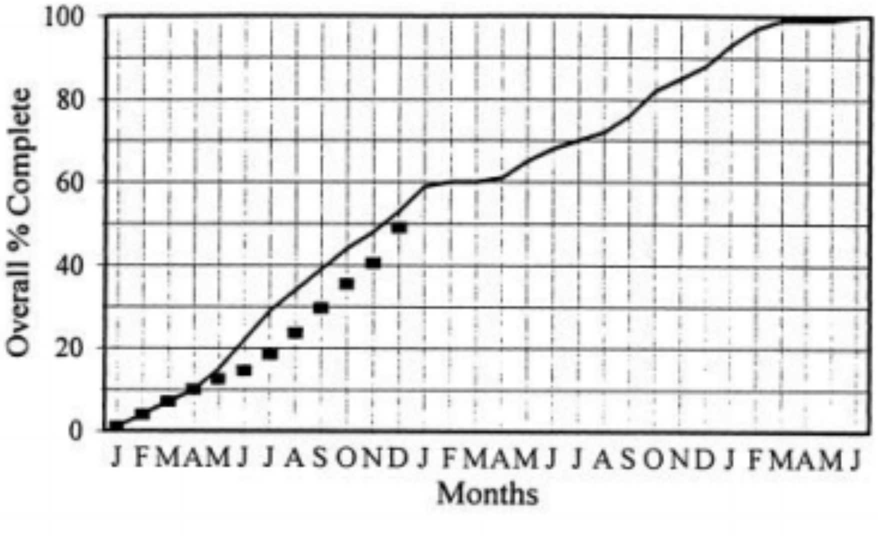


Figure B-10: Overall Progress to December, 1996

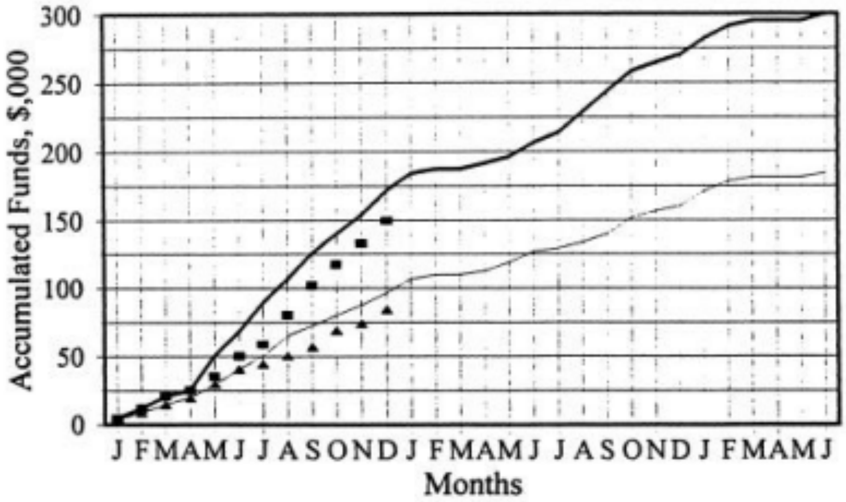


Figure B-11: Expenditures to December, 1996

Implementation and Dissemination of Research Results

An NCHRP study of technology transfer methods and implementation practices included a survey of transportation agencies and an analysis of case studies (10). Much of the information in this section is based on the data collected in the study, and from which the recommendations presented in Chapter Three were developed. Implementation "success" was defined in terms of timeliness, effectiveness, and scope of use. The study examined success from three perspectives:

- ✓ Characteristics of the research results
- ✓ Characteristics of the implementing organization
- ✓ Characteristics of the implementation process

From each perspective, the relative importance of factors that promote implementation, and those which act as barriers to implementation were rated, by participants in a workshop, on a scale of 1 to 5. The results are given in Tables B-1 to B-3 (the data were obtained from figures contained in reference 10). Barriers to implementation have been expressed on a scale of -1 to -5 (-5 being the greatest barrier).

Characteristics of Research Results

Some attributes of the research output can impede implementation. Most obviously, if the research does not meet the needs of potential users, the results will not be put into practice. Also, if users do not see evidence that a new product or process has been adequately tested, they may not want to be guinea pigs.

On the other hand, research results are more likely to be put into practice rapidly and effectively, if the researchers have accounted for real-world situations. In many cases, pilot or demonstration projects are useful steps toward full implementation. Their purpose is to evaluate the new products or processes under operational conditions, and make any necessary improvements, before full implementation on the in-service system. This is important to reduce the risk of failures. Even when full-scale implementation is adopted, the product or process may be designated experimental for a prescribed period to ensure that there is a systematic evaluation of the how well the changes are working.

Site selection for demonstration projects is much more complex than it might appear to be. The objective is to evaluate the new product or process under conditions, which are representative (with respect to site conditions, difficulty of work, contractor expertise, time of year) of the anticipated future applications while minimizing the risk of delay or failure.

Frequently the work must be incorporated in contracts already awarded, or about to be tendered. Each has its disadvantages. Changes to existing contracts are often expensive and the contractor may not have the necessary expertise. Contracts not yet awarded are subject to shifts in award schedules, often resulting in projects being moved from one construction season to another. Rarely will there be an ideal candidate and the selection must be based on compromises between ideal and available conditions. The longer the time available to plan a demonstration project, the greater are the chances of locating site meeting a larger number of the selection criteria.

Positive Factors	Rating	Barriers	Rating
Pilot projects in real settings	4.2	Mismatch between research and user needs	-4.3
Implementation package with research output	4.0	Research output not sufficiently tested	-3.8
Research adaptable to varied contexts	3.3	Research output does not fit work procedures	-3.6
Research designed for commercialization	2.5	Allocation of patents etc. not settled	-3.1

Table B-1: Factors Pertaining to the Characteristics of Research Results

Positive Factors	Rating	Barriers	Rating
Management commitment	4.8	Risk aversion	-4.2
Long-term innovation champions	4.1	Organizational inertia	-4.2
Capability to sustain innovation	4.0	Inflexible contract specifications	-3.9
Incentives for change	4.0	Discomfort with change	-3.9
In-house expertise	3.9	Legal liability	-3.8
On-the-job recognition	3.7	Inadequate resources	-3.8
Performance-oriented specifications	3.4	Skill obsolescence	-3.2
Job rotation assigned	2.7	Political involvement with managers	-3.2
		No local precedents	-2.8
		Inadequate travel budget	-2.6

Table B-2: Factors Pertaining to the Organization

Positive Factors	Rating	Barriers	Rating
Researcher-user pilot collaboration	4.6	User successes unpublicized	-3.7
Users help design research	4.4	Poor quality/relevance filters	-3.6
Targeted funding	3.6	One-way dissemination	-3.6
Easy access to researchers	3.4	Costliness	-3.6
Effective training	3.2	Unknown information source	-3.2
Mandatory innovation use	2.5	Researchers not market-oriented	-2.5

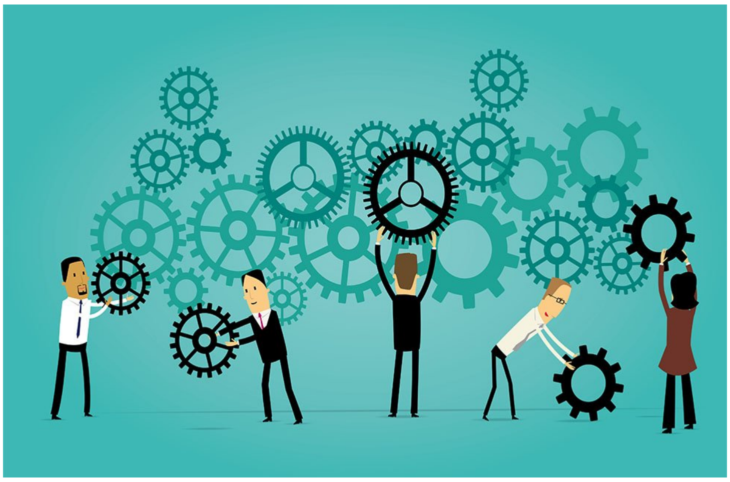
Table B-3: Factors Pertaining to the Implementation Process

Characteristics of the Organization

The most important institutional barriers to implementation include organizational inertia, risk-averse behavior, management discomfort with change, and inadequacy of resources. As noted in the section describing the characteristics of research results, new products and processes entail a degree of risk. Some will prove not worth their cost, and some may not function effectively. The organization must be prepared to encourage staff to innovate, and to support them even when new ventures are not successful. This includes a commitment on the part of senior management to provide resources for implementation efforts and the willingness of senior officials to champion innovation.

Characteristics of the Implementation Process

Collaboration between the researchers and the users throughout the research and implementation phases is the key to the successful use of research results. Many agencies involve the researchers, in-house or contract staff, in the implementation efforts and technology transfer. Commonly, this involves giving seminars or training sessions to agency staff. Depending upon the circumstances, it could also involve evaluating the success of demonstration projects or results designated experimental. However, some agencies deliberately limit the involvement of researchers in the implementation process. The main reasons for doing so are that the contractor is not familiar with the internal process of the agency, and not necessarily expert in implementation efforts. It is also recognized that the implementation effort is substantial, and often different disciplines from those needed to conduct the research. In cases where the researchers are not involved directly in the implementation efforts, it is important that they be accessible.



Cost is frequently a major impediment in implementing new products, and procurement rules that prohibit sole-sourcing can be a major obstacle. Targeted funding for implementation, and flexibility to incorporate experimental features in construction contracts are effective ways of dealing with these problems.

Evaluation of Research Projects

Expert Opinion

This method involves obtaining the opinions of people who are knowledgeable about the subject of the research and the impact of the project being evaluated. The experts can be internal or external to the agency.

Expert opinion is often solicited in the project selection phase. The opinion can be provided on an unstructured basis, or structures using performance indicators such as the quality of the research, level of innovation, or economic impact.

User or Client Opinion

This method involves obtaining the opinions of clients, often through technical advisory committees or project panels. Like expert opinion, client opinion is most commonly sought when problem statements or proposals for research projects are reviewed. Surveys are a useful method of obtaining client or user input in situations where there are numerous users, or the users are widely separated geographically.

Cost-Benefit Methods

Cost-benefit analysis seeks to assess the project in terms of the economic and social benefits generated for a particular "referent group" (e.g. an agency, a region or society as a whole) as well as the economic and social costs incurred by the referent group to carry out the research and implement the results. The definition of the referent group is important because it defines the bounds for the analysis. There are a number of general principles associated with conducting cost benefit analyses of transportation-related research projects.

- ✓ There are three main types of costs associated with a research project that must be taken into account in the analysis. These are the costs of generating the research results, the costs of introducing and supplying the results to the end users, and the costs incurred by the end users to implement the results.
- ✓ The benefits of the research project are valued at the price society is willing to pay for them. The assessment of benefits includes not only those for which prices are paid, but also benefits associated with, for example, reduced environmental damage, better air quality and improvements in health and safety, even though such benefits may be difficult to quantify.
- ✓ Once they have been identified, all the benefits and costs associated with the project are compared using a common measuring system of constant dollar values. Allowances can be made for future changes in relative real prices, but no adjustments are made for the future changes in the general price level as a result of inflation or deflation. All costs and benefits must be discounted to their present values through a social discount rate before they can be compared to determine the net benefit of the project to society. The selection of the discount rate is controversial, and has a major impact on the results of the analysis. The discount rate is intended to be the social discount rate, which represents the present generation's weighting of benefits and costs to be borne by future generations. In the private sector, the discount rate is sometimes taken to be the difference between the prime interest rate and the rate of inflation.

- ✓ The net present value is given by the formula:

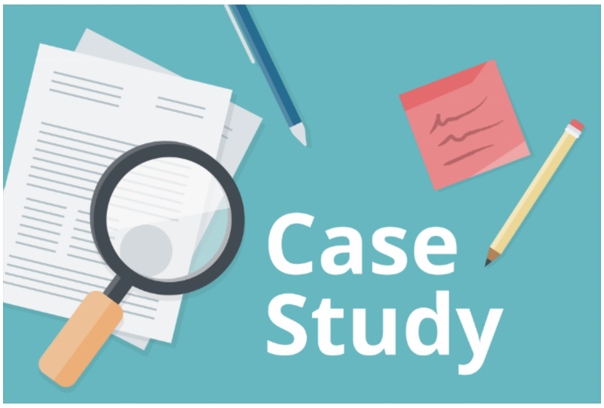
$$NPV = \sum_{i=1}^{N} \frac{(Bi - Ci)}{(1+r)^i}$$

where Bi = the benefits attributable to the project in year i
Ci = the costs attributable to the project in year i
r = the discount rate
N = the number of years over which benefits and costs (compared to the "base case") can be estimated, usually 5 to 10 years.

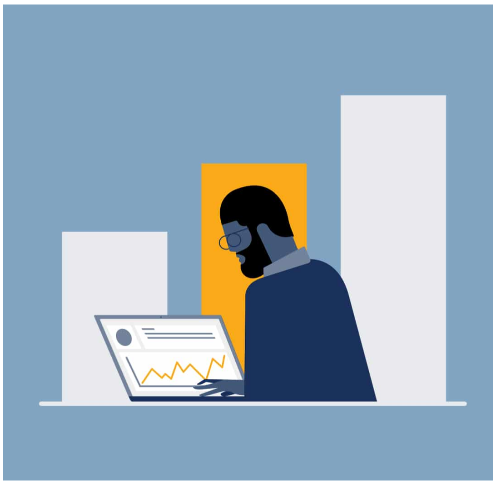
- ✓ The research project being analyzed must be incremental, and the benefits must be attributable to the results of the research. "Incremental" means that the results would not have been available in the absence of the project. "Attribution" deals with the extent to which the benefits are actually due to the research results. This is extremely important in defining the "base case" which is rarely the situation before the project was undertaken, but more properly it reflects benefits that would have occurred even if the project had not been undertaken. This includes the incorporation of developments made elsewhere, and changes that would have occurred from sound management strategies. Given the uncertainty of research, many evaluators find cost-benefit analysis impractical, except possibly for projects which have been completed for some time, and which have well-defined benefits. On the other hand, cost benefit analysis can be a useful method for deciding which potential projects are most attractive, and for demonstrating the value of investing in research.

Case Studies

Case studies involve a detailed and thorough analysis of research projects, and seek to track and document the evolution of the impacts associated with the research. The advantage of case studies is that they afford the best opportunity of identifying the relationship between the research study and the impact of the research results. They are particularly useful for evaluating projects that benefit the public good, rather than using cost-benefit analyses that assign dubious values to some impacts such as the value of a human life. Because the results are usually qualitative, it is difficult to use case studies to compare the value of projects, or to aggregate the results to demonstrate the value of research programs.



Performance Indicators



There are two main categories of performance indicator methods, partial indicators and integrated partial indicators. The first method involves the collection of information items, each of which provides some insight into the project such as cost, time, risk and potential outputs. The method of integrated partial indicators involves the collection of the same kinds of information, except that it is integrated in some way. The method usually involves summing the partial indicators to arrive at a "bottom line score". The most common approach is to evaluate each project with reference to a specific set of criteria (e.g. cost, feasibility or risk, likely impact, relevance to the agency mandate), assign a score and a weight to arrive at an overall score for the project. This method is often used to select individual projects, and to evaluate responses to requests for proposals.

PREPARING AND PRESENTING REPORTS

What is a report?

A report is a written presentation of factual information based on an investigation or research. Reports form the basis for solving problems or making decisions, often in the subjects of business and the sciences. The length of reports varies; there are short memorandum (memo) reports and long reports. Most often you will be asked to write a long report.

What makes an effective report?

- ✓ Clear, concise and accurate
- ✓ Easy for the audience to understand
- ✓ Appropriate for the audience
- ✓ Well organized with clear section headings

Report structure:

Reports follow a standardized format. This allows the reader to find the information easily and focus on specific areas. Most reports follow the following structure, but please look at your assignment question and marking guide carefully, as the format and terminology required in your report may vary from this guide. If so, check with your tutor. Please check your marking guide to determine the word limit and how marks are allocated to each section

A report must have:

- ✓ Title Page

- ✓ Table of Contents
- ✓ Abstract or Executive Summary
- ✓ Introduction (or Terms of Reference and Procedure)
- ✓ Findings and/or Discussion
- ✓ Conclusions
- ✓ Recommendations
- ✓ References

A report may also contain:

- ✓ Cover letter
- ✓ Bibliography
- ✓ Glossary
- ✓ Appendices

The table below summarizes the main headings used in reports and outlines the purpose of each section. Please note: Further headings or subheadings may be used depending on the report's content, and are specific to the individual report.

Section	Purpose
Title Page (Not part of the word count)	Gives the title of the report, the student name/number, the name of the person the report is being submitted to, and the completion date.
Table of Contents (Not part of the word count)	Shows the sections of the report. Gives the headings, subheadings and page numbers.
Abstract or Executive Summary	Gives a summary of the whole report. Outlines the report's purpose, methodology, findings, main conclusions and recommendations. Mainly written in past tense, and prepared last.
Terms of Reference	Briefly states the purpose and scope of the report. This includes who requested the report, the main issues or problems to be identified, the reason for undertaking the report and the due date of the report.
Procedure	Outlines the methods used to collect information e.g. interviews, questionnaires, observations and/or research.
Introduction (May be used instead of the Terms of Reference and Procedure)	Outlines the context, background and purpose of the report. Defines terms and sets limits of the investigation.

	The reader/audience can easily identify what the report is about, how information was gathered, and why the report is needed. Mainly uses past tense and can be written last – but is presented first.
Findings and/or Discussion For this section, avoid using the headings "Findings" or "Discussion". Instead, create headings and sub-headings that identify the main issues or problems.	Findings: What was found during the research or investigation? Gives the facts only – no interpretation by the writer of the report. Tables, graphs or diagrams can be used. Must be relevant to the issues and problems identified in the Terms of Reference. Arranged in a logical order with headings and sub-headings. Discussion: You may also be required to analyses, interpret and evaluate the findings. The discussion draws together different parts of the findings and may refer to findings of other studies and/or theories.
Conclusions	Brief statements of the key findings of the report (full explanation is given in the Findings and/or Discussion). Arranged so the major conclusions come first. Should relate directly to the objectives set out in the Terms of Reference or Introduction. Follow logically from the facts in the Findings and/or Discussion. Must be complete enough for recommendations to be made from them.
Recommendations (note: not all reports give recommendations)	The opinions of the writer of the report about possible changes, or solutions to the problems, including who should take action, what should be done, when and how it should be done.
References (Not part of the word count)	A list of the sources that are used in and referred to in the report. Use APA referencing style.
Bibliography (Not always required)	Lists any sources that were read for the research but were not cited in the report. (Bibliography is not included in the word

	count).
Appendices (Not always required)	Additional relevant information. May include interview questions, surveys, glossary etc. (Appendices are not included in the word count).

UNIT 02

APPLY AND MAINTAIN OCCUPATIONAL HEALTH AND SAFETY

This unit of competency describes the skills and knowledge to monitor and maintain work health and safety (WHS) within a work area where the person has supervisory responsibility for others

PERFORM ALL WORK SAFELY

Regardless of your job, there are some basic safe work practices that should be observed by everyone working on the job site. The objective of the safety program is to prevent injuries and to allow you to do your job efficiently and safely. It takes an effort on your part to support the safety program but, after all, that's what it's all about.

Right now, let's review some basic safe work practices. All persons must follow these safe practices and render every possible aid to safe operations and be a part of the program by reporting all unsafe conditions or practices to your supervisor or superintendent. The vast majority of work-related injuries are the result of unsafe acts of workers. That means, when you take shortcuts, you violate safety regulations or simply don't take safety seriously, injuries are more likely to occur. Your company has a responsibility and obligation to make sure that all employees observe and obey all applicable company, or national regulations and order as is necessary to the safe conduct of the work and must take such action as necessary to obtain compliance.

If you violate company safety rules, or you work in an unsafe manner, you will be provided a written safety counselling. This counselling will explain what the unsafe behaviour was and how to correct it. If it's a minor violation, then the counselling will serve as a reminder for the proper procedure. If it's a serious violation, or you continue to exhibit unsafe behaviour, disciplinary action may be warranted. The purpose of safety rule enforcement is the protection of all employees. One employee's unsafe behaviour can affect the safety of other employees and safety is too important to allow unsafe behaviour or unsafe conditions.

In the construction industry, frequent accident prevention instructions or training is provided at least every ten days. However, it is each employee's responsibility to work and act safely every day on every job. Training is simply making you more aware of safety and safety rules and it's your job to work safe and act safely every day.

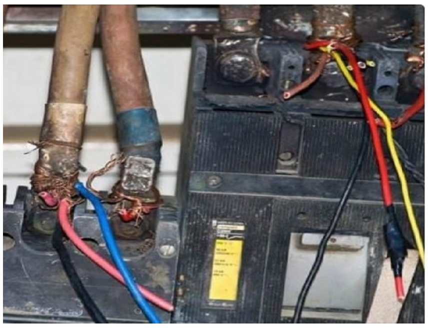
Anyone known to be under the influence of drugs or intoxicating substances which impair the employee's ability to safely perform the assigned duties shall not be allowed on the job while in that condition. If you are taking medication prescribed by a physician or taking over-the-counter medication, be sure to tell your supervisor before you begin work. Some medications may impair your ability to work or operate equipment safely. We discussed unsafe behaviour and how it leads to injuries on the job. Unsafe behaviour includes horseplay. Scuffling, practical jokes and other acts which tend to have an adverse influence on the safety or wellbeing of other employees. No one shall knowingly be permitted or required to work while the employee's ability or alertness is so impaired by fatigue, illness, or other causes that they might unnecessarily expose the employee or others to injury.

Work shall be planned and supervised to prevent injuries in the handling of materials and in working together with equipment. Employees shall not enter manholes, underground vaults, chambers, tanks, silos, or other similar places that receive little ventilation unless it has been determined that it is safe to enter. Confined spaces can be quite hazardous from toxic fumes, gas, and other hazards can gather in the spaces creating a dangerous hazard.

Machine guards and other protective devices must be in their proper place before machinery and equipment is used and employees must report any deficiencies or hazards to the supervisor when they are detected. If the equipment is unsafe to operate, do not operate the equipment until it has been replaced or repaired.

Crowding or pushing when boarding or leaving any vehicle or other conveyance is prohibited.

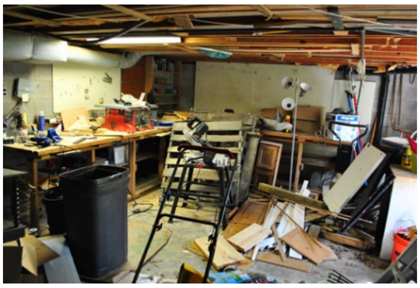
Employees must not handle or tamper with any electrical equipment, machinery, or air or water lines in a manner not within the scope of their duties unless they have received instructions and authorization from their supervisor.



If you are injured on the job, report the injury immediately.
Don't wait. Report the injury when it occurs, even if you believe that medical treatment is not necessary. If medical treatment is required, it will be provided.

When lifting anything, use the power of your legs and not your back. If you keep your back in its natural curvature by bending your legs, it's difficult to suffer a back injury.

Inappropriate footwear or shoes with thin or badly worn soles must not be worn. Wear proper footwear and clothing on the job. Materials, tools, and other objects shall not be thrown from structures until proper precautions are taken to protect others from the falling objects.



Housekeeping is important to everyone's safety so take time to keep your work area clean. If you see a hazard, correct it. If you can't correct the hazard yourself, report it so it can be corrected.

When handling chemicals or hazardous substances be sure to use personal protective equipment as necessary and follow the instructions provided on the chemical label. Never use gasoline for any type of cleaning purposes. Wash your hands and skin after handling chemicals and hazardous materials.

When using ladders, inspect the ladder before using it to make sure it is in good condition and will carry the load. Using the proper ladder on the job is equally important. Never stand on the top two steps of a ladder, and when using straight ladders, make sure the ladder extends at least 3 feet above the landing, or where the ladder is positioned on the structure.

Any damage to scaffolds, false work, or other supporting structures shall be immediately reported to your supervisor and repaired before use.

No source of ignition shall be applied to any enclosed tank or vessel, even if there are some openings, until it has been first determined that no possibility of explosion exists. An authority for the work is obtained from your supervisor. Persons using welding equipment must always be concerned in starting fires from the sparks or flash. Never weld around combustible or flammable material and, if necessary, have someone standing by with a fire extinguisher during welding operations.

When using tools and equipment, maintain these tools and equipment in good serviceable condition. Damaged tools or equipment must be removed from service and tagged "defective." Pipe or Stilson wrenches must not be used as substitute for other wrenches. Only appropriate tools shall be used for a specific job.

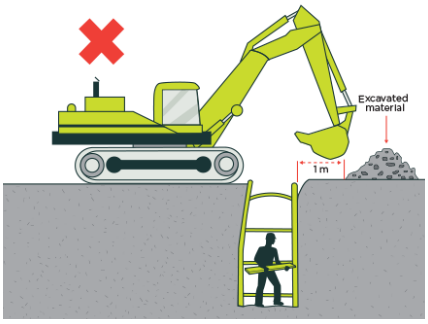
Vices must be equipped with handles and not used to punch or pry. A screwdriver should not be used as a chisel. Portable electric tools shall not be lifted or loaded by means of a power cord. Use ropes, not the power cord for lifting or lowering electrical tools. Before electrical tools are used, they must be inspected to make sure the power cord and plugs are in good condition. Cords with cuts or fray must be replaced. You cannot simply wrap electrical tape over a cut or frayed cord.

Only those persons who are trained and authorized may operate machinery or equipment. Loose or frayed clothing, long hair, dangling ties, finger rings, necklaces, and other potentially hazardous items may not be worn around moving machinery or other areas where they become entangled. Machinery shall not be serviced, repaired or adjusted while in operation, or

shall oiling of moving parts be attempted, except when equipment that is designed or fitted with safeguards to protect the person performing the work. Where appropriate, lockout-tagout procedures must be used. If you see a piece of equipment or a machine that is locked out and tagged out, do not attempt to operate this equipment. A lock and tag means that someone is working on that machine and could possibly be injured if the equipment were to be inadvertently started.

Employees shall not work under vehicles or other equipment supported by jacks or chain hoists without protective blocking that will prevent injury if jacks or hoists should fail.

Air hoses shall not be disconnected at compressors until the hose line has been bled and is free of any air pressure.



All excavations must be visually inspected before backfilling to ensure it is safe to backfill. Excavating equipment must not be operated near tops of cuts, banks or cliffs if employees are working below. Tractors, bulldozers, scrapers, and carryalls must not operate where there is a possibility of overturning in dangerous areas, like edges of deep fills, cut banks and steep slopes.

Watch out for moving vehicles and equipment on the job site. Often this equipment is noisy and the operator may not be able to hear or see you. You have the responsibility for watch out for moving equipment.

There are many more safe practices and rules that could be listed, but it's impossible to list them all. Actually, safety is simply using common sense and good judgment. If something appears to have the potential for injury, then that's the time to take steps to make sure the injury doesn't occur.

Teamwork - everyone's cooperation and a special effort can result in a safe and helpful work environment. If you take safety seriously, you'll have a much better attitude about yourself and your job. Take time for safety, because safety really does make a difference.

The meaning of key terms

Hazard means a situation or thing that has the potential to harm a person. Hazards at work may include: noisy machinery, a moving forklift, chemicals, electricity, working at heights, a repetitive job, bullying and violence at the workplace.

Risk is the possibility that harm (death, injury or illness) might occur when exposed to a hazard.

Risk control means taking action to eliminate health and safety risks so far as is reasonably practicable, and if that is not possible, minimising the risks so far as is reasonably practicable. Eliminating a hazard will also eliminate any risks associated with that hazard.

ASSIST OTHERS TO OBSERVE AND PRACTICE SAFE WORK PRACTICES

What is involved in managing risks?

Management Commitment

Effective risk management starts with a commitment to health and safety from those who operate and manage the business or undertaking. You also need the involvement and cooperation of your workers, and if you show your workers that you are serious about health and safety they are more likely to follow your lead.

To demonstrate your commitment, you should:

- ✓ Get involved in health and safety issues
- ✓ Invest time and money in health and safety
- ✓ Ensure health and safety responsibilities are clearly understood.

A Step-By-Step Process

A safe and healthy workplace does not happen by chance or guesswork. You have to think about what could go wrong at your workplace and what the consequences could be. Then you must do whatever you can (in other words, whatever is 'reasonably practicable') to eliminate or minimise health and safety risks arising from your business or undertaking.
This process is known as risk management and involves the four steps set out in this Code (see Figure 1 to the right):

- ✓ Identify hazards – find out what could cause harm
- ✓ Assess risks if necessary – understand the nature of the harm that could be caused by the hazard, how serious the harm could be and the likelihood of it happening
- ✓ Control risks – implement the most effective control measure that is reasonably practicable in the circumstances
- ✓ Review control measures to ensure they are working as planned.

Many hazards and their associated risks are well known and have well established and accepted control measures. In these situations, the second step to formally assess the risk is unnecessary. If, after identifying a hazard, you already know the risk and how to control it effectively, you may simply implement the controls.

Risk management is a proactive process that helps you respond to change and facilitate continuous improvement in your business. It should be planned, systematic and cover all reasonably foreseeable hazards and associated risks.

MONITOR AND OBSERVE OF SAFE WORK PRACTICES

Inspect the Workplace

Regularly walking around the workplace and observing how things are done can help you predict what could or might go wrong. Look at how people actually work, how plant and equipment is used, what chemicals are around and what they are used for, what safe or unsafe work practices exist as well as the general state of housekeeping.

Things to look out for include the following:

- ✓ Does the work environment enable workers to carry out work without risks to health and safety (for example, space for unobstructed movement, adequate ventilation, lighting)?
- ✓ How suitable are the tools and equipment for the task and how well are they maintained?
- ✓ Have any changes occurred in the workplace which may affect health and safety?

Hazards are not always obvious. Some hazards can affect health over a long period of time or may result in stress (such as bullying) or fatigue (such as shiftwork). Also think about hazards that you may bring into your workplace as new, used or hired goods (for example, worn insulation on a hired welding set).

As you walk around, you may spot straightforward problems and action should be taken on these immediately, for example cleaning up a spill. If you find a situation where there is immediate or significant danger to people, move those persons to a safer location first and attend to the hazard urgently.

Make a list of all the hazards you can find, including the ones you know are already being dealt with, to ensure that nothing is missed. You may use a checklist designed to suit your workplace to help you find and make a note of hazards.

PARTICIPATE IN RISK MANAGEMENT PROCESSES

A risk assessment involves considering what could happen if someone is exposed to a hazard and the likelihood of it happening. A risk assessment can help you determine:

- ✓ How severe a risk is
- ✓ Whether any existing control measures are effective

- ✓ What action you should take to control the risk
- ✓ How urgently the action needs to be taken.

A risk assessment can be undertaken with varying degrees of detail depending on the type of hazards and the information, data and resources that you have available. It can be as simple as a discussion with your workers or involve specific risk analysis tools and techniques recommended by safety professionals.

When should a risk assessment be carried out?

A risk assessment should be done when:

- ✓ There is uncertainty about how a hazard may result in injury or illness
- ✓ The work activity involves a number of different hazards and there is a lack of understanding about how the hazards may interact with each other to produce new or greater risks
- ✓ Changes at the workplace occur that may impact on the effectiveness of control measures.

A risk assessment is mandatory under the WHS Regulations for high risk activities such as entry into confined spaces, diving work and live electrical work. Some hazards that have exposure standards, such as noise and airborne contaminants, may require scientific testing or measurement by a competent person to accurately assess the risk and to check that the relevant exposure standard is not being exceeded (for example, by using noise meters to measure noise levels and using gas detectors to analyse oxygen levels in confined spaces). A risk assessment is not necessary in the following situations:

- ✓ Legislation requires some hazards or risks to be controlled in a specific way – these requirements must be complied with.
- ✓ A code of practice or other guidance sets out a way of controlling a hazard or risk that is applicable to your situation and you choose to use the recommended controls. In these instances, the guidance can be followed.
- ✓ There are well-known and effective controls that are in use in the particular industry, that are suited to the circumstances in your workplace. These controls can simply be implemented.

IMPLEMENTING EMERGENCY PROCEDURES

How to do a risk assessment

All hazards have the potential to cause different types and severities of harm, ranging from minor discomfort to a serious injury or death.

For example, heavy liquefied petroleum gas (LPG) cylinders can cause muscular strain when they are handled manually.

However, if the cylinder is damaged causing gas to leak which is then ignited, a fire could result in serious burns. If that leak occurs in a store room or similar enclosed space, it could result in an explosion that could destroy the building and kill or injure anyone nearby. Each of the outcomes involves a different type of harm with a range of severities, and each has a different likelihood of occurrence.

Work out how severe the harm could be

To estimate the severity of harm that could result from each hazard you should consider the following questions:

- ✓ What type of harm could occur (e.g. muscular strain, fatigue, burns, laceration)? How severe is the harm? Could the hazard cause death, serious injuries, illness or only minor injuries requiring first aid?
- ✓ What factors could influence the severity of harm that occurs? For example, the distance someone might fall or the concentration of a particular substance will determine the level of harm that is possible. The harm may occur immediately something goes wrong (e.g. injury from a fall) or it may take time for it to become apparent (e.g. illness from long-term exposure to a substance).
- ✓ How many people are exposed to the hazard and how many could be harmed in and outside your workplace? For example, a mobile crane collapse on a busy construction site has the potential to kill or injure a large number of people.
- ✓ Could one failure lead to other failures? For example, could the failure of your electrical supply make any control measures that rely on electricity ineffective? „ Could a small event escalate to a much larger event with more serious consequences? For example, a minor fire can get out of control quickly in the presence of large amounts of combustible materials.

Workout how hazard may cause harm

In most cases, incidents occur as a result of a chain of events and a failure of one or more links in that chain. If one or more of the events can be stopped or changed, the risk may be eliminated or reduced.

One way of working out the chain of events is to determine the starting point where things begin to go wrong and then consider: 'If this happens, what may happen next?' This will provide a list of events that sooner or later cause harm. See the case study in Appendix A.

In thinking about how each hazard may cause harm, you should consider:

- ✓ The effectiveness of existing control measures and whether they control all types of harm,
- ✓ How work is actually done, rather than relying on written manuals and procedures
- ✓ Infrequent or abnormal situations, as well as how things are normally meant to occur.

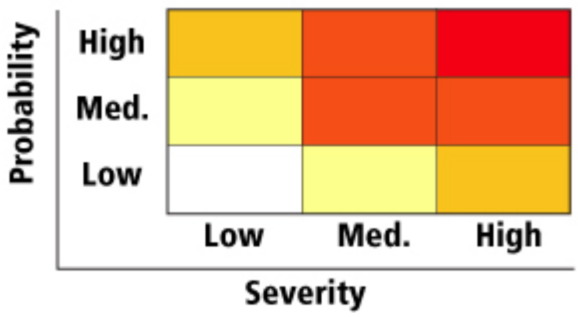
Consider maintenance and cleaning, as well as breakdowns of equipment and failures of health and safety controls.

Work Out the Likelihood of Harm Occurring

The likelihood that someone will be harmed can be estimated by considering the following:

- ✓ How often is the task done? Does this make the harm more or less likely?
- ✓ How often are people near the hazard? How close do people get to it?
- ✓ Has it ever happened before, either in your workplace or somewhere else? How often?

Table 1: Risk matrix



You can rate the likelihood as one of the following:

- ✓ Certain to occur - expected to occur in most circumstances
- ✓ Very likely - will probably occur in most circumstances
- ✓ Possible – might occur occasionally
- ✓ Unlikely – could happen at some time
- ✓ Rare – may happen only in exceptional circumstances

The level of risk will increase as the likelihood of harm and its severity increases.

UNIT 03

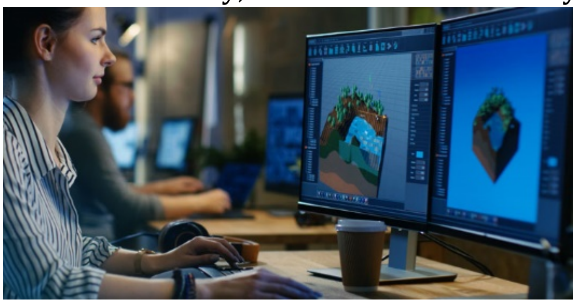
CARRY OUT DATA ENTRY AND RETRIEVAL PROCEDURES

This unit deals with the skills and knowledge required to operate computer to enter, manipulate, and retrieve and to access data and communicate via the Internet

INITIATE COMPUTER SYSTEM

Introduction to computers

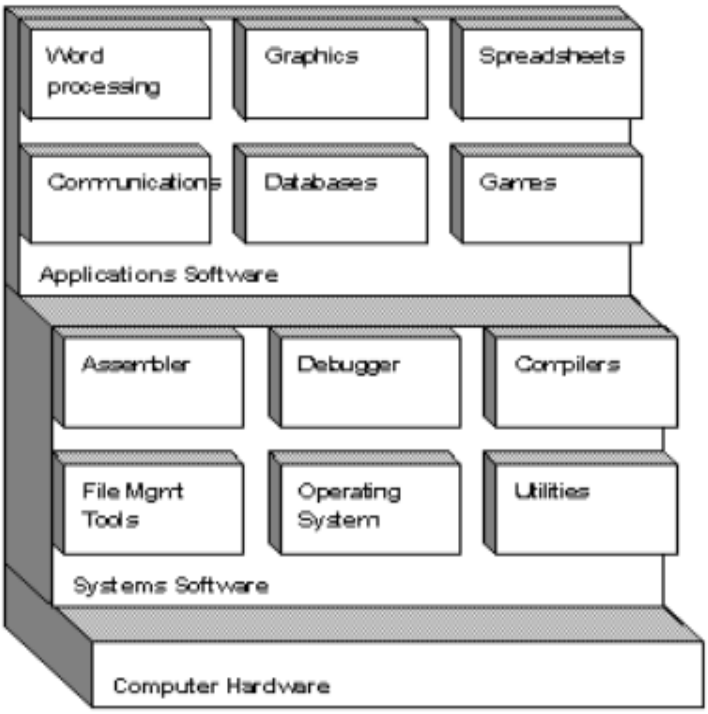
While the computer has been with us for) only about half a century, its use dates all the way back to the fourth Century B.C. The first known apparatus was a simple counting aid called the abacus, and may have been invented in Babylonia (now Iraq). Throughout the centuries, computers have changed the way we act, think and view the world. In short, it has revolutionized the world. Today's personal computer, which has been around for only fifteen years, has surpassed its earlier predecessor.



Although computers are used to schedule airlines, predict the weather, play music, control space stations and keep the wheels of the world economy turning; essentially computers do only four things:

- ✓ Receive input
- ✓ Process information
- ✓ Produce output
- ✓ Store information

These four basic functions are responsible for everything computers do.
Computer System:



There are three essential ingredients of any computer system:

- ✓ Hardware
- ✓ Peripherals
- ✓ Software

Hardware - Consists of the microprocessor (the computer's brain), the memory and the input or output connections which get data in and out of the microprocessor.

Peripherals - Are the devices that allow us to communicate with the computer. . Peripheral devices can be external -- such as a mouse, keyboard, printer, external zip drive or scanner -- or internal, such as a CD-Rom, CD-R or internal modem. Internal peripheral devices are often referred to as integrated peripherals

Software – Also called computer program, is essential to make the system work. Without software a computer can do nothing

Software is often divided into two categories:

- ✓ Systems software: Includes the operating system and all the utilities that enable the computer to function.
- ✓ Applications software: Includes programs that do real work for users. For example, word processors, spreadsheets and database management systems.

NOTE: It is very important to distinguish between the Operating System and Application Software.

Check Equipment and Work Environment for Readiness

Checking your equipment and work environment for readiness to perform scheduled tasks involves checking that your computer and its peripherals are installed and functional. Your check must also include ensuring that the layout of your work space minimizes potential hazards. You should note the following:

- ✓ The lighting must be sufficient for the task and there should be sufficient contrast between the screen and the background
- ✓ Distracting noises should be minimized
- ✓ There should be sufficient leg room for you to change positions easily
- ✓ Windows should have blinds or curtains
- ✓ The software should be appropriate for the task
- ✓ The screen must have a stable image, without glitter, glare or reflections

- ✓ The keyboard must be usable, adjustable, detachable and legible
- ✓ The work surface must allow a flexible arrangement of objects, with sufficient space for documents, keyboard, etc
- ✓ The chair should be adjustable in height and have an adjustable backrest in both height and tilt
- ✓ Cables should be properly installed that is, they should be kept as short as possible and be fastened in place or routed through cable ducts. Check to make sure the system is safe before you turn it on
- ✓ The power supply must be adequate. Is there Uninterrupted Power Supply (U.P.S.)?

TIP: Advise the computer technician or another responsible person if you find faults with your system. Do not poke around inside the system as this may cause serious damage to both you and your computer.

When working with computers, seating is particularly important. Your seat must provide the following posture requirements:

- ✓ Adjustable back support
- ✓ Good lumbar support
- ✓ Adjustable seat height
- ✓ No excess pressure under the thighs or back of the knees
- ✓ Space to change position when needed
- ✓ Adjustable screen position in height and angle to allow a comfortable head position
- ✓ Spaces in front of the keyboard to support the hands and wrists during pauses in work

Identify hardware components and their functions

Every computer system contains hardware components that specialise in each of these four functions:

Input devices - feed data into the computer. The keyboard is the most common input device. Other input devices include pointing devices like the mouse and trackball.

Output devices - produce output through two main types of devices: monitor screens for immediate visual output and printers for permanent paper output.

A processor or central processing unit (CPU) - processes information, performs all the necessary arithmetic calculations and make decisions based on information values. The CPU is, in essence, the computer's "brain."

Memory and storage devices - used to store information, but they serve different purposes. The computer's memory (sometimes called primary storage) is used to store programmes and data that need to be instantly accessible to the CPU. Storage devices (sometimes called secondary storage), including disks and tape drives, serve as long-term repositories for data. A storage device such as disk drive can be considered as a combination of input and output device because the computer sends information out to the storage device (output), and later retrieves that information from it (input).

These four components, when combined make up the hardware of the computer system.

Power up the computer System

To power up the computer simply means to turn it on. You may also see the word 'initialize' which refers to the process of starting up a program or system. The key word is process. Computers first need time to warm up before they are put to use. Once the power switch has been activated, the computer will automatically go through a series of "self-checks". These are critical before the system is booted so that the computer operates efficiently. Once the checks are complete, you may be prompted for login details. After this, the next screen you will see, featuring a number of icons, is called the desktop

TIP: Ensure that you use the correct start up and shut down procedures that are recommended by your computer manufacturer.

Apply access code

If you are connected to a network, you are likely to need a password which allows you access when you type it in using the keyboard. If this is the case, ensure that you log on using the correct username and password.

Examine System Information

When a computer is switched on, one of the first things it does is to read instructions from one of its disks. These instructions tell it how to operate and are known as the Operating System (OS). This process happens quite quickly and is called booting up.
Information about your computer system (processor speed and amount of installed memory), are available on the system itself. Ask your learning facilitator to show you how to access this information.

Customize Desktop Configuration

Simply put, your desktop is what you are looking at when your computer is on and no programs are open. You can arrange the icons on this electronic desktop just as you can arrange real objects on a real desktop. You can:

- ✓ Move them around
- ✓ Put one on top of another
- ✓ Reshuffle them
- ✓ Throw them away

This flexibility allows you to customise your desktop to suit your individual requirements and/or special needs in accordance with organisational guidelines.

The advantages of customising your desktop configuration is that the most used programs are easily accessible in one area, and if you plan to run more than one program at a time, it is better to have them in the same group window.
Each programme, such as word processor, spreadsheet or database appears as an icon with its name under it, and many computers already come with some of these icons already loaded.

Use help functions

Many programs come with the instruction manual, or a portion of the manual, integrated into the program. Should you encounter a problem or forget a command while running the program, you can bring up the documentation by pressing the Help key or entering a HELP command. In Windows, the Help key is the function key labelled F1.
Once you summon the Help system the program often displays a menu of Help topics. Choose the appropriate topic for the problem you are experiencing. The program will then display a help screen that contains the desired documentation.
Some programs are more sophisticated, displaying different Help messages depending on where you are in the program. Such systems are said to be context sensitive.

ENTER DATA

TYPES OF DATA

Data Types are an important concept of statistics, which needs to be understood, to correctly apply statistical measurements to your data and therefore to correctly conclude certain assumptions about it. This blog post will introduce you to the different data types you need to know, to do proper exploratory data analysis (EDA), which is one of the most underestimated parts of a machine learning project.

Introduction to Data Types

Having a good understanding of the different data types, also called measurement scales, is a crucial prerequisite for doing Exploratory Data Analysis (EDA), since you can use certain statistical measurements only for specific data types.

You also need to know which data type you are dealing with to choose the right visualization method. Think of data types as a way to categorize different types of variables. We will discuss the main types of variables and look at an example for each. We will sometimes refer to them as measurement scales.

Categorical Data

Categorical data represents characteristics. Therefore it can represent things like a person's gender, language etc. Categorical data can also take on numerical values (Example: 1 for female and 0 for male). Note that those numbers don't have mathematical meaning.

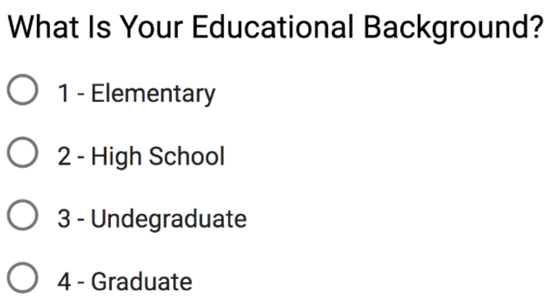
Nominal Data

Nominal values represent discrete units and are used to label variables, that have no quantitative value. Just think of them as „labels". Note that nominal data that has no order. Therefore if you would change the order of its values, the meaning would not change. You can see two examples of nominal features below:

The left feature that describes if a person is married would be called "dichotomous", which is a type of nominal scales that contains only two categories.

Ordinal Data

Ordinal values represent discrete and ordered units. It is therefore nearly the same as nominal data, except that it's ordering matters. You can see an example below:



Note that the difference between Elementary and High School is different than the difference between High School and College. This is the main limitation of ordinal data, the differences between the values is not really known. Because of that, ordinal scales are usually used to measure non-numeric features like happiness, customer satisfaction and so on.

Numerical Data

Discrete Data

We speak of discrete data if its values are distinct and separate. In other words: We speak of discrete data if the data can only take on certain values. This type of data can't be measured but it can be counted. It basically represents information that can be categorized into a classification. An example is the number of heads in 100 coin flips.

You can check by asking the following two questions whether you are dealing with discrete data or not: Can you count it and can it be divided up into smaller and smaller parts?

Continuous Data

Continuous Data represents measurements and therefore their values **can't be counted but they can be measured.** An example would be the height of a person, which you can describe by using intervals on the real number line.

Interval Data

Interval values represent **ordered units that have the same difference**. Therefore we speak of interval data when we have a variable that contains numeric values that are ordered and where we know the exact differences between the values. An example would be a feature that contains temperature of a given place like you can see below:

Temperature?

- ○ - 10
- ○ -5
- ○ 0
- ○ + 5
- ○ + 10
- ○ + 15

The problem with interval values data is that they don't have a "true zero". That means in regards to our example, that there is no such thing as no temperature. With interval data, we can add and subtract, but we cannot multiply, divide or calculate ratios. Because there is no true zero, a lot of descriptive and inferential statistics can't be applied.

Ratio Data

Ratio values are also ordered units that have the same difference. Ratio values are the same as interval values, with the difference that they do have an absolute zero. Good examples are height, weight, length etc.

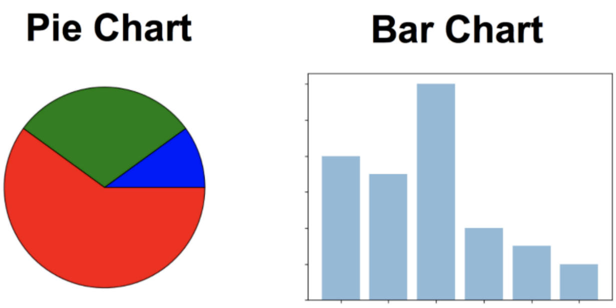
Why Data Types are important?

Datatypes are an important concept because statistical methods can only be used with certain data types. You have to analyze continuous data differently than categorical data otherwise it would result in a wrong analysis. Therefore knowing the types of data you are dealing with, enables you to choose the correct method of analysis.

Statistical Methods

Nominal Data

When you are dealing with nominal data, you collect information through:
Frequencies: The Frequency is the rate at which something occurs over a period of time or within a dataset.
Proportion: You can easily calculate the proportion by dividing the frequency by the total number of events. (e.g how often something happened divided by how often it could happen)
Percentage.
Visualisation Methods: To visualise nominal data you can use a pie chart or a bar chart.



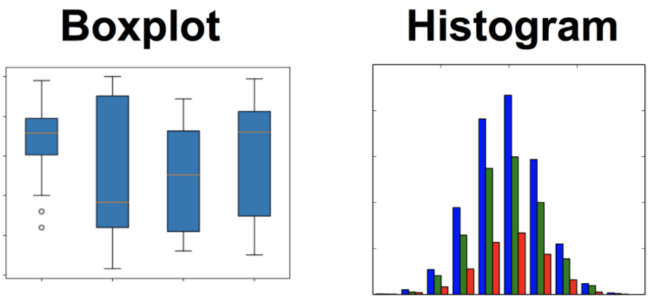
Ordinal Data

When you are dealing with ordinal data, you can use the same methods like with nominal data, but you also have access to some additional tools. Therefore you can summarise your ordinal data with frequencies, proportions, percentages. And you can visualise it with pie and bar charts. Additionally, you can use percentiles, median, mode and the interquartile range to summarise your data.

Continuous Data

When you are dealing with continuous data, you can use the most methods to describe your data. You can summarise your data using percentiles, median, interquartile range, mean, mode, standard deviation, and range.

Visualisation Methods:
To visualise continuous data, you can use a histogram or a box-plot. With a histogram, you can check the central tendency, variability, modality, and kurtosis of a distribution. Note that a histogram can't show you if you have any outliers. This is why we also use box-plots.



RETRIEVE AND AMENDA DATA

Information has become the most significant source of our day-to-day life. Information available on internet may create some confusion among its users because of its diversity. In order to get proper and exact information from internet, users need to know the effective techniques and strategies. This paper focuses on the different information retrieval processes and techniques which help users to get the required information and also to save their valuable time.

Keywords: Information retrieval, Search process, Search strategies, Retrieval techniques.

Introduction:

Data is an observed fact and when any meaning is assign to data or when it is processed, it becomes information. Information reduces uncertainty and it is communicable. Information leads to confirmation but when information is processed and internalized it becomes knowledge. Today, plenty of information available in print and non-print format which leads to information overload. Internet is one of the vital sources of information. Sometimes it becomes impossible for the users to understand the available information or they do not understand where to find it or they are unable to access the right information. These factors leads to their stress, delay in decision making, waste of time etc.

Information Retrieval One of the best examples of information retrieval system (IRS) is library system where information is stored, processed, organized and retrieved on demand of its users.

Different types of information retrieval systems have been developed since 1950's to meet in different kinds of information needs of different users. Information retrieval system offers different search approaches those deals with three basic aspects. These aspects are as follows.

- ✓ Information storage and organization.
- ✓ Information representation.
- ✓ Information access.

Objectives of and Retrieval/Information Retrieval System (ISAR/IRS):

- ✓ To provide information to the user in least time with least efforts.
- ✓ To act as facilitator between information and user.
- ✓ To provide non-ambiguous search results through proper indexing.
- ✓ User friendliness.

Functions of Information Storage and Retrieval/Information Retrieval System (ISAR/IRS):

To identify sources of information relevant to the areas of the target user community,

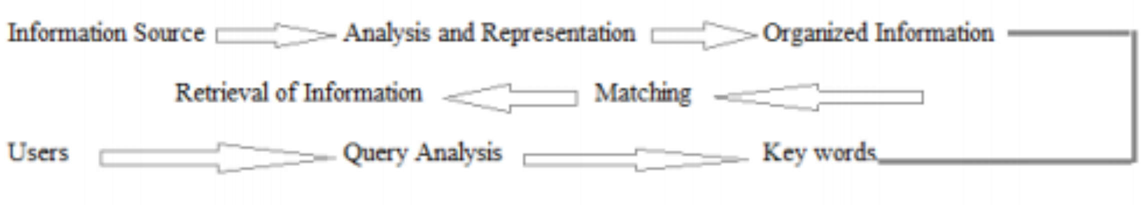
- ✓ To analyze the contents of the sources.
- ✓ Represents contents of analyze sources that will match queries.
- ✓ Analyze user queries that will match with database.
- ✓ Retrieve the information that is relevant.
- ✓ Necessary adjustments in system based on feedback from the user.

Components of Information Storage and Retrieval/Information Retrieval System (ISAR/IRS):

According to Lancaster the major components of an information retrieval system are....

- ✓ Document selection sub-system.
- ✓ Indexing sub-system.
- ✓ Vocabulary sub-system.
- ✓ Searching sub-system.
- ✓ Matching sub-system.

Outline of Information Storage and Retrieval/Information Retrieval System (ISAR/IRS):



Kinds of information retrieval system:

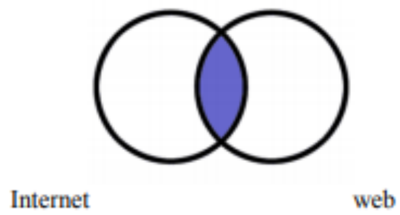
1. Offline Search: In offline search, users can get the required information with or without the help of computer and internet for example: libraries, CD-ROM etc.

✓ Online Search: means the search of a remotely located database through interactive communications with the help of computer and communication channel. Online databases can be access through vendor or directly. For example: OPAC, Databases, Internet etc.

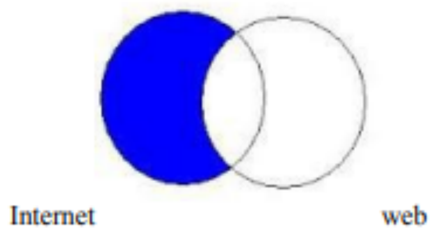
Retrieval Techniques:

Retrieval techniques are designed to help users to locate the information they need effectively and efficiently. These techniques help users to find out the required information easily. There are two types of retrieval techniques.

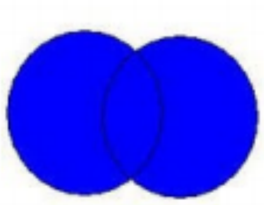
1. Basic Retrieval Techniques:
   a. Boolean Searching George Boole (1815-1864) developed AND, OR, NOT Boolean operators. By using these techniques user can narrow down their search to get the required information.
      i. AND: It includes addition of two different concepts for narrowing down the search. It retrieves all those items where all the constituent terms occur.



      ii. NOT: It is separation of complex concepts into individual simpler ones. It allows users to specify those terms that they do not want to occur in the retrieval records. It excludes unwanted results. Search output will decrease with increase in NOT term.



      iii. OR: The inclusion of more concepts to expand their connotation. It is used for broadening a search. It allows users to combine two or more search terms that system will retrieve all those terms that contain either one or all of the constituent terms.



b. Truncation Search :
   It is also known as wildcard, stemming, term masking, conflation algorithm etc…
   There are three types of truncation.
   i. Right truncation: truncation is on right side of the term. For example... Lib*
   ii. Left truncation: truncation is on left side of the term. For example... *rary
   iii. Simultaneous with left and right side. For example... *polymer*
c. Proximity search :
   This search facility allows users to specify…
   i. Whether two search terms should occur adjacent to each other.
   ii. Whether one or more words occur in between the search terms.
   iii. Whether the search terms should occur in some paragraph irrespective of the intervening words. Proximity search is as good as AND. It searches for the occurrence of two or more search terms but it specifies the distance between the search terms. For example…

   Sun within four words after moon (sun # 2 # after moon)
d. Field Searching :
   Document is presented by attributes such as Author, Title, Publication date, Document type, File type etc. these attributes are called as field searching. Search is possible with the help of these fields also.
e. Case Sensitive Searching :
   For languages such as English, French, Spanish upper and lower cases makes a difference. Case sensitive searching allows pinpointing exactly how a term is represented in a query and the system. For example...
   Web - World Wide Web.
   Web - web woven by spiders.
f. Range Searching :
   It is very useful in numerical searching. It is important in selecting records within certain data ranges. For example...
   Greater than (>)
   Less than (<)
   Equal to (=)
   Not equal to (1=0 or <>)
   Greater than or equal to (> =)
   Less than or equal to (< =)

2. Advanced Retrieval Techniques :

   g. Fuzzy Search :
      It sounds related to truncation search but with a major difference. Truncation is intended to retrieve different forms of term s when they share some parts in common. Fuzzy searching is designed to find terms that are spelled incorrectly at data entry or query point.

   h. Weighted Search :
      For weighted searching, weights are assigned to terms when a search query is composed to indicate proportionally their significance or the emphasis the user placed upon. For example…internet 3 AND web 5

MONITOR OPERATION OF EQUIPMENT

Preventive maintenance

Preventive maintenance includes measures such as systematic and routine cleaning, adjustment and replacement of equipment parts at scheduled intervals. Manufacturers generally recommend a set of equipment maintenance tasks that should be performed at regular intervals: daily, weekly, monthly or yearly. Following these recommendations will ensure that the equipment performs at maximum efficiency and will increase the lifespan of the equipment. This will also help to prevent:

- ✓ Inaccurate test results due to equipment failure
- ✓ Delays in reporting results
- ✓ Low productivity
- ✓ Large repair costs.

Maintenance plan

A maintenance plan will include preventive maintenance procedures as well as provision for inventory, troubleshooting and repair of equipment. When implementing an equipment maintenance program, some of the initial steps will include:

- ✓ Assigning responsibility for providing oversight;
- ✓ Developing written policies and procedures for maintaining equipment, including routine maintenance plans for each piece of equipment that specify the frequency with which all maintenance tasks should be performed;
- ✓ Developing the format for records, creating logs and forms, and establishing the processes to maintain records;
- ✓ Training staff on the use and maintenance of the equipment, and ensuring that all staff understand their specific responsibilities

Equipment inventory

It is recommended that a label is attached to the instrument indicating when the next maintenance or service should be performed.

The laboratory should keep an inventory log of all equipment in the laboratory. The log should be updated with information on new equipment and include documentation of when old equipment is retired. For each piece of equipment, the equipment inventory log should have a record of:

- ✓ Instrument type, make and model number, and serial number so that any problems can be discussed with the manufacturer;
- ✓ Date the equipment was purchased, and whether it was purchased new, used or reconditioned;
- ✓ Manufacturer/vendor contact information;
- ✓ Presence or absence of documentation, spare parts and maintenance contract;
- ✓ Warranty's expiration date;
- ✓ Specific inventory number indicating the year of acquisition (this is especially useful for larger laboratories); for example, use the style "yy-number" (04- 001, 04-002, etc.) Where "yy-number" equals the last two numbers of the year followed by a number attributed in the year.

An inventory process must be conducted if the laboratory does not have an existing inventory system for equipment. This could be conveniently organized following a model grid, room by room; for example, conduct an inventory of equipment in the reception area, then the sample collection area, the serology testing area, and the parasitology testing area. During the inventory, the condition of the equipment should be documented as functional, partially functional or nonfunctional. Equipment that is not functioning needs to be evaluated as to whether or not it can be repaired. Nonrepairable equipment should be retired, and work should be scheduled for equipment needing repair

Inventory of spare parts

To ensure that the laboratory does not run out of spare parts, an inventory record of those used most frequently should be kept for each piece of equipment. The record should include:

- ✓ Part name and number;
- ✓ Average use of the part, and the minimum to keep on hand;
- ✓ Cost;
- ✓ Date when the part is placed into storage and when it is used (in and out stock log);
- ✓ Quantity of each part remaining in inventory.

ACCESS AND TRANSMIT INFORMATION VIA THE INTERNET

In order to work with the Internet we need to know certain related terms like www, web browsers, web pages, websites, etc. We should know how to get connected to the Internet. Once connected – how to use it.

Most of the terms on the Internet are prefixed with the term web. The electronic pages seen on the Internet are known as web pages. A web page can be defined as the document that we see on the Internet. Many web pages linked with each other combine to form a website. A

web page can be written in the language known as HTML (Hyper Text Markup Language). HTML is a very simple language having a number of options to represent text. Many other scripting languages have now been developed which can be embedded into HTML, giving it the power to interact with the users. (These are discussed in detail in the next Unit). These dynamic web pages can take inputs from users and give information accordingly – taking in the location of the user before displaying the weather forecast. For example, a protocol called Hyper Text Transfer Protocol (HTTP) is used to transmit and receive the web pages.

Connecting to the Internet

In order to activate Internet services on any computer, it requires an Internet connection from an Internet Service Provider. There are several Internet Service Providers (ISPs) in India like VSNL, BSNL, Airtel, Reliance, etc. They charge some nominal fee for installation and connection. Depending on the requirement we can get an Internet connection in any of the following ways:

1. Dial-up connection : We can get connected to the Internet by dialing the ISP's number. This is useful if the network is either confined to small group of computers or for a single PC (Figure 7.4).

- ✓ Leased lines : A dedicated line is laid specifically for the connection. This provides a fairly high speed, but is expensive. This is suitable for an organisation requiring uninterrupted, high speed Internet connection.
- ✓ Broadband : This also provides a good speed. While leased line requires a separate telephone line, broadband can be delivered using an existing telephone line. This is ideal for home and small businesses requiring high speed Internet.
- ✓ WiFi Broadband : These days even wireless connections are available. For this we need to have a Wi Fi card attached to the computer and a wireless modem.
- ✓ When we connect to the Internet we must know its speed parameters. The speed of the Internet is measured in the number of bits transferred per unit time. Generally,

the speed of the Internet is measured in kbps (kilo bits per second), but these days some organisations are providing high speed connections in Mbps (Mega bits per second).

In order to have a connection we need a device called the modem. This device converts the digital signal from the computer into an analogue signal that can travel through the telephone line. On the other end, this analogue signal is again converted back to digital form by the modem at the destination end. Some computer systems have internal modems (built-in within the motherboard) while in some systems there might be a need to have an external modem to have an Internet connection.

Another device called a router can be attached to the computer to access the Internet. The router is a device used for connecting two different networks.

Uses of the Internet

The Internet is extensively used for a wide variety of purposes. Some of these are mentioned below:

Search for Information

A number of programs called search engines are available to search for the information on any topic. Some famous search engines are provided by: www.google.com, wikipedia.com, webopedia.com, MSN.com, Yahoo.com, etc.

E-mail (Electronic Mail) Services

The Internet is commonly used for sending and receiving e-mails. We can send a message electronically to any person on the globe, provided that person has an e-mail-id. This service is fast and economical.

Chatting

Chatting involves textual exchange of message in real time. Chat servers provide facility to create virtual chat rooms and only the members associated with these rooms are allowed to share messages. Chat works best if the time is scheduled by both the parties who are willing to chat – as both the parties must be connected to the Internet while chatting. Some common chat engines are : Yahoo Messenger, Google Talk, Rediff Bol, etc.

Instant Messenger Service

These tools can be used to send messages instantly. It also allows us to talk to anyone anywhere in the world. This is a cheaper and quicker method compared to other services. Unlike chatting, it is not necessary to have an account with the same provider. Additionally, both the users need not be connected while sending messages. We can easily download the messenger software from Internet e.g. MSN Messenger, Yahoo Messenger, etc

Newsgroup

Newsgroup is an e-service hosted by many newsgroup organisations. One can become a member of a newsgroup and read and share current affairs and messages. Newsgroups cover a broad domain of interests including education, science and technology, medicine, arts, sports, etc. USENET is one such example.

Teleconferencing

People can have a conference or meeting sitting at different locations with a microphone attached to their computers.

Video Conferencing

In teleconferencing we are able to talk to each other sitting at different places but in video-conferencing we can also see what is happening at the other side. We have observed that the anchor, panelists and experts sitting at different locations across the globe communicate and share their views in many news channels. For this, we need a web-camera and a microphone connected to the computer system, high bandwidth connection, and video-conferencing software.

E-Commerce

E-commerce or Electronic-Commerce means online transactions of business. In this, the vendor and customer conduct a transaction sitting at different geographical locations, connected through the Internet. The customer need not strain himself by visiting a number of shops outside in scorching heat or heavy rains. He can do shopping by sitting at home, visiting the desired e-commerce site and placing an order online. E.g. http://shopping.indiatimes.com, http://ebay.com, http:/ /shopping.rediff.com, etc.

M-Commerce

It is an acronym for mobile commerce. It is an upcoming technology after e-commerce. It involves buying and selling of goods and services electronically through wireless handheld devices at any place. We can do transactions through our mobile phones also.

Managing Email Accounts

To see the mails received, click on Inbox. A number against the Inbox indicates the number of unread mails. Once the Inbox is open, we shall see all the mails listed there. To read a mail, we need to just click on the mail that we wish to read.

After going through the mails we can either let them remain in our account for future reference or we can also delete the same. There are options for deleting or transferring them to trash. Trash is a folder where we keep the mails to be deleted.

To send an e-mail, both the sender and receiver must have an e-mail account. To send an e-mail, follow the steps listed below:

1. Click on the 'Compose' option.
2. Enter the e-mail address of the receiver against any of the three options - To , CC and BCC.
    a. To: Address(es) mentioned in this box are visible to every receiver.
    b. CC: stands for Carbon Copy. The mail will be sent to the To address as well as CC address. The addresses typed in To as well as in CC are visible to all other receivers.
    c. BCC: Stands for Blind Carbon Copy. Each user whose addresses are typed in BCC is unaware of the fact that the same message has also been sent to others.

Instead of typing in the address, we can also insert the same from the address book (Section 7.5.7):

a. Click Insert Address or Address Book.
b. Select the addresses by Checking (ticking) them.
c. Click OK or Insert option to insert the address in the recipient mailbox.

3. Write in the message in the text box as indicated in the figure
4. After typing in the message click on send option as indicated in the figure 7.10.

In order to close the e-mail session, we can click on options like logout or sign out.

CLOSE DOWN COMPUTER SYSTEM

Shutting down a computer safely closes all the programs that are open and exits the Operation System in order to keep the hardware from damage and to prevent the computer from corrupted systems.

Shutting down a computer using Windows 7:

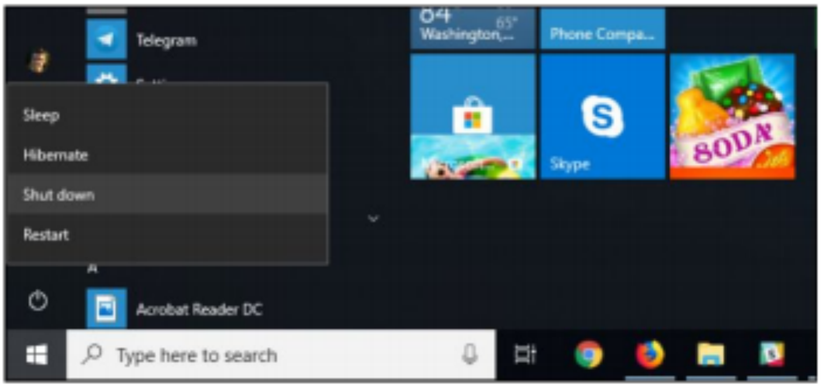
1. Click the Windows Icon at the lower left side of the screen.
2. Click the Shutdown button.

or Press Ctrl+Alt+Del and click the power button in the bottom-right corner of the screen.

From the Windows desktop, press Alt+F4 to get the Shut down Windows screen and select Shut down.

Shutting down a computer using Windows 10:

1. Click the Windows Icon at the lower left side of the screen.
2. Click the Shutdown button to properly shutdown a computer
   or Press Ctrl+Alt+Del and click the power button in the bottom-right corner of the screen.
3. From the Windows desktop, press Alt+F4 to get the Shut down Windows screen and select Shut down.



UNIT 04

APPLY MATHEMATICS FOR WATER OPERATIONS

The aim of this module is to enable the candidate to: Use calculation to solve simple problems, construct plane figures, and develop patterns

PERFORM SIMPLE MATHEMATIC CALCULATIONS

Definition of Fractions

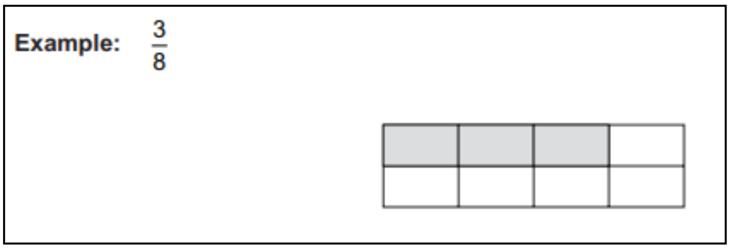
There are two types of fractions, both of which describe less than a whole object. The object can be an inch, a foot, a mile, a ton, a bundle of weld rods, other measurements, etc. The two types of fractions are:

1. Common fractions (fractions)
2. Decimal fractions (decimals)

Common fraction examples are: $\frac{1}{2}, \frac{3}{4}, \frac{5}{8}$
Decimal fraction examples are: .50, .75, .625

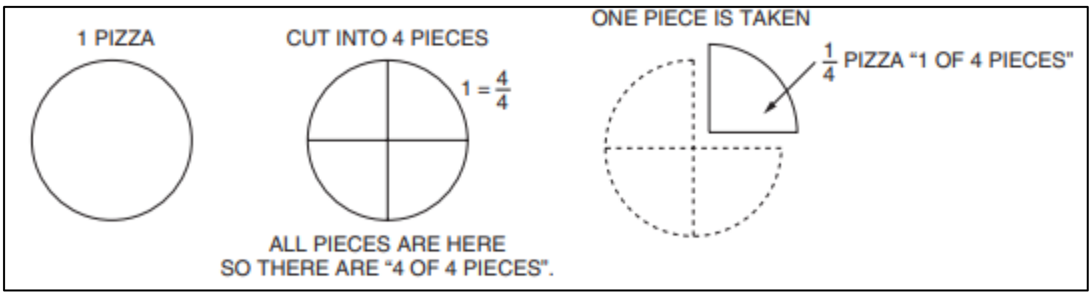
Basic principles

The bottom number (the denominator) of every fraction shows the number of pieces any one whole object is divided into; all pieces are of equal size. The top number (the numerator) shows information about that divided object.

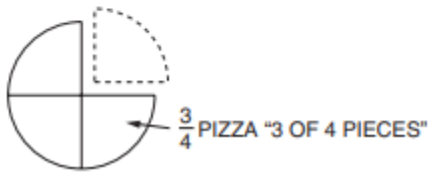


3 is the numerator, and 8 is the denominator. This fraction shows that an object has been divided into 8 equal pieces, and that 3 of those 8 pieces are shaded.

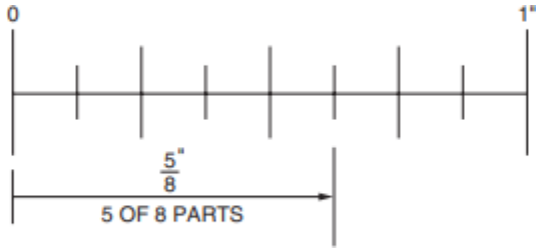
Let's work with other simple examples. If we have one whole unsliced pizza, we can divide it into pieces, and then make fractions about the pizza. This example is cut into 4 pieces (quarters). Fractions concerning this pizza will have the bottom number 4. To describe 1 of those pieces, the fraction is written 1 /4, ("1 of 4 pieces").



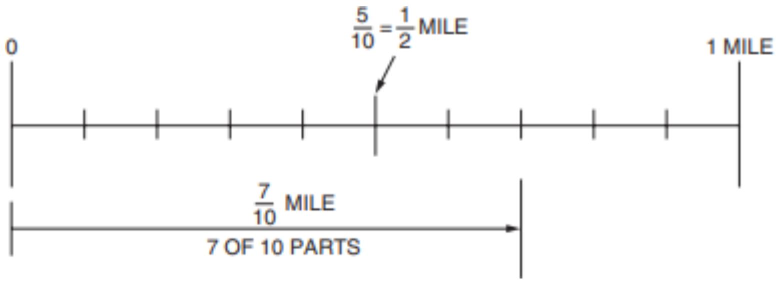
¾ indicates that "3 of 4 pieces" are still available.



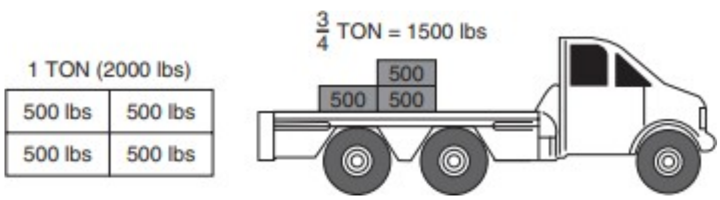
3. 5/8″ (five-eights inch) shows that an inch is divided into 8 parts and that 5 of those 8 parts have been measured.



4. 7/10 of a mile (seven-tenths mile) shows that a mile is divided into 10 parts, and we've measured 7 of those 10 parts.



5. 3/4 ton (three-fourths, or three-quarters of a ton) shows that a ton of hay (2,000 pounds) has been divided into 4 parts, and 3 of those 4 parts can be hauled on a flat-bed truck.



The fractions 5/8, 7/10, and 3/4 and their verbal descriptions “5 of 8 pieces,” “7 of 10 parts,” and “3 of 4 parts,” give your mind a clear picture of each object, how many pieces it was cut up into, and how many of those pieces are being described. With this, you can give accurate information to anyone: a customer, a fellow worker, your foreman, or on a test you may be taking to get into an apprenticeship.

Decimal fractions are similar to common fractions in that they describe part of a whole object.

In decimals, an object is divided into tenths, hundredths, thousandths, etc. Welders, however, primarily work with tenths and hundredths.

Note: For all decimal problems in this workbook, round to hundredths (two “places” unless otherwise noted. You may round to three, or four, places if that place number is a 5 (i.e., .125 or .0625). Greater accuracy is achieved if only the final answer is rounded off, not the numbers used to arrive at the answer.

A decimal point separates the whole numbers from the parts, and the whole numbers are always to the left of the decimal point.

The first place after the decimal point is called tenths. The second place is called hundredths; and the third place is called thousandths.

Example:

Tenths	Hundredths	Thousandths
.758	.7 5	8

Tenths describes 1 whole object divided into 10 parts. Hundredths describes 1 whole object divided into 100 parts.

Rounding Off Decimals

“Rounding off” helps express measurements according to the needs of our trade. Welders generally round off to the nearest tenths or hundredths.

Rounding to tenths:

If the number directly to the right is 5 or more, increase the tenth-place number by 1. If the number directly to the right is 4 or less, the tenth-place number stays the same.

Examples:

.68 rounded to tenths is .7.
.64 rounded to tenths is .6.

Rounding to hundredths:

If the number directly to the right is 5 or more, increase the hundredth-place number by 1. If the number directly to the right is 4 or less, the hundredth-place number stays the same.

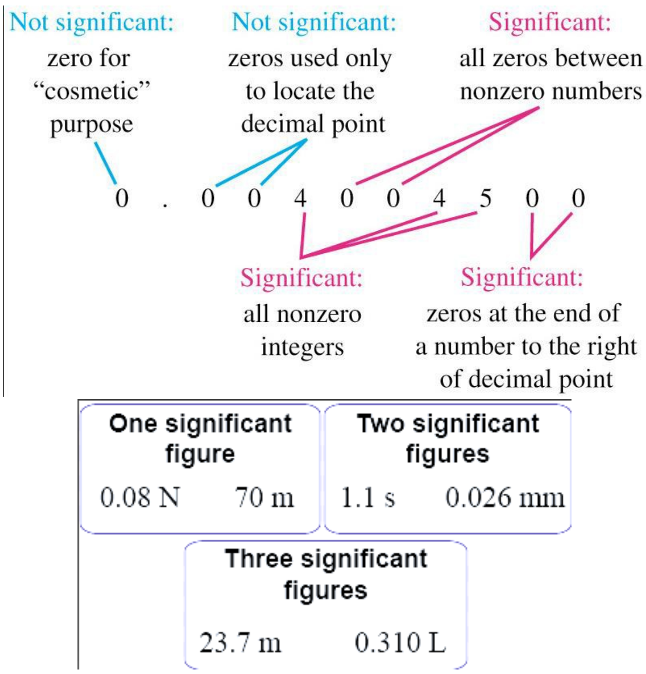
Examples:

.357 rounded to hundredths is .36.
.351 rounded to hundredths is .35

0s placed at the end of a decimal have no effect on the value. Examples:
.5 = .50
.50 = .500
0s placed in front of the decimal point have no effect on the value, as long as there are no whole numbers.
Example: .25 = 0.25

Significant figures

The significant figures of a number are digits that carry meaning contributing to its measurement resolution.



Estimation

To **estimate** means to find something close to the correct answer. In other words, you are approximate

9411 → 9000
3849 → 4000
9000 + 4000 = 13,000

Identify and use the multiples and sub-multiples of units

Formally agreed by the 11th General Conference on Weights and Measures (CGPM) in 1960, the SI is at the centre of all modern science and technology. The definition and realization of the base and derived units is an active research topic for petrologists with more precise methods being introduced as they become available.

Base units

Physical Quantity	Name of Unit	Abbreviation
Mass	Kilogram	kg
Length	Meter	m
Time	Second	s[a]
Temperature	Kelvin	K
Amount of substance	Mole	mol
Electric current	Ampere	A
Luminous intensity	Candela	cd

Some prefixes

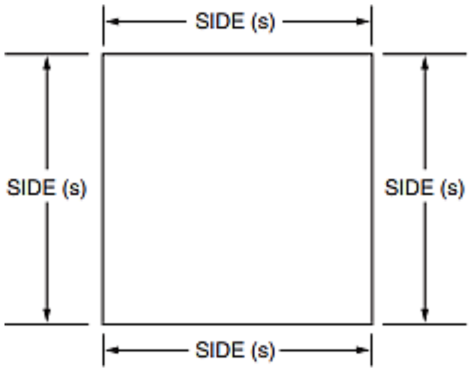
Prefix	Abbreviation	Meaning	Example
Giga	G	10^9	1 gigameter (Gm) $= 1 \times 10^9$ m
Mega	M	10^6	1 megameter (Mm) $= 1 \times 10^6$ m
Kilo	k	10^3	1 kilometer (km) $= 1 \times 10^3$ m
Deci	d	10^{-1}	1 decimeter (dm) = 0.1 m
Centi	c	10^{-2}	1 centimeter (cm) = 0.01 m
Milli	m	10^{-3}	1 millimeter (mm) = 0.001 m
Micro	μ[a]	10^{-6}	1 micrometer (μm) $= 1 \times 10^{-6}$ m
Nano	n	10^{-9}	1 nanometer (nm) $= 1 \times 10^{-9}$ m
Pico	p	10^{-12}	1 picometer (pm) $= 1 \times 10^{-12}$ m
Femto	f	10^{-15}	1 femtometer (fm) $= 1 \times 10^{-15}$ m

Table 1.2 Derived quantities and their units

Physic Quantity	Expression	Unit
Area	length × breadth	m^2
Volume	area × height	m^3
Velocity	displacement/ time	$m\ s^{-1}$
Acceleration	velocity / time	$m\ s^{-2}$
Density	mass / volume	$kg\ m^{-3}$
Pressure	force / area	$N\ m^{-2}$ or Pa

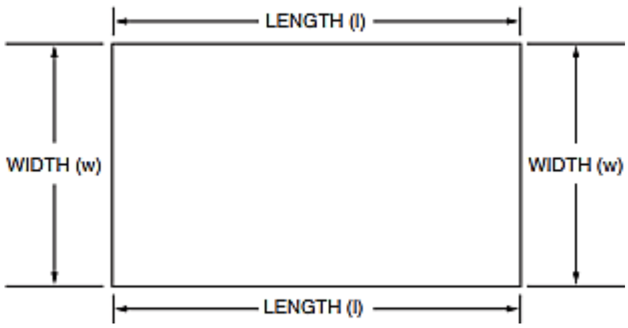
Perform calculations on: Perimeter and Area

The distance around a figure is called the "perimeter." Square
A four-sided figure, as shown below. All four sides are of equal length, and all four angles are 90°.



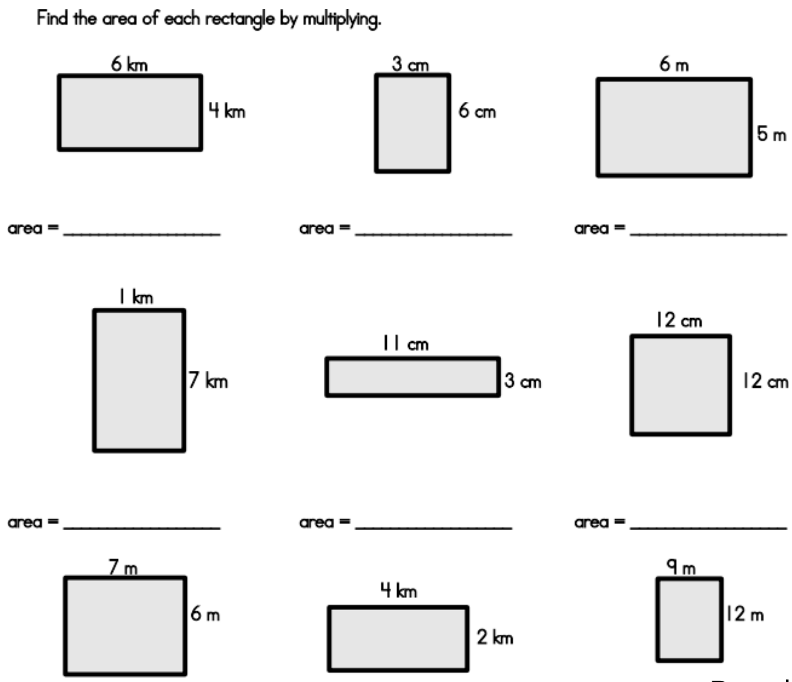
Rectangle

A four-sided figure, as shown below. The lengths are equal only to each other and the widths are equal only to each other. All four angles are 90°.



Area of Square

Formula: A= Side x Side
Area of Rectangle Formula: A= L x H



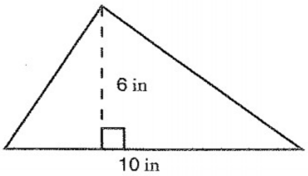
Area of triangle

$$A = \frac{1}{2}\,bh$$

Form

Examples: Find the area.

(a)

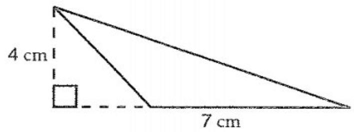


$A = \frac{1}{2}\,bh$

$A = \frac{1}{2}(10)(6)$

$A = 30\text{ in}^2$

(b)



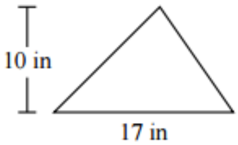
$A = \frac{1}{2}\,bh$

$A = \frac{1}{2}(7)(4)$

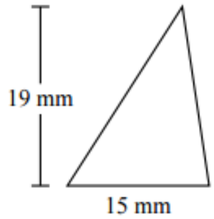
$A = 14\text{ cm}^2$

Find the area of each triangle. Units are not to scale.

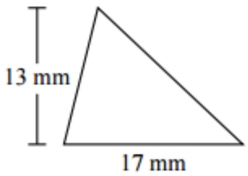
1)



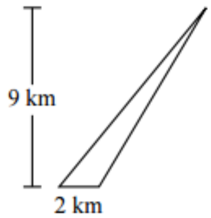
2)



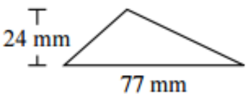
3)



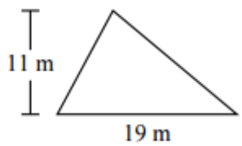
4)



5)

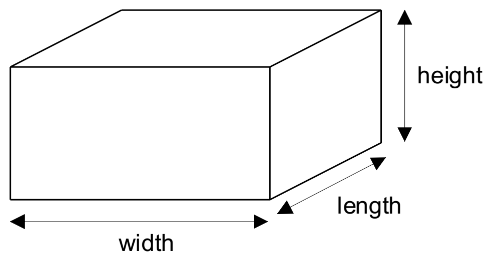


6)

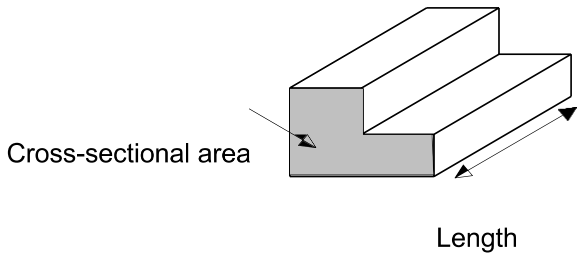


Volume and Surface Area

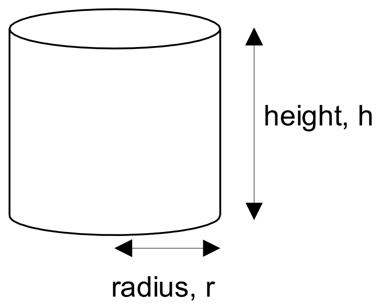
Volume of **cuboid** = length × width × height



Volume of **prism** = cross-sectional area × length



Volume of cylinder = $\pi r^2 h$,
Where r is the radius and h is the height of the cylinder.



Example: 1

A cuboid measures 15 cm by 12 cm by 8 cm. Find the capacity of the cuboid. Give your answers in liters.
Solution:
Volume = $15 \times 12 \times 8 = 1440 \text{ cm}^3$.
As 1 litre = 1000 cm^3, the capacity of the cuboid = 1.44 litres.

Example: 2

A cylinder has a volume of 965 cm^3. If the height of the cylinder is 16 cm, find the radius.
Give your answer to 2 significant figures.

Solution:
Substitute the information from the question into the formula for the volume of a cylinder:

$$\text{Volume of cylinder} = \pi r^2 h$$
$$965 = \pi \times r^2 \times 16$$
$$965 = \pi \times 16 \times r^2$$
$$965 = 50.26548 \times r^2$$
$$19.198 = r^2$$
$$4.38156 = r$$

So the radius of the cylinder is 4.4 cm (to 2 SF)

Exercise question

A can of drink has the shape of a cylinder. The can has a radius of 4 cm and a height of 15 cm. Calculate the volume of the cylinder. Give your answer correct to three significant figures.

Exercise question

Calculate the volume of the triangular prism.

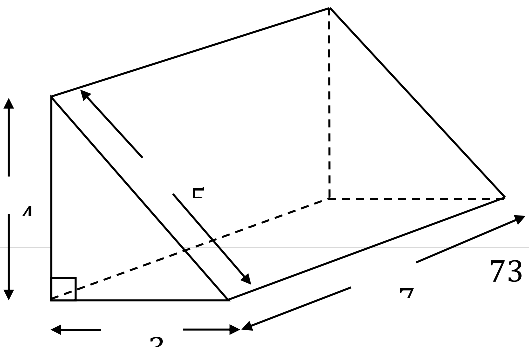
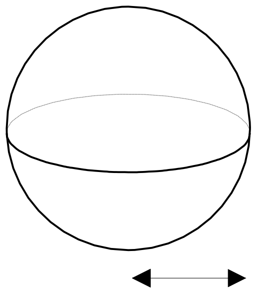


Diagram **NOT** accurately drawn

Volume of a sphere

Volume of a **sphere**

$= \frac{4}{3}\pi r^3$

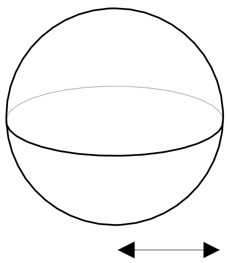


Example: 3

A sphere has a volume of 86.5 cm^3. Find the radius of the sphere. Solution:

A **hemisphere** is half a sphere. Example

The radius of a sphere is 6.7 cm. Find the volume.



Solution:

Substitute *r* = 6.7 cm into the formula

Volume = $\frac{4}{3}\pi r^3$

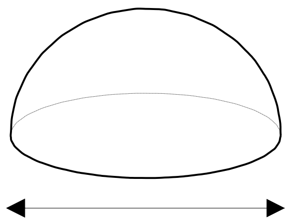
V = $\frac{4}{3} \times \pi \times 6.7^3$

V = 1259.833 (remember to use the cube button on your calculator)

V = 1260 cm^3 (to 3 SF)

Example: 2

Find the volume of the hemisphere shown in the diagram.



Solution:

The diameter of the hemisphere is 18.4 cm.
Therefore, the radius is 9.2 cm.

Volume of the hemisphere = $\frac{1}{2} \times$volume of sphere

$$= \frac{1}{2} \times \frac{4}{3} \pi r^3$$

$$= \frac{1}{2} \times \frac{4}{3} \times \pi \times 9.2^3$$

$$= \frac{1}{2} \times 3261.76$$

= 1630 cm^3 (to 3 SF)

Example 3:

A sphere has a volume of 86.5 cm3. Find the radius of the sphere.
Solution:

Substitute into the formula for the volume of a sphere: Volume = $\frac{4}{3} \pi r^3$

86.5 = $\frac{4}{3} \pi r^3$

So 86.5 = $4.18879 r^3$

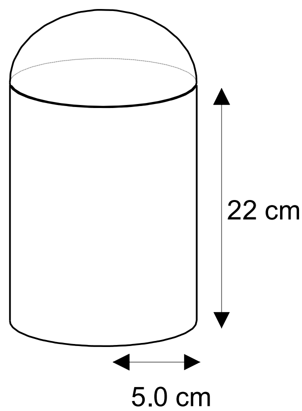
i.e. 20.65035 = r^3

So r = 2.74 cm (to 3 SF) (cube rooting)

The sphere has radius 2.74 cm.

Examination style question

The object shown is made up from a cylinder and a hemisphere.
The cylinder has radius 5.0 cm and height 22 cm. Find the volume of the object.



Solution:

Volume of cylinder = $\pi r^2 h$

$$= \pi \times 5^2 \times 22$$

= 1728 cm3 (to nearest whole number)

The hemisphere must also have radius 5 cm.

Volume of the hemisphere = $\frac{1}{2} \times$volume of sphere

$$= \frac{1}{2} \times \frac{4}{3} \pi r^3$$

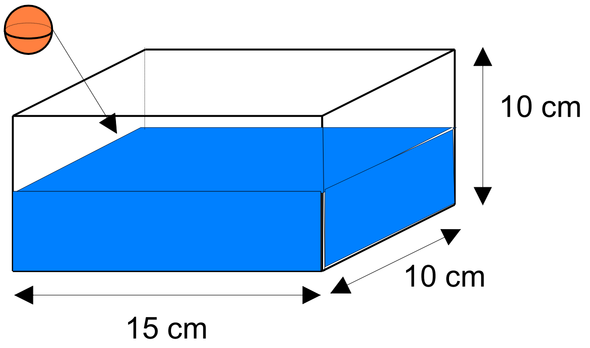
$= \frac{1}{2} \times \frac{4}{3} \times \pi \times 5^3$

$= 262\ cm^3$

Therefore total volume of the object = 1728 + 262 = 1990 cm^3.

Example

A tank measures 15 cm by 10 cm by 10 cm. The tank is half-full of water.



A solid metal sphere with radius 2 cm is placed into the tank.
Assuming that the sphere sinks to the bottom of the tank, calculate the amount by which the water level in the tank rises.
Solution
As the sphere will be completely submerged, it will displace its volume of water.

Volume of sphere = $\frac{4}{3}\pi r^3 = \frac{4}{3} \times \pi \times 2^3 = 33.51\ cm^3$.

Therefore, the water displaced is 33.51 cm^3.
The water displaced has the form of a cuboid with measurements 15 cm by 10 cm by *h* cm, where *h* is the height by which the water level rises.
So $15 \times 10 \times h = 33.51$
i.e. $h = 0.22$ cm
The water rises by 0.22 cm.

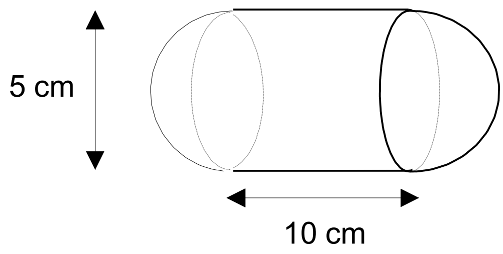
Examination question

A solid plastic toy is made in the shape of a cylinder which is joined to a hemisphere at both ends.

The diameter of the toy at the joins is 5 cm.

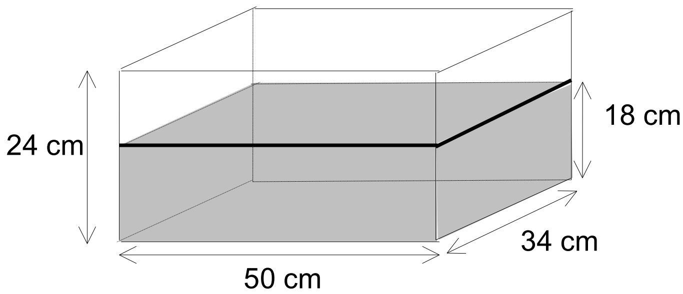
The length of the cylindrical part of the toy is 10 cm.

Calculate the volume of plastic needed to make the toy. Give your answer correct to three significant figures.



Examination question

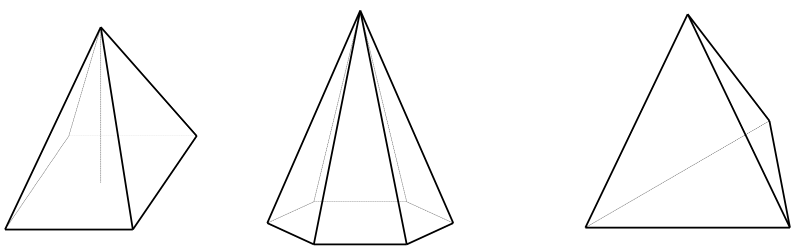
A water tank is 50 cm long, 34 cm wide and 24 cm high. It contains water to a depth of 18 cm.



Four identical spheres are placed in the tank and are fully submerged. The water level rises by 4.5cm. Calculate the radius of the spheres.

Volume of a pyramid

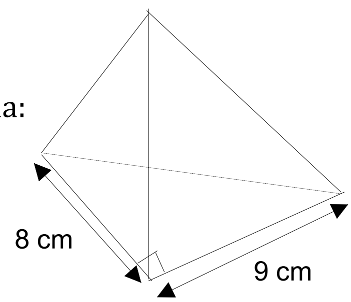
Pyramids come in a range of shapes. They can have bases which are any shape e.g. triangular, square, rectangular, circular etc.



The volume of any **pyramid** can be found using the formula:

$$\text{Volume of } \textbf{pyramid} = \frac{1}{3} \times \text{base area} \times \text{height}$$

Example:



The pyramid shown has a square base. The square has sides of length 12 cm. The height of the pyramid is 10 cm. Find the volume.

Solution:
The area of the square base is 12 × 12 = 144 cm^2
So, the volume of the pyramid is:

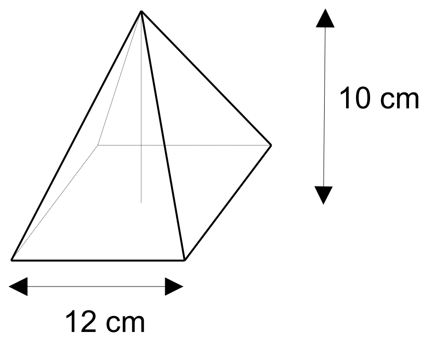
$$\text{Volume} = \frac{1}{3} \times 144 \times 10$$
$$= 48 \times 10$$
$$= 480 \text{ cm}^3.$$

Example: 2

The diagram shows a triangular-based pyramid. The base of the pyramid is a right-angled triangle. The volume of the pyramid is 325 cm^3. Find the height of the pyramid.

Solution:

The base of the pyramid is as shown:



The area of the base is $\frac{1}{2} \times 9 \times 8 = 36\,\text{cm}^2$.

Substitute information into the formula for the volume of a pyramid.

Volume of pyramid = $\frac{1}{3} \times \text{base area} \times \text{height}$

325 = $\frac{1}{3} \times 36 \times \text{height}$

325 = 12 × height.

So, height = 325 ÷ 12 = 27.08 cm (to 4 SF).

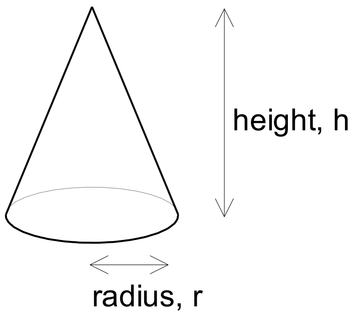
Volume of a cone

A cone is a pyramid with a circular base. Volume of cone = $\frac{1}{3}\pi r^2 h$

The formula for the volume of a cone is:

Volume of cone = $\frac{1}{3}\pi r^2 h$

Where *r* is the radius of the cone and *h* is the height of the cone.



Where *r* is the radius of the cone and *h* is the height of the cone.

Example 1

The base of a cone has a radius of 4 cm. The height of the cone is 6 cm.
Find the volume of the cone. Leave your answer in terms of π.

Solution:

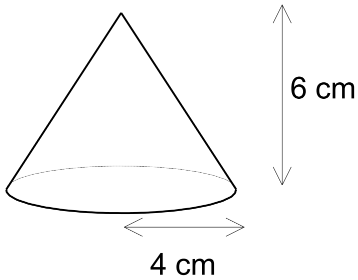
Substitute the information into the formula for the volume of a cone

Volume of cone = $\frac{1}{3}\pi r^2 h$

$= \frac{1}{3} \times \pi \times 4^2 \times 6$

$= 2 \times \pi \times 16$ (start by finding 1/3 of 6)

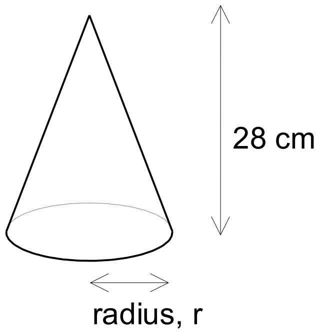
volume = 32π cm^3.



Example 2:

A cone has a volume of 1650 cm^3. The cone has a height of 28 cm.
Find the radius of the cone. Give your answer correct to 2 significant figures.

Solution:
Substitute information into the formula:



Volume of cone = $\frac{1}{3}\pi r^2 h$

1650 = $\frac{1}{3} \times \pi \times r^2 \times 28$

1650 = $29.32153r^2$ (evaluating $\frac{1}{3} \times \pi \times 28$)

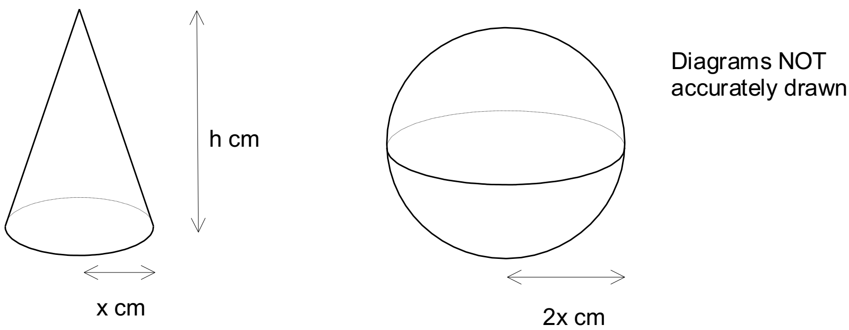
$r^2 = 56.2726$

i.e. r = 7.5 cm (to 2 SF)

The radius of the cone is therefore 7.5 cm.

Problem solving:

The radius of the base of a cone is x cm and its height is h cm. The radius of a sphere is $2x$ cm.



The volume of the cone and the volume of the sphere are equal.
Express h in terms of x.
Give your answer in its simplest form.

Solution:

The volume of the cone is $\frac{1}{3}\pi r^2 h = \frac{1}{3}\pi x^2 h$

The volume of the sphere is $\frac{4}{3}\pi r^3 = \frac{4}{3}\pi(2x)^3$ (note: the brackets around $2x$ are important)

$= \frac{4}{3}\pi \times 8x^3$ (cubing both 2 and x)

$= \frac{32}{3}\pi x^3$

As the sphere and the cone have the same volume, we can form an equation:

$\frac{1}{3}\pi x^2 h = \frac{32}{3}\pi x^3$

$\pi x^2 h = 32\pi x^3$ (Multiplying both sides by 3)

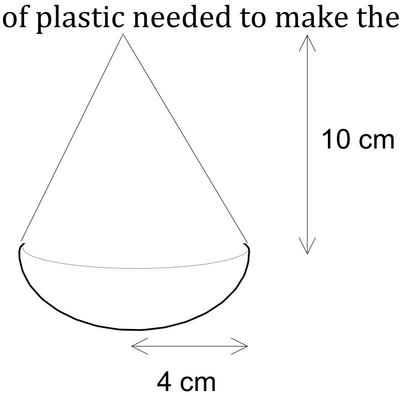
$x^2 h = 32x^3$ (Dividing both sides by π)

$h = 32x$ (Dividing both sides by x^2)

Past examination question

A child's toy is made out of plastic. The toy is solid.
The top of the toy is a cone of height 10 cm and base radius 4 cm.
The bottom of the toy is a hemisphere of radius 4 cm.

Calculate the volume of plastic needed to make the toy.

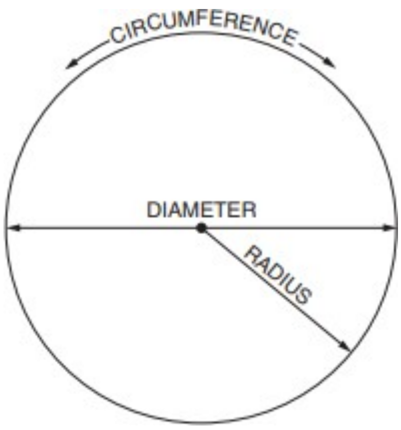


Geometry

Geometry is essential to welding. Several welding projects require you to understand, calculate and measure welds at different angles accurately. Moderate knowledge of geometrical measurements will make it easier for you to connect metals together while advanced knowledge will make it possible to work on complex projects.
Welders also use geometrical knowledge for calculating the length and size of various shapes and calculate the radius, diameter, and circumference for pieces that have a round shape.
In order to use geometrical angles, welders will also need to have the right drafting tools such as triangles. The triangles make it easier to connect 90, 45 & 60 degree angles together. A compass is also used for precise measurements and calculation of points between different angles. Both tools are helpful when creating joints and help ensure that they're square. They can also be used to determine the radius, diameter and circumference of a circle.

Identify the elements of a circle Parts

Circle: A circle is a closed curved object, all parts of which are equally distant from the center



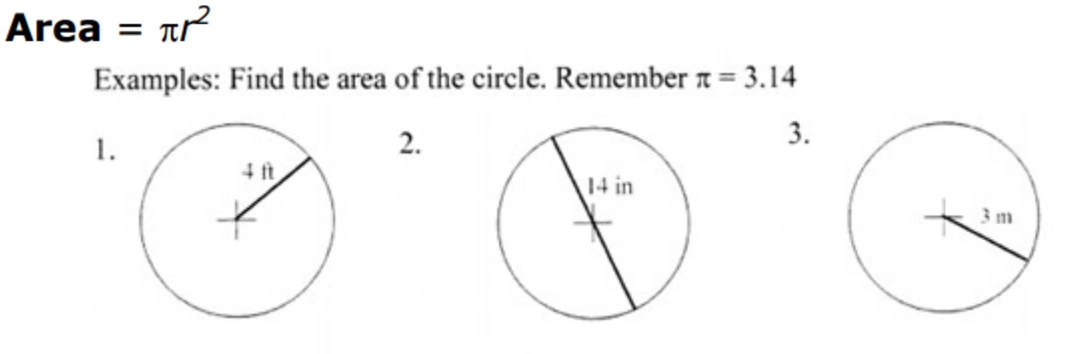
Circumference: Circumference is the distance around a circle: it is similar in meaning to perimeter.
Symbol used is C.

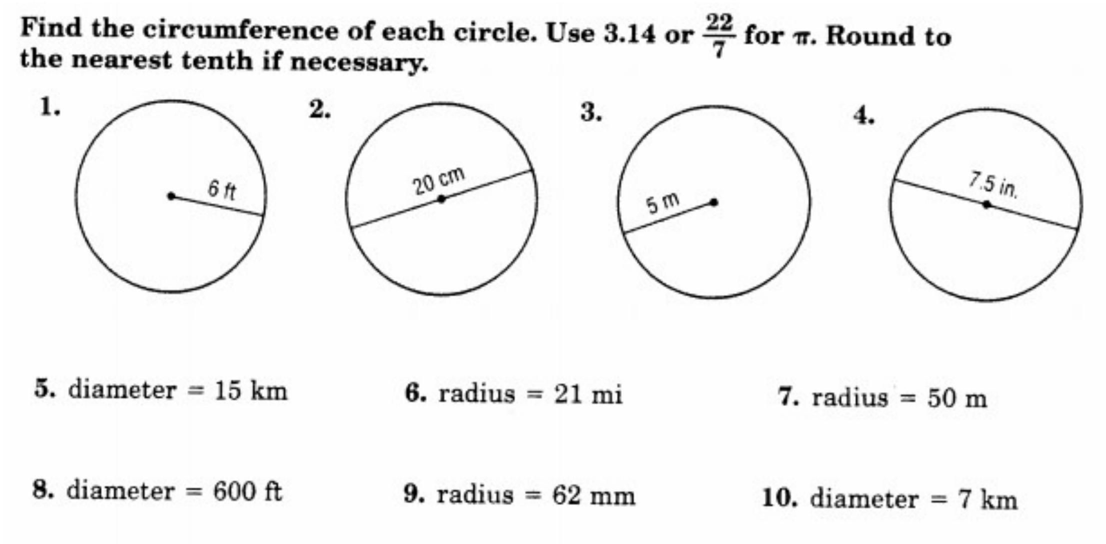
Radius: The radius is a straight line measurement from the center, to the edge, of the circle: it is one-half the diameter. Symbol used is r.

Diameter: The diameter is a straight line through the center of the circle, traveling from edge to edge. It divides the circle in half, and is equal in length to 2 radii. Symbol used is (D).
Diameter is designated on blueprints with the symbol Ø.

Pi: The circumference of any circle is 3.1416 times the diameter of that circle. The number 3.1416 is represented by the Greek letter “pi”. The symbol used is π. Welding shops round π to 3.14.

The formula for calculating the circumference of a circle is:





Identify and use the ratio of sides of 45° and 60° right angled triangles.

Trigonometry

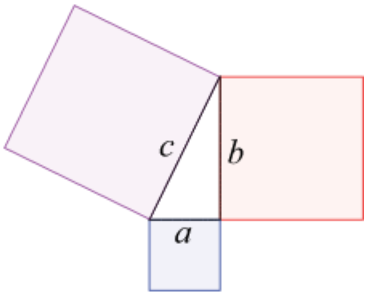
Speaking of angles, welders must also possess a good understanding of trigonometry for creating angled structures. Trigonometry helps welders determine the area of the weld and the angle it should be created at for handling pressure under various environmental conditions.

Trigonometry helps welders determine the strength of the weld and how joints should be made to ensure that they will not break with usage. The welder can test the strength of the joint without breaking it by applying module testing methods such as ultrasonic waves based on tangents, signs and cosigns. Testing methods help the welder determine imperfection in the weld and adjust it to create a durable structure.

Trigonometry is one of the more complex mathematical skills and takes time to master. It can be difficult to understand it if you aren't already good at geometry. The good part is that you can learn and improve your understanding of angled joints by taking a course in trigonometry.

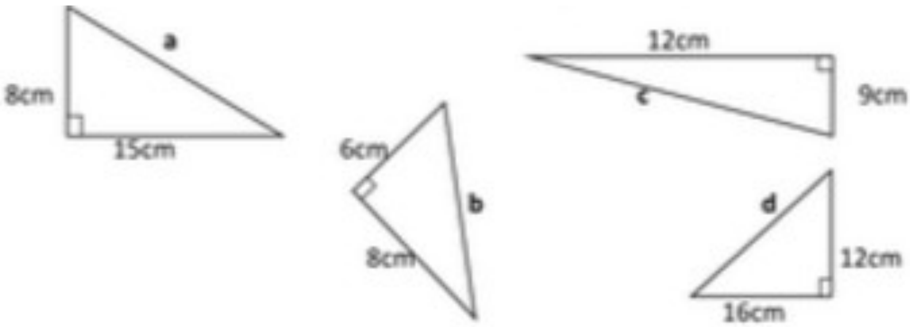
Pythagoras' Theorem

It states that the square of the hypotenuse (the side opposite the right angle) is equal to the sum of the squares of the other two sides.

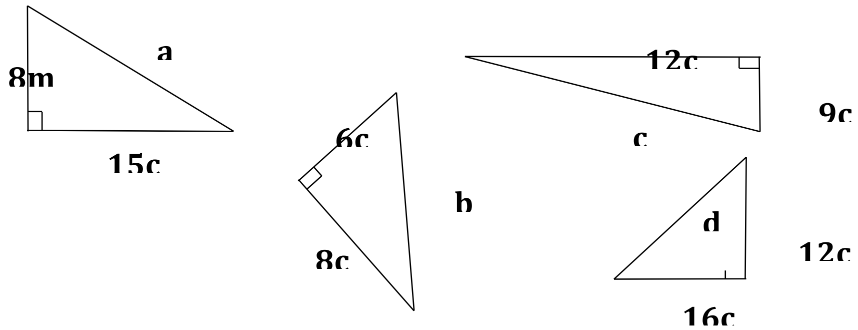


$a^2+b^2=c^2$

Find hypotenuse of following



Using Pythagoras, find the length of the side labeled with letters.

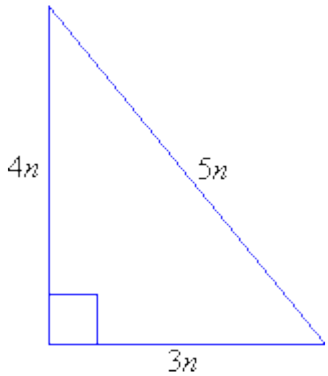


6.

3-4-5 Right Triangle

A 3-4-5 triangle is right triangle whose lengths are in the ratio of 3:4:5. When you are given the lengths of two sides of a right triangle, check the ratio of the lengths to see if it fits the 3:4:5 ratio.

Side1 : Side2 : Hypotenuse = 3n : 4n : 5n



Example 1:

Find the length of the hypotenuse of a right triangle if the lengths of the other two sides are 6 inches and 8 inches.

Solution:

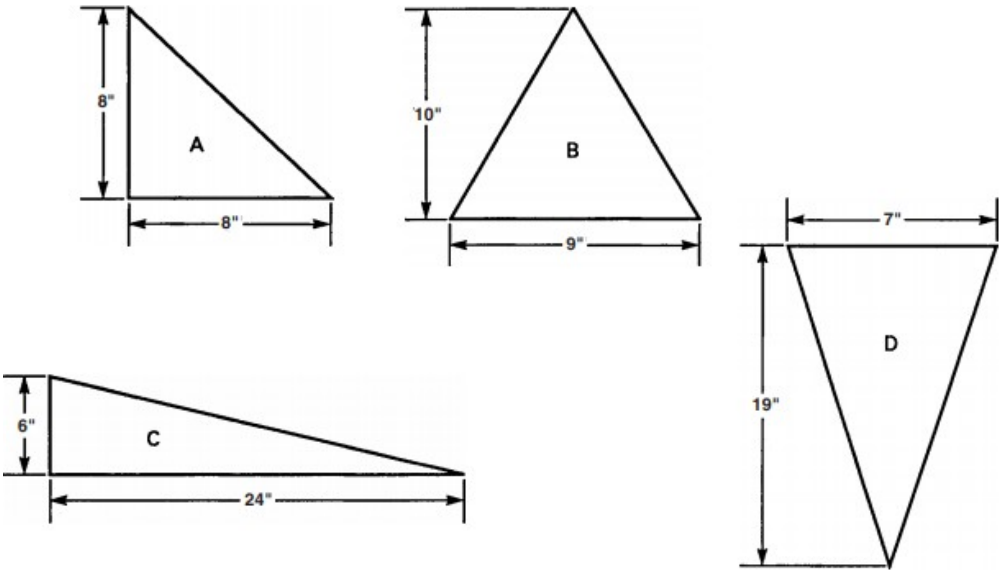
Step 1: Test the ratio of the lengths to see if it fits the $3n : 4n : 5n$ ratio. 6 : 8 : ? = 3(2) : 4(2) : ?
Step 2: Yes, it is a 3-4-5 triangle for $n = 2$.

Step 3: Calculate the third side $5n = 5 \times 2 = 10$

Answer:

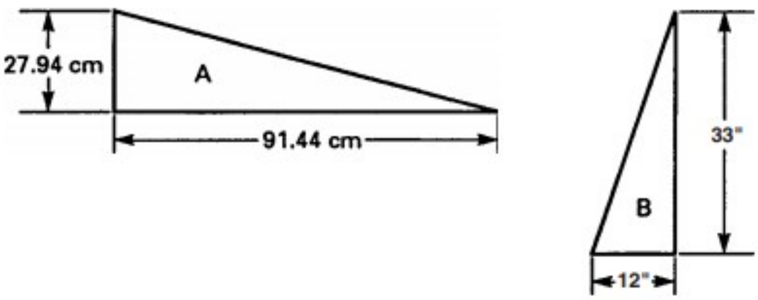
The length of the hypotenuse is 10 inches.

Solve simple workshop problems involving Pythagoras and right-angled triangles. These four triangular shapes are cut from sheet metal. What is the area of each piece in square inches?



1. Triangle A ___________
2. Triangle B ___________
3. Triangle C ___________
4. Triangle D ___________

Two pieces of sheet metal are cut into triangular shapes.



5. Find, in square centimeters, the area of triangle A. ___________
6. Find, in square inches, the area of triangle B. ___________

Convert Degrees Minutes Seconds to Decimal Degrees

Latitude and Longitude coordinates are often presented in degrees, minutes, and seconds, such as 39° 45' 30" (39 degrees, 45 minutes, 30 seconds). However, we can only plot values in decimal degrees. So, for example, 39° 45' is referred to as 39.75°

Converting from degrees, minutes, and seconds is actually quite easy. Consider the latitude value 39° 25' 30". This value needs to be converted to use it in Strater. There are 60 minutes in one degree and 3600 seconds in one degree. To convert minutes and seconds to decimal degrees, divide minutes by 60, divide seconds by 3600, and then add the results to obtain the decimal equivalent. Use the following formula to make the conversion:

Decimal degrees = Degrees + (Minutes/60) + (Seconds/3600)

For Example, to convert 39° 25' 30" to decimal degrees

1. First, convert minutes and seconds to their degree equivalents and add the results
   25'/60=0.4167°

   30"/3600=.0083°
2. and 0.4167° + 0.0083° = 0.425°
3. Then, add this number to the number of degrees. 39° + 0.425° = 39.425°
   So, the final result is: 39° 25' 30" = 39.425°

APPLY KNOWLEDGE OF MATHEMATICS IN WATER OPERATIONS

Water Measurement Units

There are two conditions under which water is measured—water at rest and water in motion. Water at rest is measured in units of volume. Water in motion is measured in units of flow— unit of volume for a convenient time unit. It is important that the difference between a unit of volume and a unit of flow be kept in mind.

Volume Units

Water at rest; i.e., ponds, lakes, reservoirs, and in the soil, is measured in units of volume — gallon, cubic foot, acre-inch, and acre-foot.

Cubic Foot – The volume of water that would be held in a container one foot wide by one foot long by one foot deep.

Acre-Inch – The volume of water that would cover one acre (43,560 square feet) one inch deep.

Acre-Foot – The volume of water that would cover one acre one foot deep.

Flow Units

Water in motion; i.e., flowing in streams, canals, pipelines, and ditches, is measured in units of volume per unit of time—gallons per minute (gpm), cubic feet per second (cfs), acre-inches per hour and acre feet per day. Cubic feet per second, sometimes written second-feet (sec. ft. or cusec) is most commonly used for measuring flow of irrigation water moving by gravity from streams and reservoirs. Gallons per minute is most commonly used for measuring flow from pumps.

Cubic foot per second – The quantity of water equivalent to a stream one foot wide by one foot deep flowing with a velocity of one foot per second.

Gallon per minute – The quantity of water equivalent to a stream which will fill a gallon measure once each minute.

A flow of one cfs is approximately equal to either 450 gpm, one acre-inch per hour, or two acre-feet per day (24 hours).

Conversion Factors

The following equivalents are useful for converting from one unit to another and for calculating volumes from flow units.

Volume Units

One gallon
= 231 cubic inches
= 0.13368 cubic foot weighs approximately 8.33 pounds

One cubic foot
= 1,728 cubic inches
= 7.481 gallons (7.5 for ordinary calculations) weights 62.4 pounds (62.5 for ordinary calculations)

One acre-inch
= 3,630 cubic feet
= 27,154 gallons (27,200 for ordinary calculations)
= 1/12 acre-foot weighs approximately 113.1 tons

One acre-foot
= 43,560 cubic feet
= 325,851 gallons
= 12 acre-inches weighs approximately 1,357 tons

Flow Units

One gallon per minute
= 0.00223 (approximately 1/450) cubic foot per second
= 0.00221 acre-inch per hour
= 0.00442 acre-foot per (24 hour) day
= 1 acre-inch in 452.6 hours (450 for ordinary calculations)
= 1 acre-foot in 226.3 days

One cubic foot per second
= 448.83 gallons per minute (450 for ordinary calculations)
= 1 acre-inch in 1 hour and 30 seconds (1 hour for ordinary calculations)
= 1 acre-foot in 12 hours and 6 minutes (12 hours for ordinary calculations)
= 1.984 acre-feet per (24 hours) day (2 acre-feet for ordinary calculations)

Million gallons per day (mgd)
= 694.4 gallons per minute (695 for ordinary calculations)
= 1.547 cubic feet per second (1.5 for ordinary calculations)

Conversion Table.

To convert from: To: Multiply by:
Cubic-ft Gallons 7.5
Acre-in Cubic-ft 3,630
Acre-ft Cubic-ft 43,560
Acre-ft Acre-in 12 cfs gpm 450
Acre-in per hr cfs 1
Acre-ft per hr cfs 12

Conversion between English and Metric Units

Agricultural producers in many parts of the world use Metric (also called SI) units in their routine water measurements. The most commonly-used volume units in Metric system include liter, cubic meter, and hectare-millimeter, while common flow units are liter per minute (lpm) and cubic meter per second (cms). The following conversion table can be used to convert between English and Metric units.

Irrigation water management does begin with knowing how much water is available and involves some arithmetic. The most common mistake when working with water measurement units is to accidentally substitute one flow unit or volume unit for another without proper conversion. Usually the final answer appears obviously wrong; however, this is not always true. When checking your arithmetic, also check the measurement unit to see they are correct.

English/Metric Conversion Table.

To convert from: To: Multiply by:
Gallons Liters 3.8
Cubic-meter Cubic-ft 35.3
Cubic-ft Liters 28.3
Acre-in Hectare-mm 10.3
gpm lpm 3.8
cfs lpm 1700
cms cfs 35.3

Flow Units

Water in motion; i.e., flowing in streams, canals, pipelines, and ditches, is measured in units of volume per unit of time—gallons per minute (gpm), cubic feet per second (cfs), acre-inches per hour and acre feet per day. Cubic feet per second, sometimes written second-feet (sec. ft. or cusec) is most commonly used for measuring flow of irrigation water moving by gravity from streams and reservoirs. Gallons per minute is most commonly used for measuring flow from pumps.

Cubic foot per second - The quantity of water equivalent to a stream one foot wide by one foot deep flowing with a velocity of one foot per second.

Gallon per minute - The quantity of water equivalent to a stream which will fill a gallon measure once each minute of time.

A flow of one cubic foot per second is approximately equal to either 450 gallons per minute, one acre-inch per hour, or two acre-feet per day (24 hours).

Conversion Formulas

The following formulas are handy for computing the approximate depth of water applied to a field.

$$\frac{\text{Cubic feet per second x hours}}{\text{acres}}$$ =acre-inches per acre, or average depth in inches.

$$\frac{\text{Gallons per minute x hours}}{\text{450 x acres}}$$ =acre-inches per acre, or average depth in inches.

Calculating the Weight of Water

The challenge of calculating the weight of water really comes down to exactly what it means to find the *weight* of water, and whether the use of the term is for a specific reason or is simply a colloquial way of asking for the *mass* of water. In any case, you can easily find the result using the general formula for density and the value of the density of water.

Mass vs. Weight

The most important thing to understand before you try to calculate the weight of water is the difference between mass and weight. The mass of a substance is a measure of how much matter is present, and it's measured in kilograms or pounds. Most of the time, this is the most useful measure when you want to see how much of a substance is present.

The weight of a substance or an object is the *force* that gravity exerts on it due to its mass. For this reason, weight is technically measured in newtons or pounds-force. When most people say "weight" in real life, they are actually referring to the mass of the substance, because in colloquial language the words are basically interchangeable. However, in physics they have very specific meanings, and as such, you have to be careful to ensure you're using the right words and calculating the right quantities.

Water Measurement Calculator – mL to g

The metric system has a lot of advantages when it comes to converting between masses and volumes of water. This really comes down to the convenient value for the density of water, but if you just want to calculate the weight or mass of water without going into much detail, this is the simplest approach to use.

In short, 1 mL (milliliter) of water has a mass of 1 g, so 1 liter has a mass of 1 kg. You can use this fact to work out the mass of water from any volume: for example, 450 mL is 450 g, and 1.35 liters is 1.35 kg.

Volume to Mass in General

You should learn the general formula for density to convert the mass of anything to the volume, or vice-versa, and of course you can also use this for water. Density ρ is defined as the mass m divided by the volume V, or (equivalently) the mass per unit volume of a substance. The formula is:

$$\rho = \frac{m}{V}$$

However, if you're looking to calculate the mass or weight of water (or another substance) you can re-arrange the formula to:

$$m = \rho V$$

Then all you need to find is the volume of water you're trying to measure and the density of water. Make sure that the units match before making the calculation. For example, if you have the density of water in kg/m3, you need to measure the volume in m3, and if you've measured the volume in ft3, you'll need the density in lb/ft3. The density of water in kg/m3 is 1,000 kg/m3, and in lb/ft3 it is 62.4 lb/ft3.

So if you have 0.01 m^3 of water, this is:

$$\begin{aligned} m &= \rho V \\ &= 1000 \text{ kg/m}^3 \times 0.01 \text{ m}^3 \\ &= 10 \text{ kg} \end{aligned}$$

Mass to Weight of Water

Finally, you can convert between mass and weight (if you really do need the weight rather than the mass) using the formula:

$$W = mg$$

Where *W* is the weight, *m* is the mass and g = 9.81 m/s^2 = 32.17 ft/s^2, the acceleration due to gravity. So continuing from the previous example gives:

$$\begin{aligned} W &= mg \\ &= 10 \text{ kg} \times 9.81 \text{ m/s}^2 \\ &= 98.1 \text{ N} \end{aligned}$$

Again, you need to make sure the units match up, so if you have the mass in lb, you'll need the acceleration due to gravity in ft/s^2 to ensure the answer makes sense.

Wastewater Conversion Table

$$\text{Alkalinity, as mg } CaCO_3\text{/L} = \frac{(\text{Titrant Volume, mL})(\text{Acid Normality})(50{,}000)}{\text{Sample Volume, mL}}$$

$$\text{Amps} = \frac{\text{Volts}}{\text{Ohms}}$$

$$\text{Area of Circle} = (0.785)\ (\text{Diameter}^2)\ \text{ or }\ (\Pi)\ (\text{Radius}^2)$$

$$\text{Area of Cone (lateral area)} = (\Pi)\ (\text{Radius})\sqrt{\text{Radius}^2 + \text{Height}^2}$$

$$\text{Area of Cone (total surface area)} = (\Pi)\ (\text{Radius})\ (\text{Radius} + \sqrt{\text{Radius}^2 + \text{Height}^2}\ )$$

$$\text{Area of Cylinder (total outside surface area)} = [\text{Surface Area of End \#1}] + [\text{Surface Area of End \#2}] + [(\Pi)\ (\text{Diameter})\ (\text{Height or Depth})]$$

$$\text{Area of Rectangle} = (\text{Length})\ (\text{Width})$$

$$\text{Area of a Right Triangle} = \frac{(\text{Base})(\text{Height})}{2}$$

$$\text{Average (arithmetic mean)} = \frac{\text{Sum of All Terms}}{\text{Number of Terms}}$$

$$\text{Average (geometric mean)} = [(X_1)\ (X_2)\ (X_3)\ (X_4)\ (X_n)]^{1/n}$$ The nth root of the product of n numbers

$$\text{Biochemical Oxygen Demand (unseeded), in mg/L} = \frac{(\text{Initial DO, mg/L}) - (\text{Final DO, mg/L})}{\frac{\text{Sample Volume, mL}}{\text{Final Diluted Volume, mL}}}$$

$$\text{Chemical Feed Pump Setting, \% Stroke} = \frac{(\text{Desired Flow})(100\%)}{\text{Maximum Flow}}$$

$$\text{Chemical Feed Pump Setting, mL/min} = \frac{(\text{Flow, MGD})(\text{Dose, mg/L})(3.785\text{ L/gal})(1{,}000{,}000\text{ gal/MG})}{(\text{Liquid, mg/mL})(24\text{ hr/day})(60\text{ min/hr})}$$

Circumference of Circle = (Π) (Diameter)

$$\text{Composite Sample Single Portion} = \frac{\text{(Instantaneous Flow) (Total Sample Volume)}}{\text{(Number of Portions) (Average Flow)}}$$

$$\text{Cycle Time, min.} = \frac{\text{Storage Volume, gal}}{\text{Pump Capacity, gpm - Wet Well Inflow, gpm}}$$

$$\text{Degrees Celsius} = \text{(Degrees Fahrenheit - 32)} (^{5}/_{9}) \text{ or } \frac{(^{\circ}F - 32)}{1.8}$$

Degrees Fahrenheit = [(Degrees Celsius) ($^{9}/_{5}$) + 32] or [(Degrees Celsius) (1.8) + 32]

$$\text{Detention Time} = \frac{\text{Volume}}{\text{Flow}}$$ Note: Units must be compatible.

Electromotive Force (E.M.F), volts = (Current, amps) (Resistance, ohms) or E =IR

$$\text{Feed Rate, lbs/day} = \frac{\text{(Dosage, mg/L)(Capacity, MGD)(8.34 lbs/gal)}}{\text{(Purity, decimal percentage)}}$$

$$\text{Filter Backwash Rate, gpm/sq ft} = \frac{\text{Flow, gpm}}{\text{Filter Area, sq ft}}$$

$$\text{Filter Backwash Rise Rate, in/minute} = \frac{\text{(Backwash Rate, GPM/sq ft) (12 in/ft)}}{\text{(7.48 gal/cu ft)}}$$

$$\text{Filter Yield, lbs/hr/sq ft} = \frac{\text{(Solids Loading, lbs/day)(Recovery, \% / 100\%)}}{\text{(Filter Operation, hr/day)(Area, sq ft)}}$$

Flow Rate, cfs = (Area, sq ft) (Velocity, ft/sec) or Q = AV where: Q = flow rate, A = area, V= velocity

$$\text{Food/Microorganism Ratio} = \frac{\text{BOD}_5\text{, lbs/day}}{\text{MLVSS, lbs}}$$

Force, pounds = (Pressure, psi) (Area, sq in)

$$\text{Gallons/Capita/Day} = \frac{\text{Volume of Wastewater Produced, gpd}}{\text{Population}}$$

$$\text{Hardness, as mg CaCO}_3\text{/L} = \frac{\text{(Titrant Volume, mL)(1,000)}}{\text{Sample Volume, mL}}$$ Only when the titration factor is 1.00 of EDTA

$$\text{Horsepower, Brake (bhp)} = \frac{\text{(Flow, gpm) (Head, ft)}}{\text{(3,960) (Decimal Pump Efficiency)}}$$

$$\text{Horsepower, Motor (mhp)} = \frac{\text{(Flow, gpm) (Head, ft)}}{\text{(3,960) (Decimal Pump Efficiency) (Decimal Motor Efficiency)}}$$

$$\text{Horsepower, Water (whp)} = \frac{(\text{Flow, gpm})(\text{Head, ft})}{3{,}960}$$

$$\text{Hydraulic Loading Rate, gpd/sq ft} = \frac{\text{Total Flow Applied, gpd}}{\text{Area, sq ft}}$$

$$\text{Leakage, gpd} = \frac{\text{Volume, gallons}}{\text{Time, days}}$$

Mass, lbs = (Volume, MG) (Concentration, mg/L) (8.34 lbs/gal)

Mass Flux, lbs/day = (Flow, MGD) (Concentration, mg/L) (8.34 lbs/gal)

$$\text{Mean Cell Residence Time (MCRT) or Solids Retention Time (SRT), days} = \frac{\text{Aeration Tank TSS, lbs} + \text{Clarifier TSS, lbs}}{\text{TSS Wasted, lbs/day} + \text{Effluent TSS, lb/day}}$$

$$\text{Molarity} = \frac{\text{Moles of Solute}}{\text{Liters of Solution}}$$

$$\text{Normality} = \frac{\text{Number of Equivalent Weights of Solute}}{\text{Liters of Solution}}$$

$$\text{Number of Equivalent Weights} = \frac{\text{Total Weight}}{\text{Equivalent Weight}}$$

$$\text{Number of Moles} = \frac{\text{Total Weight}}{\text{Molecular Weight}}$$

$$\text{Organic Loading Rate} = \frac{\text{Organic Load, lbs BOD}_5\text{/day}}{\text{Volume}}$$

$$\text{Organic Loading Rate-RBC, lbs BOD}_5\text{/day/1,000 sq ft} = \frac{\text{Organic Load, lbs BOD}_5\text{/day}}{\text{Surface Area of Media, 1,000 sq ft}}$$

$$\text{Organic Loading Rate-Trickling Filter, lbs BOD}_5\text{/day/1,000 cu ft} = \frac{\text{Organic Load, lbs BOD}_5\text{/day}}{\text{Volume, 1,000 cu ft}}$$

$$\text{Oxygen Uptake Rate/Oxygen Consumption Rate, mg/L/minute} = \frac{\text{Oxygen Usage, mg/L}}{\text{Time, minute}}$$

$$\text{Population Equivalent, Organic} = \frac{(\text{Flow, MGD})(\text{BOD, mg/L})(8.34\text{ lbs/gal})}{\text{lbs BOD/day/person}}$$

$$\text{Recirculation Ratio-Trickling Filter} = \frac{\text{Recirculated Flow}}{\text{Primary Effluent Flow}}$$

$$\text{Reduction in Flow, \%} = \frac{(\text{Original Flow - Reduced Flow})(100\%)}{\text{Original Flow}}$$

$$\text{Reduction of Volatile Solids, \%} = \frac{(\text{In} - \text{Out})(100\%)}{\text{In} - (\text{In} \times \text{Out})}$$ All information (In and Out) must be in decimal form

$$\text{Removal, \%} = \frac{(\text{In} - \text{Out})(100)}{\text{In}}$$

$$\text{Return Rate, \%} = \frac{(\text{Return Flow Rate})(100\%)}{\text{Influent Flow Rate}}$$

$$\text{Return Sludge Rate-Solids Balance} = \frac{(\text{MLSS})(\text{Flow Rate})}{\text{Return Activated Sludge Suspended Solids} - \text{MLSS}}$$

$$\text{Slope, \%} = \frac{\text{Drop or Rise}}{\text{Distance}} \times 100$$

$$\text{Sludge Density Index} = \frac{100}{\text{SVI}}$$

$$\text{Sludge Volume Index, mL/g} = \frac{(\text{SSV}_{30}\text{, mL/L})(1{,}000 \text{ mg/g})}{\text{MLSS, mg/L}}$$

$$\text{Solids, mg/L} = \frac{(\text{Dry Solids, grams})(1{,}000{,}000)}{\text{Sample Volume, mL}}$$

$$\text{Solids Concentration, mg/L} = \frac{\text{Weight, mg}}{\text{Volume, L}}$$

$$\text{Solids Loading Rate, lbs/day/sq ft} = \frac{\text{Solids Applied, lbs/day}}{\text{Surface Area, sq ft}}$$

Solids Retention Time (SRT): *see* Mean Cell Residence Time (MCRT)

$$\text{Specific Gravity} = \frac{\text{Specific Weight of Substance, lbs/gal}}{\text{Specific Weight of Water, lbs/gal}}$$

$$\text{Specific Oxygen Uptake Rate/Respiration Rate, (mg/g)/hr} = \frac{\text{OUR, mg/L/min (60 min)}}{\text{MLVSS, g/L (1 hr)}}$$

$$\text{Surface Loading Rate or Surface Overflow Rate, gpd/sq ft} = \frac{\text{Flow, gpd}}{\text{Area, sq ft}}$$

Three Normal Equation = $(N_1 \times V_1) + (N_2 \times V_2) = (N_3 \times V_3)$, where $V_1 + V_2 = V_3$

Two Normal Equation = $N1 \times V_1 = N_2 \times V_2$, where N = concentration (normality), V = volume or flow

$$\text{Velocity, ft/second} = \frac{\text{Flow Rate, cu ft / sec}}{\text{Area, sq ft}} \text{ or } \frac{\text{Distance, ft}}{\text{Time, second}}$$

$$\text{Volatile Solids, \%} = \frac{(\text{Dry Solids, g} - \text{Fixed Solids, g})(100)}{\text{Dry Solids, g}}$$

Volume of Cone = (1/3) (0.785) ($Diameter^2$) (Height)

Volume of Cylinder = (0.785) ($Diameter^2$) (Height)

Volume of Rectangular Tank = (Length) (Width) (Height)

Waste Milliequivalent = (mL) (Normality)

Watts (DC circuit) = (Volts) (Amps)

Watts (AC circuit) = (Volts) (Amps) (Power Factor)

$$\text{Weir Overflow Rate, gpd/ft} = \frac{\text{Flow, gpd}}{\text{Weir Length, ft}}$$

$$\text{Wire-to-Water Efficiency, \%} = \frac{\text{Water Horsepower, HP}}{\text{Power Input, HP or Motor HP}} \times 100$$

$$\text{Wire-to-Water Efficiency, \%} = \frac{\text{(Flow, gpm) (Total Dynamic Head, ft) (0.746 kw/hp) (100)}}{\text{(3,960) (Electrical Demand, kilowatts)}}$$

Temperature Conversion

The three common temperature scales are Celsius, Fahrenheit, and Kelvin. Each scale has its uses, so it's likely you'll encounter them and need to convert between them. Fortunately, the conversion formulas are simple:

Celsius to Fahrenheit	° F = 9/5 (° C) + 32
Kelvin to Fahrenheit	° F = 9/5 (K - 273) + 32
Fahrenheit to Celsius	° C = 5/9 (° F - 32)
Celsius to Kelvin	K = ° C + 273
Kelvin to Celsius	° C = K - 273
Fahrenheit to Kelvin	K = 5/9 (° F - 32) + 273

Population Equivalent

A means of expressing the strength of organic material in wastewater. In a domestic wastewater system, microorganisms use up about 0.2 pound (90 grams) of oxygen per day for each person using the system (as measured by the standard BOD test). May also be expressed as flow (100 gallons/person/day or 378 liters/person/day) or suspended solids (0.2 lb SS/person/day or 90 grams SS/person/day).

Density and Specific Gravity

Density and specific gravity have very similar, but not quite identical definitions.

Density is the mass of material per unit volume.

Specific gravity is a ratio of the mass of a material to the mass of an equal volume of water at 4 ^{o}C. Because specific gravity is a ratio, it is a unitless quantity. For example, the specific gravity of water at 4^{o}C is 1.0 while its density is 1.0 gcm^{-3}.

Detention Time

Detention time is the length of time water is retained in a vessel or basin or the period from the time the water enters a settling basin until it flows out the other end. When calculating unit process detention times, we are calculating the length of time it takes the water to flow through that unit process. Detention times are normally calculated for the following basins or tanks:

Flash mix chambers (seconds)
Flocculation basins (minutes)
Sedimentation tanks or clarifiers (hours)
Wastewater ponds (days)
Oxidation ditches (hours)
To calculate the detention period of a basin, the volume of the basin must first be obtained with the formula: V = L x W x D

Detention time is calculated in units of time. The most common are seconds, minutes, hours and days. If detention time is desired in minutes, then the flow rate used in the calculation should have the same time frame (cfm or gpm, depending on whether tank volume is expressed as cubic feet or gallons). If detention time is desired in hours, then the flow rate used in the calculation should be cfh or gph.

The simplest way to calculate detention time is to divide the volume of the container by the flow rate into the container. The theoretical detention time of a container is the same as the amount of time it would take to fill the container if it were empty. For volume, the most common units used are gallons; however, on occasion, cubic feet may also be used. Time units will be in whatever units are used to express the flow. For example, if the flow is in gpm, the detention time will be in days. If, in the final result, the detention time is in the wrong time unit, simply convert to the appropriate units.

Detention time can be determined using the following formula:

$$\text{Detention Time} = \frac{\text{Volume}}{\text{Flow}} \qquad *\textit{Units must be compatible}$$

UNDERTAKE WATER/WASTEWATER CALCULATIONS

Service Line Flushing Time

General Service Connection Flushing Procedures

1. Flushing a service connection should not be started until after the water main serving the service connection has been thoroughly flushed by the public water supply system's operating staff.
2. Once the waterline/water main has been thoroughly flushed, begin the process of flushing the service connection by locating the outside spigot/faucet that is closest to the water main.
3. Run the water with the outside spigot/faucet open for at least 10-15 minutes to flush the service line. Lengthy or complex service lines may require flushing for more than 10-15 minutes.
4. A hose may be attached to the outside spigot/faucet to redirect the water to avoid ponding. In doing so, make sure the flow is high and nothing is attached to the end of the hose. Additional flushing time may be necessary to compensate for any restrictions imposed by the attached hose.
5. Wait 30 – 60 minutes without using any water, if possible, to allow the water in the water main to settle.
6. Open the outside spigot/faucet again and check water clarity.
7. If necessary, flush the service line through the outside spigot/faucet for another 10-15 minutes. Depending on the flushing of the water main, it may be necessary to repeat the flushing of the service line checking water clarity each time.
8. After the water from the outside spigot/faucet appears clear, begin the general process of flushing the service connection's interior pipes and faucets.
9. If possible, begin flushing at a cold water faucet that is both on the lowest level of the service connection's structure and closest to its water meter.
10. Fully open each cold water faucet one at a time and run for at least five minutes. Prior to flushing remove all faucet attachments such as aerators, screens, etc. to maximum flow.
11. Flush remaining cold water faucets moving upwardly in the service connection's structure and away from its water meter. Be sure to include tubs and showers.
12. Individually open each remaining outside spigot/faucet and similarly flush as above.

13. Flush hot water heaters according to the manufacturer's instructions for flushing. Disconnect power to the hot water heater at the circuit breaker box and allow the hot water heater to sufficiently cool before flushing to avoid being burned. Begin flushing hot water taps on the lowest level of the service connection's structure. Individually open the hot water faucets and run until the warm water turns to cold water. Restore power to the hot water heater once all hot water faucets have been thoroughly flushed.
14. Flush items such as in-line filters, treatment systems, water softeners, refrigerator water dispensers (direct or tanked) with enough water to replace at least 1-2 volumes of all connecting lines and tanks. To avoid contamination, consider replacing all filters, especially if they are at the end of their useful service life.
15. Refer to owner's manuals for flushing water softening systems, reverse osmosis systems, and other types of filtering systems. To avoid contamination, consider replacing all filters, especially if they are at the end of their useful service life.
16. Other items that utilize water such as coffee makers, pitcher type water filters, and dental cleaning appliances should be cleaned and their filters replaced.
17. If water from taps is not clear, repeat steps 2 through 16.
18. Once flushing has been completed, verify that all spigots and faucets are closed.

Composite Sampling

Wastewater sampling is generally performed by one of two methods, grab sampling or composite sampling. Grab sampling is just what it sounds like; all of the test material is collected at one time. As such, a grab sample reflects performance only at the point in time that the sample was collected, and then only if the sample was properly collected. Composite sampling consists of a collection of numerous individual discrete samples taken at regular intervals over a period of time, usually 24 hours. The material being sampled is collected in a common container over the sampling period. The analysis of this material, collected over a period of time, will therefore represent the average performance of a wastewater treatment plant during the collection period.

Numerous industry references list various parameters for wastewater testing and whether samples should be collected using grab sampling or composite sampling methods. For example, grab sampling allows the analysis of specific types of unstable parameters such as pH, dissolved oxygen, chlorine residual, nitrites and temperature. However, the most widely used indicators of treatment plant performance, including CBOD5 (five day carbonaceous biochemical oxygen demand), TSS (total suspended solids) and TN (total nitrogen) require the use of composite sampling techniques. STANDARD METHODS (20th Edition, Section 1060 § B, "Collection and Sampling") states "A sample can represent only the composition of its source at the time and place of collection." Grab samples may be used to represent "some well-mixed surface waters, but rarely, wastewater streams" for water quality evaluation. The widely varying flow patterns of residential treatment plants make it impossible to evaluate performance by analyzing a single grab sample of effluent. Residential treatment plants receive a frequent number of short hydraulic surges throughout the day followed by intermittent periods of no flow whatsoever.

Routine variations in the volume and strength characteristics of incoming wastewater create fluctuations in the quality of treatment plant effluent. Therefore, an effluent grab sample taken at one specific time throughout the daily flow pattern will not be representative of system performance over the entire day.

While the limitations of determining system performance by grab sampling are apparent, the use of grab samples for the evaluation of a residential treatment unit is further compromised if the sample is collected from a location where the effluent does not have sufficient velocity to keep the effluent solids in suspension.

While the limitations of determining system performance by grab sampling are apparent, the use of grab samples for the evaluation of a residential treatment unit is further compromised if the sample is collected from a location where the effluent does not have sufficient velocity to keep the effluent solids in suspension. WASTEWATER SAMPLING FOR PROCESS AND QUALITY CONTROL (Manual of Practice No. OM-1, § "Representative Sampling") directs that samples be collected "at points where the sample stream or tank is well mixed." The manual goes on to say "avoid taking samples at points where solids settling occurs or floating debris is present. These situations occur normally in quiescent areas, where the velocity of the flow has decreased." For this reason, plant performance can never be evaluated by a sample of effluent taken from a pump chamber, distribution box, sump, roadside ditch or any device that contains effluent below the flow line. The intermittent flow pattern of an individual residence intensifies this problem by allowing effluent solids to settle out within a sump during low flow periods. Even the few solids present in a high quality effluent will settle out when retained within a sump. If only a very few solids settle within a sump during a low flow period today, they remain and accumulate with additional solids settling out over successive days. Any sample drawn from a sump will contain effluent suspended solids combined with days, weeks, months or years worth of accumulated solids. A sample of liquid from such a sump cannot be analyzed for overall system performance, as it is scientifically impossible to determine what portion of the solids were suspended in the effluent and what portion of the solids had accumulated in the sump over a period of time. Using any sample drawn from a sump to evaluate the performance of a residential wastewater treatment plant is simply inappropriate. Samples must be taken from a location where the effluent is free-flowing and has sufficient velocity to keep the effluent solids in suspension.

Composite samples of effluent collected, stored, analyzed, tabulated and averaged over an extended period of time provide the only verifiable indication of treatment plant performance. Collecting and analyzing these composite samples is often an expensive and time-consuming process. For these reasons, most regulatory organizations recognize independent third-party certifiers, who use composite sampling methods to conduct performance evaluation and accurately measure system performance in a standardized, reproducible setting. Attempting to evaluate a residential treatment system in the field by analyzing a grab sample taken from a sump or any other containment vessel provides a compound degree of error and will yield erroneous conclusions about system performance.

Biochemical Oxygen Demand

To determine the value of the BOD in mg/L, use the following formula:

BOD, mg/L = [(Initial DO - Final DO) x 300]/mL sample

For example:

Initial DO = 8.2 mg/L

Final DO = 4.4 mg/L

Sample size = 5 mL

BOD mg/L = [(8.2 - 4.4) x 300]/5 = (3.8 x 300)/5 = 1140/5 = 228 mg/L

Whenever a sample is dechlorinated, it must be seeded. If the sample is seeded, a correction factor must be calculated to determine the effects that the seed material has on the DO depletion. A number of BOD's must be run on the seed material to determine the seed correction factor.

UNIT 05

PREPARE BASIC TECHNICAL DRAWING

This unit covers identifying the drawing requirements, preparing or making changes to engineering drawings, preparing an engineering parts list and issuing the drawings

IDENTIFY DRAWING REQUIREMENTS

Introduction

When you take a project management class, you are likely to be told about the three major constraints of a project – Cost, Schedule, and Scope. You will then spend an exuberant amount of time developing, analyzing, calculating, and optimizing the schedule. Likewise you will review budget categories, analyze depreciation, and determine acceptable variances. However, when it comes to the scope section, very often you will get a 15-minute mandatory session on change control and how to avoid scope creep.

Okay, So what's my point? Please bear with me for a bit longer. In one of the classes I teach I do a teambuilding exercise where the students, in teams, brainstorm reasons that projects succeed. The one answer that always makes it up on the list, in some form, is "well defined requirements", in other words – SCOPE!

So, if defining scope is a critical part of succeeding on a project (and I would argue that it is, by far, the most important of the three constraints!), why don't we focus more time and attention on it? Because it is difficult! Very often, customers don't know exactly what they want, the "I can't describe it, but I'll recognize it when I see it" syndrome, or the language barriers between the customer and the project team makes the communication of the necessary requirements a nightmare.

That's the problem definition (stating that Scope is difficult would have been more to the point, but I'm an instructor so even the obvious takes time to state).

Selecting an approach to requirements gathering

There are many types of requirements, as there are many approaches to capturing them. Before starting into the actual capturing of requirements, a plan for the requirements gathering process must be developed. Often the first step for that should be to determine what the roles and responsibilities should be during this phase of the project. While the project manager would normally be responsible for the requirements of the project, it should typically be the customer, or an analyst, who is responsible for the requirements of the product. Even though the same person may play both roles, their overall responsibilities are different and it is important to be aware of which role is involved in what steps.

The project scope defines how the product (or service) will be developed while the product scope defines the actual functions and features of that same product. The traditional focus in project management has been on developing a product faster, cheaper, and better. The requirements of that product though are often assumed to be correct. This is changing through the popularity of agile approaches where it is assumed that the customer does not have a clear understanding of what they want up front, but rather that requirements gathering is a discovery process, where the customer gradually discovers the product requirements through iterations, prototyping and modelling.

There are many good techniques to gather requirements, all of them have their time and place and it is good for the project team to spend some time upfront determining the right approach for the specifics of this project. Some of the techniques to consider are:

- ✓ One-on-one interviews. An easy to arrange approach to requirements gathering that works well in a single-user environment where requirements are expected to be non-controversial. However, it is easy to get side tracked in these interviews so the interviewer must have the ability to keep the focus on the topics discussed and to be well prepared.

- ✓ Surveys. Surveys are a good technique to reach a large number of customers. Surveys must be kept simple and it is often difficult to get a significant number of the surveys to be returned. However, if the questions are specific and clear, the survey can serve as a great tool to take the pulse of the customer.
- ✓ Job shadowing or observation. This seems to be a fast growing technique for requirements gathering and it works great when the analyst is not real familiar with the business or when the customer has difficulties verbalizing the requirements. It does tend to primarily focus on the as-is situation of the business so if business processes are changing or a new business is started, this may not give the desired result. It is also noteworthy that observation tends to change the behavior of the person being observed, so the analyst may not get an accurate picture of the customer's true problem.
- ✓ Facilitated sessions, or as I will refer to them, JAD (Joint Application Development) sessions. This are designed for multi stakeholder situations where there is a need to build consensus between the stakeholders.

JAD sessions

Joint application design was pioneered by IBM in the late 1970's and the early 1980's, and popularized further by James Martin who made it a key technique for RAD (Rapid Application Development) projects.

So, what is it? Well, consider a traditional project (I'll look at an IT project for example, since that is my background). First there will be a customer, often a functional manager, who will meet with you and get started, giving you some level project goals. Then you're sent out on the interview circuit – find out what the purchasing department needs, see if the finance group has any requirements (thy usually do!), talk to the material management department, and so on through all necessary departments and divisions…. After that you lock yourself in a room to compare all the requirements, identify the inconsistencies, and try to figure out best way to deal with them.

In the best-case scenario, you make a few more rounds to all your stakeholders and get an agreement – at worst (and unfortunately this happens more often), you decide to "interpret" the requirements or maybe tweak them enough so they fit together. This will invariably result in a product that is less than the customer wanted.

However, by using JAD you would bring the stakeholders together into a number of sessions (normally two or four), where they, with the guidance of a facilitator, will determine and come to an agreement on the requirements. By having the stakeholders actually discuss and come to a consensus on system requirements, you are starting out with a greater level of ownership up front. If you also choose to develop and review prototypes during these sessions, you will greatly help the users visualize what the end product will actually look like.

Since JAD is a techniques largely focused on group dynamics and team synergy, it is important to get the right people involved. The key people for a JAD session are:

The Facilitator

The facilitator should be selected based on their ability to work with and lead a group of people in consensus building. They should be neutral to the outcome of the session, meaning that they should not have a vested impact in steering the discussion in a certain direction. This normally means that the project manager or the developers do not make good facilitators. Ideally, it should be a person that has a general understanding of the customer's business areas, who is comfortable with modeling techniques that are to be used in the session and who can deal with a group of disagreeing people and move them along in the decision process.

While the facilitator is not the most important person for the project, they are the one with the most influence on the success of the JAD session itself. They need to be able to sense how the JAD team is functioning, to deal with conflicts, and to make sure that the goals of the session are being met.

The Scribe

The scribe, or scribes, will capture the key decisions, and the rational behind those decisions. If a 3-day JAD session is being held and at the end there is no documentation of the outcome, then everyone has just wasted 3 days. Have one scribe focus on conversations and one on models. This will improve the odds of catching everything important. The scribe must have good listening skills and must understand the business that is being discussed. You don't want constant interruptions from the scribe, requesting clarifications of items that are well understood by the rest of the room.

The Analyst

The analyst is the person focusing on capturing the right information. Often the analyst will also be the facilitator, but when that happens they are playing two different roles. The facilitator is focusing on getting the group to consensus and to meet the session goals while the analyst is there to make sure that the right questions are asked and that the models correctly identifies the business. The analyst is really more of a subject matter expert on the customer's business.

The Customer

Obviously you cannot hold a JAD session without a customer. While it is true that you may not be able to select your customer, there are ways to influence the selection of them. Identify the criteria that you are looking for and meet with management ahead of time and explain the importance of the role and the characteristics of the person that is needed.

There are other people that will be involved in JAD sessions as well. The sponsor should kick off the session and set the tone, Subject Matter Experts may be brought in for portion of the session to explain a process or a technology. The developers should also attend the session, but especially in the beginning it will important that play more of an observer role than an active role.

Having a successful session

Since the goal of a JAD session is to create team synergy and build consensus, the facilitator must create an environment where the stakeholders work well together and can accomplish the session objectives. To start off on the right track, it is important to have the sponsor or a

key executive from the organization, attend the meeting and show management support for the project. This will ensure that everyone understands and supports the goals.
There must also be ground rules established for the JAD session. Ideally most of the ground rules are established by the participants themselves. This tends to lead to the team enforcing the rules, rather than the facilitator. Sample ground rules include:

- ✓ Breaks and how to handle late comers
- ✓ Decision process and how consensus is defined
- ✓ What to do when a topic goes longer than the agenda
- ✓ Rules to deal with participants monopolizing the conversation

One of the biggest difficulties during a JAD session is to stay on track and prevent the team from going off on tangents. A great tool for this is the Parking Lot. A parking lot serves two main purposes, first, it allows the team to capture important information that should be addressed, but not by this team at this time. The second benefit is for the facilitator. It allows moving a person off a topic which is not in line with the goals of the session. There may not be intent to ever re-visit the topic again, but by putting it in writing and making it visible, it may allow the team to put the topic aside.
The facilitator must be monitoring the team through-out the session to assess how well they function. All teams will go through a team development cycle such as Forming/Storming/Norming/Performing.
In the forming stage, the team is insecure and need a lot of guidance. Team building and clear assignments are important for this stage. In the storming stage the team is now trying to assess the competency of other team members and figure out where they fit. The facilitator needs to let the team storm, while making sure that the ground rules are being followed. In the norming stage the team is falling in to natural roles and responsibilities and the team starts to find its purposes. When that has been sorted out the team is in the performing stage. In real life the team will move back and forth between these stages and the facilitator should adjust their facilitation style based on that.

Implementing a JAD approach

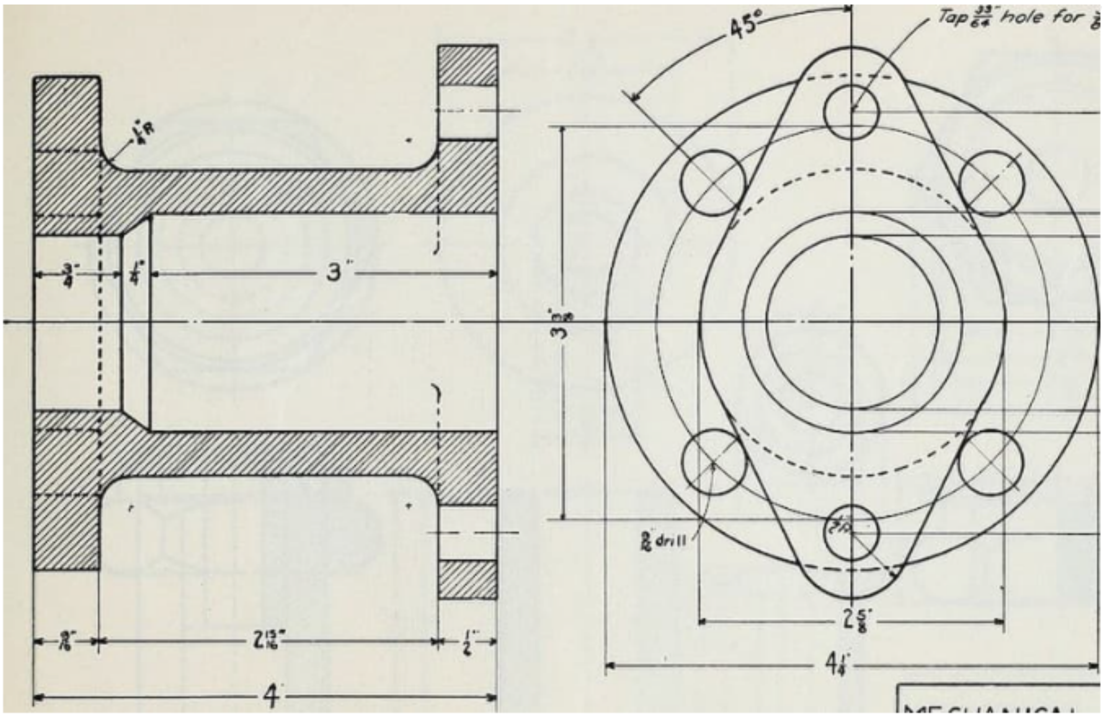
To get started, select a core JAD team within your organization. Have them get up to speed on the various versions of JAD (as many as there are authors), pick one and start the education process, some of the key steps are:

1. Sell it to your management to the customer. If you **don't** get buy-in **this will fail,** so make sure you put together a good sales presentation.
2. Train your core team on the techniques you'll be using (could be Process Modeling, Data Modeling, Prototyping, etc.)
3. Train some facilitators (select people that can lead a discussion, not necessarily the ones that want to do the most talking)
4. Pick a pilot project. Pick something not too large, something that you can afford to learn one and work through.
5. Train all participants (the users in the sessions have to understand the technique)
6. Schedule and run the pilot session.
7. Do an extensive lessons and learned session.

If you plan it right, you should now have a great foundation for many future successes with Joint Application Designs. Good Luck!

DEVELOP KNOWLEDGE AND PROPER TECHNIQUES IN PREPARING DRAWINGS AND SKETCHES

Engineering Drawings Basics



An engineering drawing is a subcategory of technical drawings. The purpose is to convey all the information necessary for manufacturing a product or a part.

Engineering drawings use standardised language and symbols. This makes understanding the drawings simple with little to no personal interpretation possibilities.

So let's look at the different line and view types you will come across in the engineering discipline.

The Purpose of Engineering Drawings

As already said, such a technical drawing has all the information for manufacturing a part or welding and building an assembly. The info includes dimensions, part names and numbers, etc. So once a manufacturing engineer gets the drawing, he can start the production process without a second thought.

First, we have to pause for a second and address our own customers here to avoid confusion. The drawings you submit for instant pricing and manufacturing in our system do not need any of this. The same applies to 3D models. CAD files and drawings made according to our design tips include all the necessary information for making your product. The only time we ask for a drawing is if you want to specify tolerances.

Still, knowing all the rules and basics of formatting is an absolute must in the industry, as traditional manufacturing companies still need detailed drawings.

How to Make Drawings?

A few decades ago, you would have had to sit down at a drawing board covered with papers of different size, rulers, calipers, etc. Today, all these instruments are still good for manual drafting but no contemporary manufacturer really wants such drawings.

Why? Because most of the machinery uses CNC systems that can read the information straight from the files and produce a cutting program accordingly. Drawings done by hand would just add a lot of manual work for manufacturing engineers.

So, we are left with only one option really – every engineer should use CAD (computer aided design) software because of its many advantages.

You can, of course, use CAD for making drawings from scratch. But the easier option is to first make a 3D model and create the drawings from that, as the programs generate the views with only a few clicks. All you need to do is add the dimensions. Having models also makes updating the drawings for revisions simple.

Basic Components of an Engineering Drawing

Let's see what makes up an engineering drawing. A single drawing includes many elements with quite a few variations to each of them. So let's take a closer look here.

Different Types of Lines

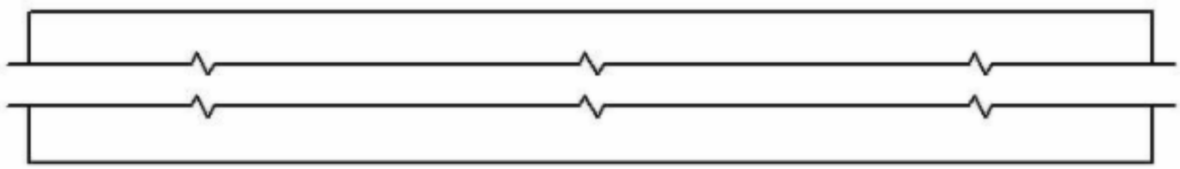
Not every line on an engineering drawing is equal. The different options make it possible to show both visible and hidden edges of a part, centre lines, etc.

The most common is a continuous line, also known as a drawing line. This represents the physical boundaries of an object. Put simply, these lines are for drawing the objects. The line thickness varies – the outer contour uses thicker lines and inner lines are thinner.

Hidden lines can show something that would not be otherwise visible on the drawings. For example, hidden lines may show the length of an internal step in a turned part without using a section or a cutout view (we explain both later).

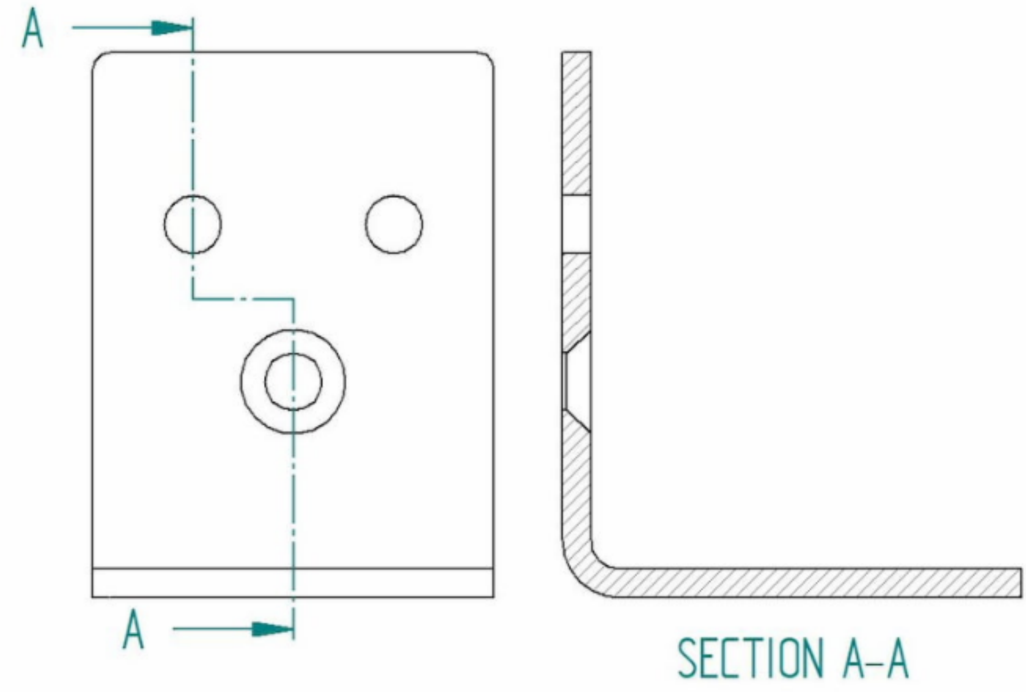
Centre lines are used to show hole and the symmetric properties of parts. Showing symmetricity can reduce the number of dimensions and make the drawing more eye-pleasing, thus easier to read.

Extension lines annotate what is being measured. The dimension line has two arrowheads between the extension lines and the measurement on top (or inside, like in the image above) the line.



Break lines indicate that a view has been broken. If you have a part that is 3000 mm long and 10 mm wide with symmetric properties, using a break-out makes gives all the info without using as much space.

While a good way for giving information to people, CNC machines need full views in order to cut the parts. Otherwise, the manufacturing engineer has to reconstruct the whole part from the measurements.



When using a cutout view, the cutting plane lines show the trajectory of the cutout. Here you can see that the A-A cutting line brings both types of holes into the view.

Types of Views

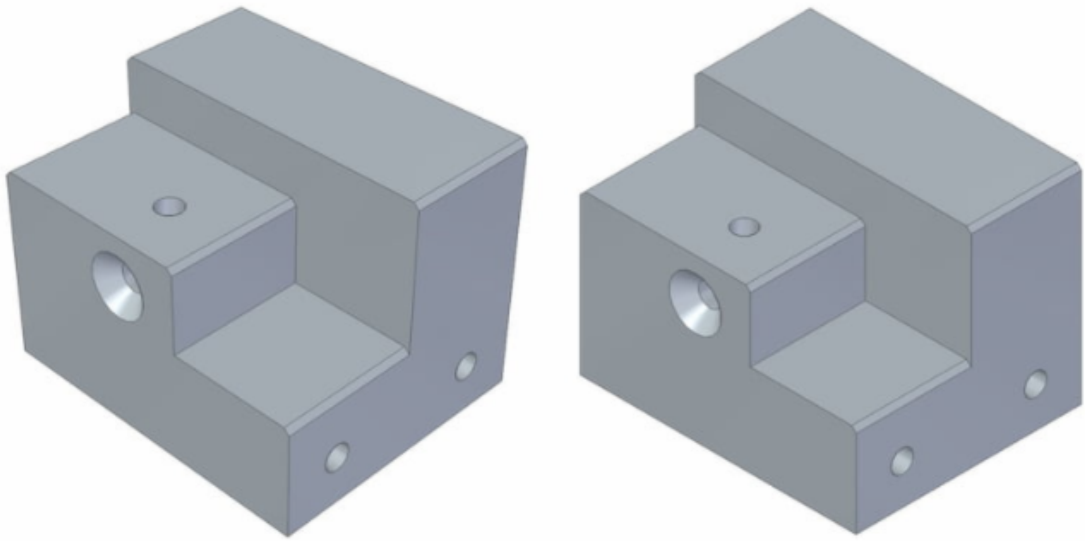
So let's take a closer look at the different types of views that are often present in a manufacturing drawing. Each serves a certain purpose. Bear in mind that adding views should follow the same logic as dimensioning – include as little as possible and as much as necessary.

A tip for good engineering practice – only include a view if it contributes to the overall understanding of the design.

Isometric View

Isometric drawings show parts as three-dimensional. All the vertical lines stay vertical (compared to front view) and otherwise parallel lines are shown on a 30-degree angle.

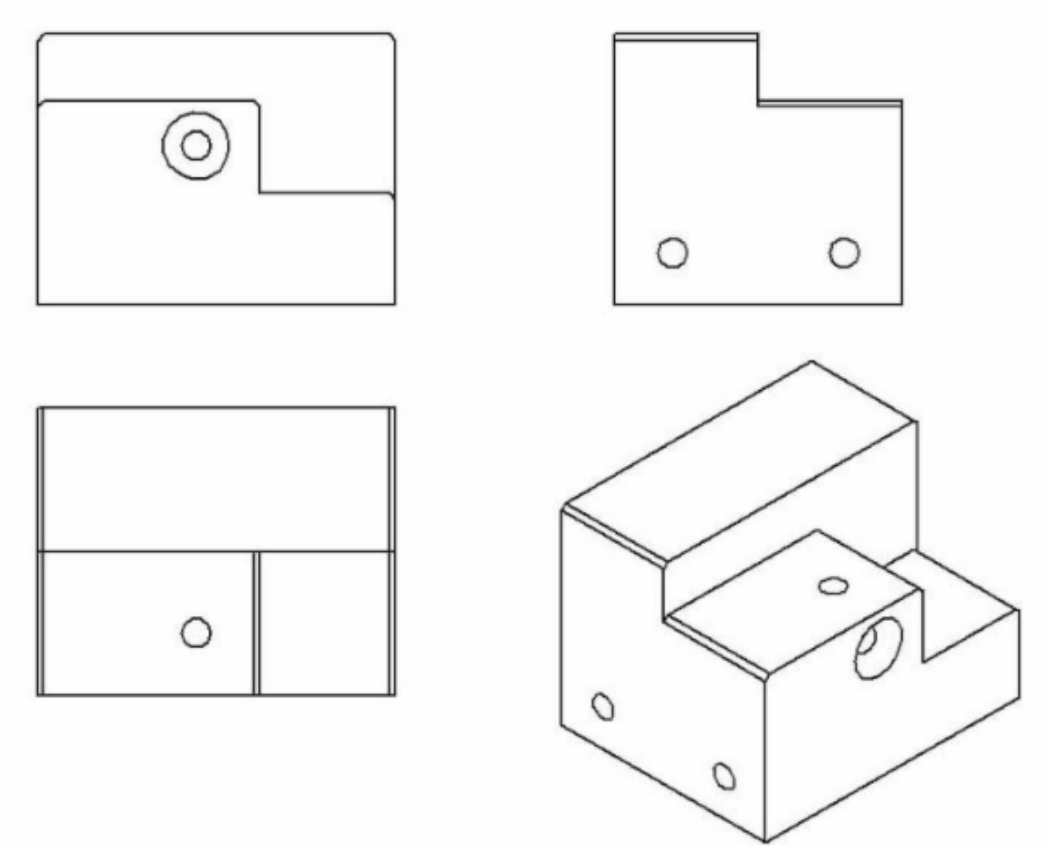
The lines that are vertical and parallel are in their true length. Which means you can use a ruler and the scaling of the drawing to easily measure the length straight from a paper drawing, for example. The same does not apply to angled lines.



Left – perspective; right – isometric

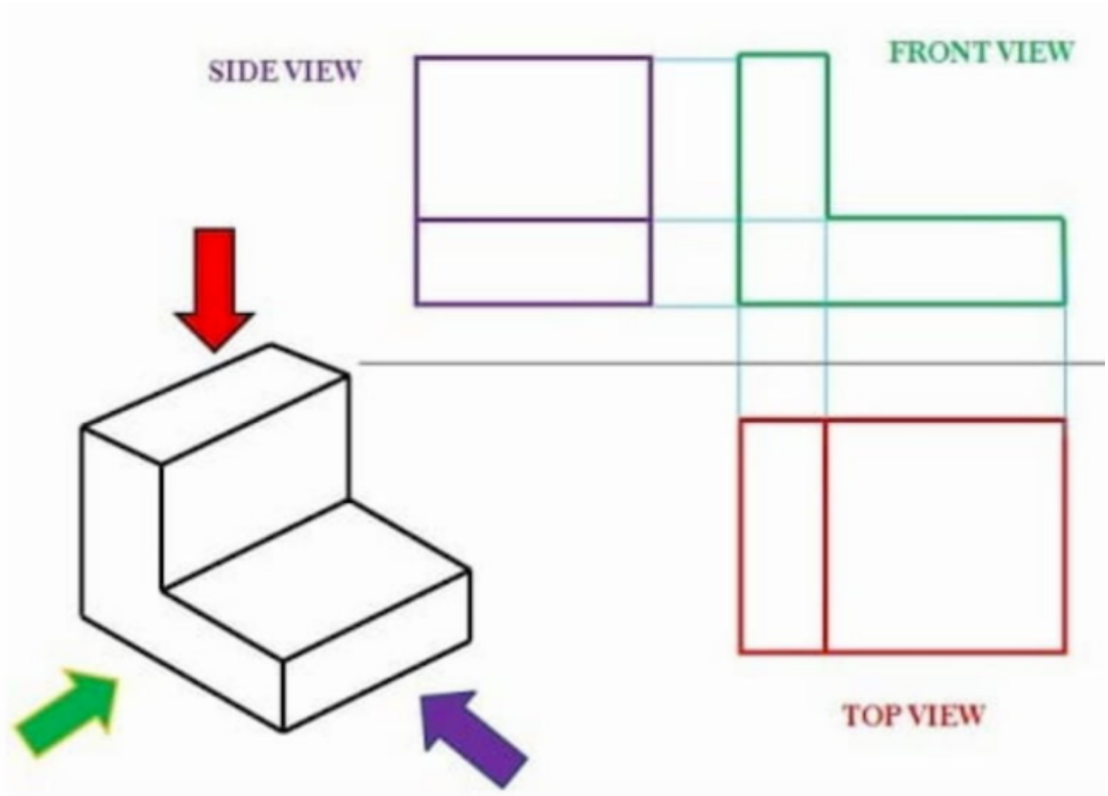
It is important to distinguish the isometric view from a perspective view. A perspective view is an artistic one that represents an object as it seems to the eye. Engineers stay true to the dimensions rather than optical illusions.

Orthographic View



This is the bread and butter of an engineering drawing. An orthographic view or orthographic projection is a way of representing a 3D object in 2 dimensions.

Thus, a 2D view has to convey everything necessary for part production. This kind of representation allows avoiding any kind of distortion of lengths.



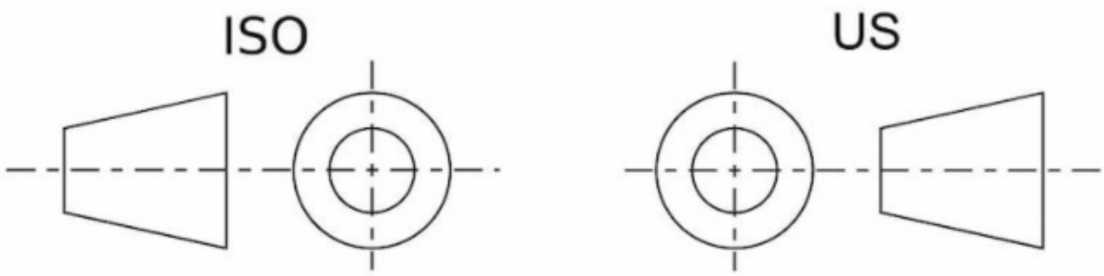
Orthographic projection (ISO standard)

The most common way to communicate all the information is by using three different views in a multiview drawing:

- ✓ Front view
- ✓ Top view
- ✓ Side view

It may be possible that some additional views are necessary to show all the info. But again, less is more.

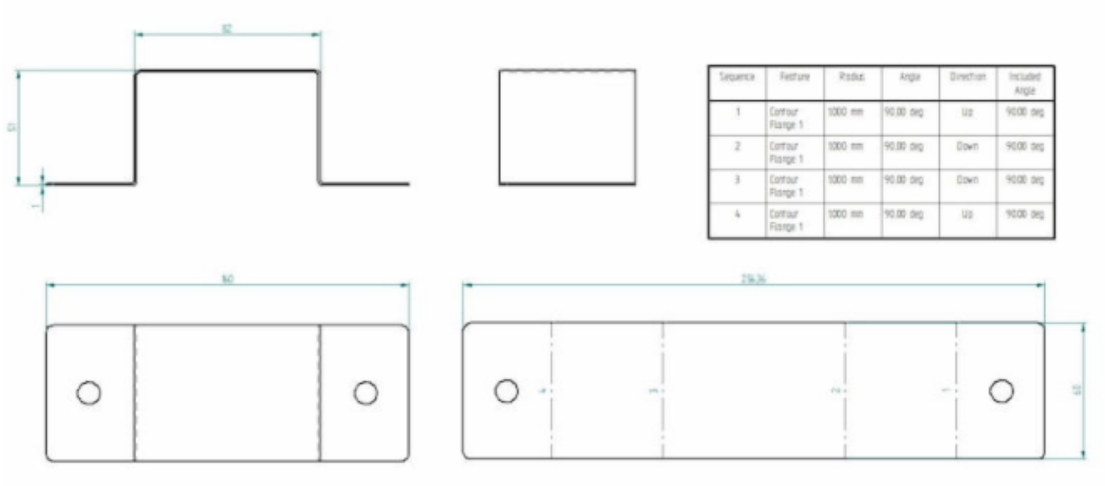
The positioning of the views differs a bit regionally. For example, look at the image below to compare the US and ISO layouts.



The one on the left is called first-angle projection. Here, the top view is under the front view, the right view is at the left of the front view, etc. The ISO standard is primarily used in Europe.

On the right, you can see a third-angle projection. The right view is on the right, top view on the top of the front view, etc. This system is especially popular in the US and Canada.

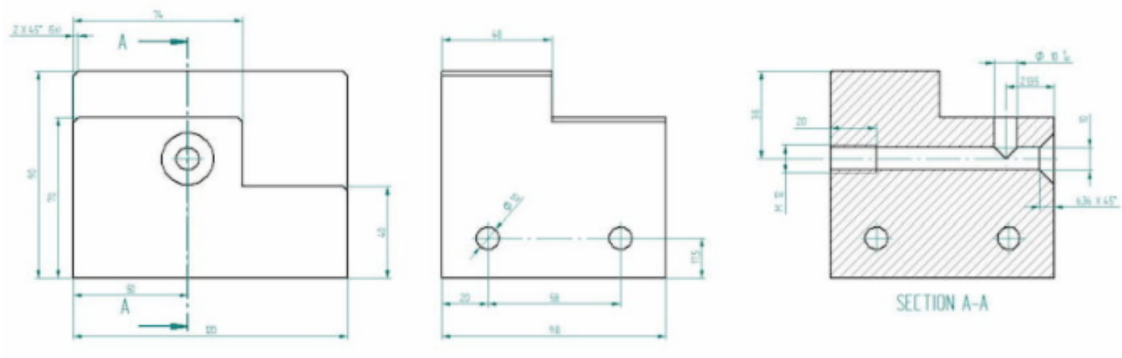
Flat Pattern



Creating a flat pattern view is usually pretty simple. Just be aware that you are using the sheet metal environment when making sheet metal parts in CAD. There you have the option to "generate a flat pattern" which you can easily add to the main drawing.

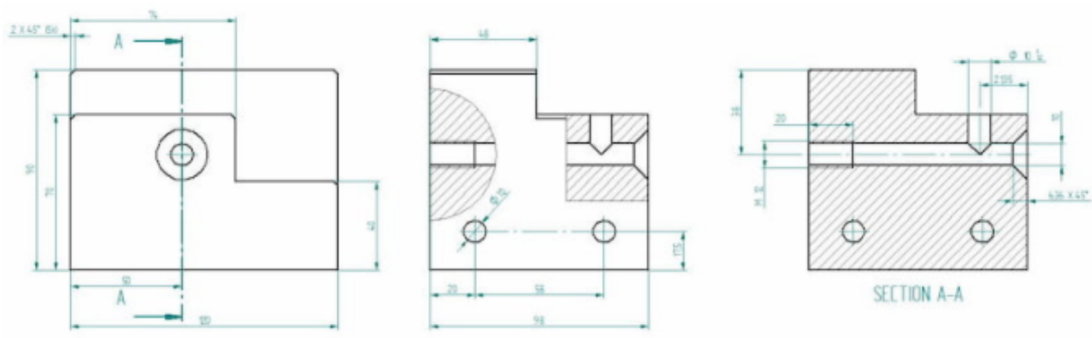
If you are using the standard part environment, the same option is not available. Still, many CAD programs have the possibility to convert a standard part into sheet metal if the part properties correspond to sheet metal (e.g. uniform thickness, inside radius, etc.).

Section View



A section view can easily display some of the part features that are not evident when looking just from the outset. Cross section is the preferred option compared to hidden lines as it brings more clarity. The cross hatching feature is and indicator for cross sectional views.

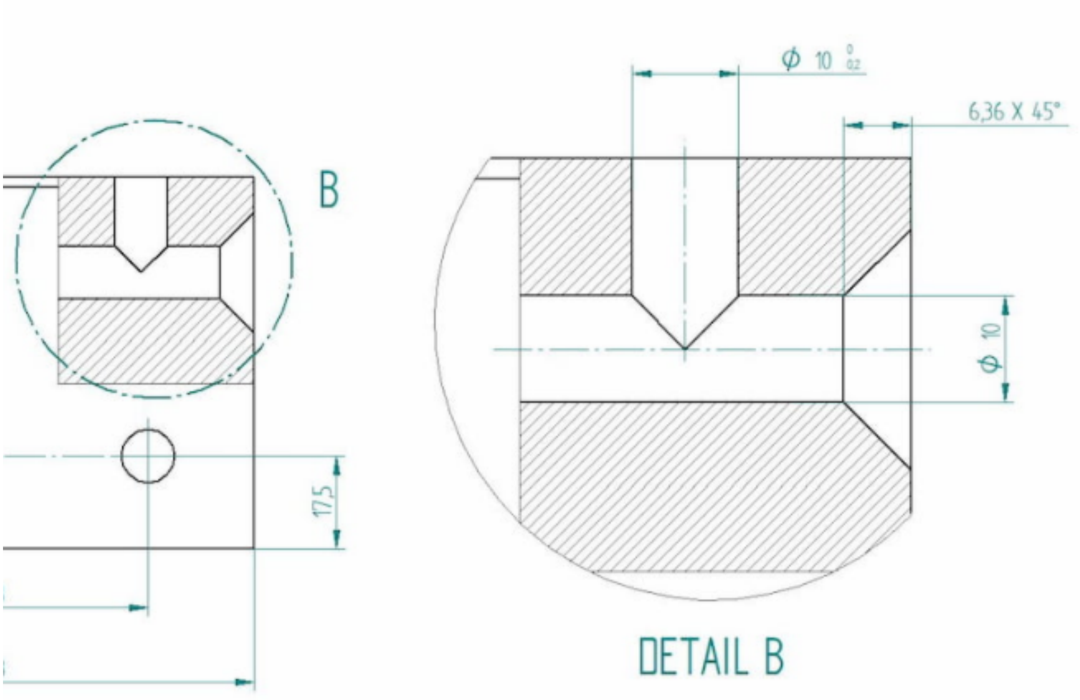
Cutout View



This is the same image we used for illustrating the section view. With one slight difference – the side view includes cutouts. Cutouts can reduce the number of different views on a single drawing.

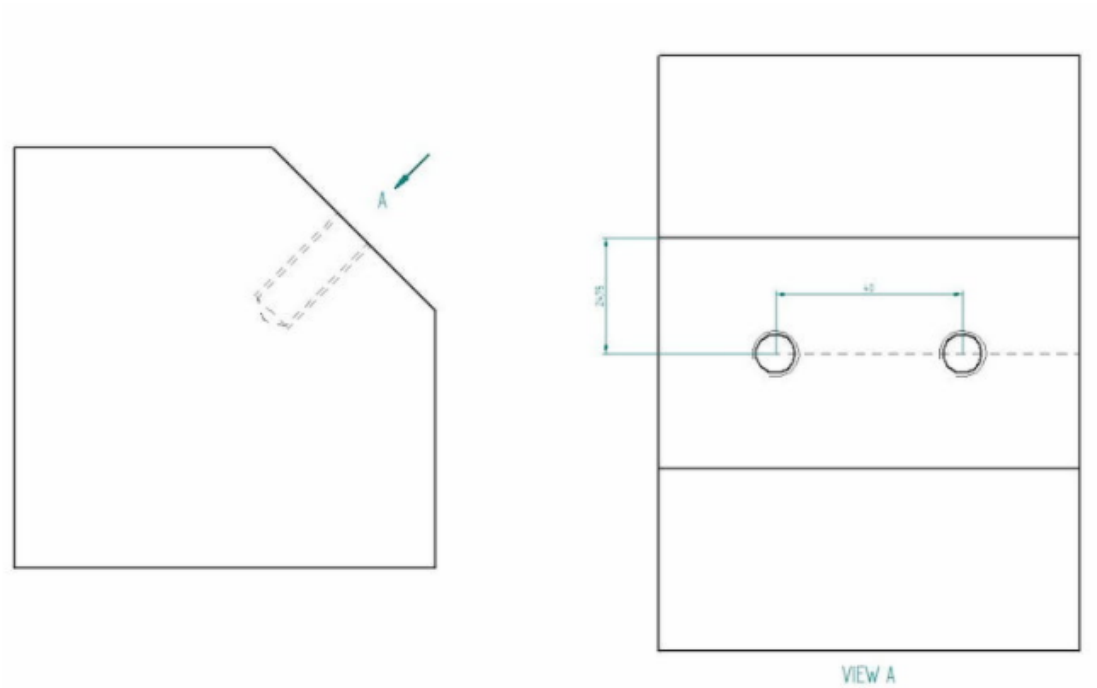
Thus, we could easily delete the section view and add all the necessary dimensions to cutouts.

Detail View



The detail view gives us a close-up of a selected section of a larger view. This can be especially useful if an otherwise large part includes many important dimension in a small area. Using the detail view improves the readability of these measurements.

Auxiliary View



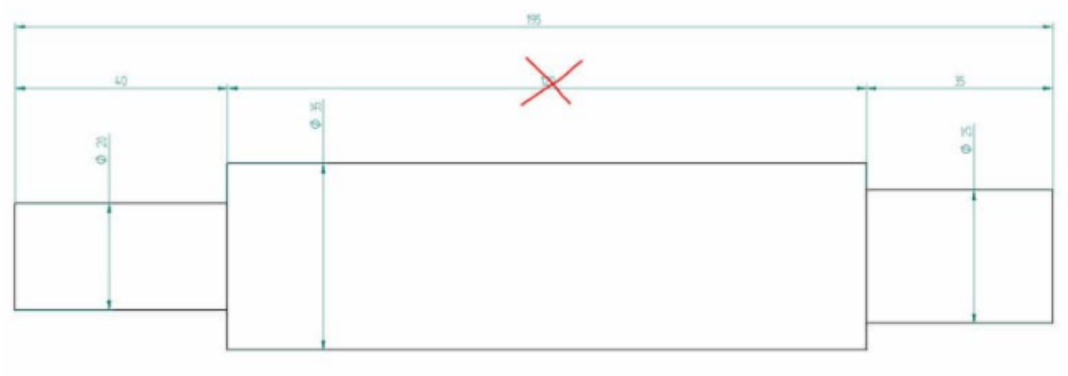
An orthographic view to represent planes that are not horizontal or vertical. It helps to show inclined surfaces without any distortion.

Dimensions

As said before, new CNC machines are actually able to read the dimensions straight from the lines. But a traditional manufacturing drawing shows all the necessary dimensions for producing the parts.

The keyword here is necessary. Avoid using the auto-dimensioning feature that a lot of CAD programs offer because they tend to show everything they can find. For a beginner, it may seem like adding it all ensures that no mistakes can be made.

Actually, it can result in a confusing web of measurements that is left for the manufacturing engineer to untangle. Also, adding all dimensions you can find makes it hard to pinpoint which ones are the most important.



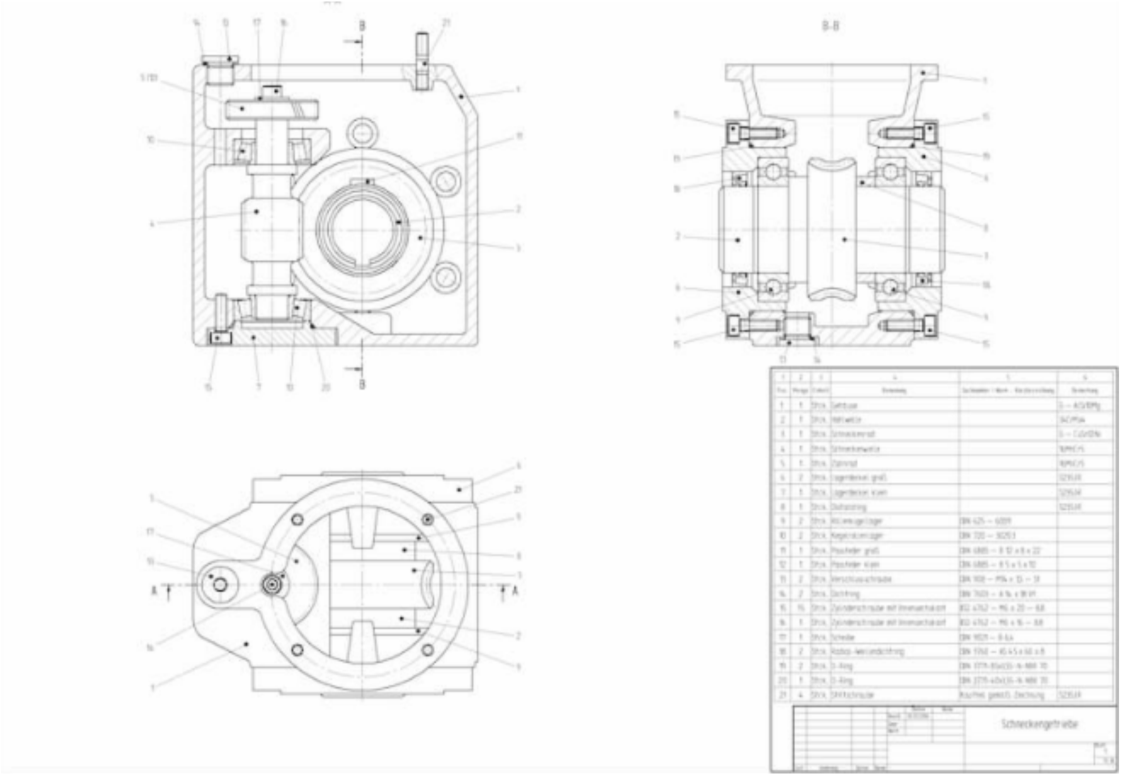
The image above shows a shaft with all the measurements. In reality, it creates a closed system whereby the manufacturer cannot guarantee all these dimensions 100%. Therefore, you have to determine the most important ones. In our case, we chose the end steps to be more important than the length of the central part. Thus, we should delete the 120 mm dimension.

One crucial bit of information that is missing from CAD models is geometric dimensioning and tolerancing (GD & T). For example, when looking to produce a shaft for a bearing system, limits and fits are of high importance. The right dimensions can guarantee a longer lifetime with less maintenance.

While you can fetch all the dimensions automatically by clicking the measure button, adding engineering tolerances needs manual action.

Therefore, adding dimensions with lower and upper limits or fit classes is still important. Regarding Fractory's service, we would ask you to enclose a separate drawing with these parameters. Note that you do not have to provide the whole dimensioning – only include the tolerances of a single hole on your engineering drawings if necessary.

Information Blocks



BOM and title block in the lower right corner

The little boxes in the bottom right corner show additional information. The title block includes the author's name, part name, part number, quantity, coating, scale, etc. There can be much more info on there but the title blocks vary widely between different companies.

Information blocks also include a bill of materials, or BOM for short. These blocks list all the components used in the assembly, along with additional information like quantities, part names, etc.

Assembly Drawings

Many engineers' drawings make the mistake of trying to include all the information about each individual part in an assembly drawing. To avoid this, remember the purpose of these engineering drawings during the creation process – they must make the assembling easy.

Exploded views, section views, numbered parts, general dimensions, cutouts, detail views (or close-ups) are all tools you can use to achieve this goal.

It should be clear where each part goes and how it is attached – whether it needs welding, bolted connections, riveting or something else. The bill of materials is there to help you, so make sure the information available there is correct regarding part numbers, names and quantities.

Keeping everything above in mind will help you create assembly drawings that make life easier on the shop floor. A piece of great advice I once received goes like this – keep the thinking in the drawing-room. Avoiding multiple interpretation possibilities at later steps will significantly decrease the number of errors.

How to create Technical Drawings

I am optimistic about technology, someday, giving us the power to imagine things and directly build an exact physical replica of what we have in our minds.

Unfortunately, we are not quite there yet, and to go from idea to a physical product we need to first "translate" what we have in our mind into a format that other humans and machines can interpret and use to build a product.

For most creative processes, machines still need humans to instruct them what to do.
This is what designers and engineers do, they evaluate your idea and your requirements and produce the formats that will allow anyone to visualize the idea and then help machines build the final product.

We call them the product Technical Drawings. I will go through the most common formats that are generated to help define your physical product idea based on which stage the product is or the level of detail needed.

Design Sketches

One of the most basic and relatively simple formats to start with are design sketches. But these are not simply rough hand-drawings made on a piece of paper.

In order for design sketches to be useful in the development and fabrication process, they must have a certain level of accuracy and information included on them. These design sketches are commonly produced by an Industrial Designer and they often create them by hand although nowadays most use computer software. This is the first level of detail about your idea and it should include the following main elements:

- ✓ **Visual aesthetics** that show the main design intent and give a clear understanding of the product look. Materials & Finishes of the product and different components.
- ✓ **General dimensions** of the product to have a reference (with low accuracy) when fabricating a mock-up or prototype.
- ✓ **Description of the main functionalities** that help to understand how parts are fixed together, how they move or how they are supposed to function.

With this information, a professional (or even yourself if you have certain skills) can fabricate mock-ups of the product and explore different designs and material alternatives.

2D Drawings

In the past, 2D drawings or blueprints were common in any product development and they were literally laying around any office or workshop. Today they are mostly used in their digital format but they are still commonly used.

The two-dimensional world is not dead yet.

Depending on which product you are developing 2D drawings are the main technical drawings used. That's the case with most soft-goods for example, where parts and layers of the product can be produced from 2D patterns.

Despite the rise of 3D modeling which has made these "flat" versions less relevant, they are still widely used as support documentation since they provide certain information that is critical in the development.

These technical 2D drawings are mainly created by Mechanical Engineers and are highly accurate and precise. This is what you would expect to see in a 2D drawing:

- ✓ **Product views**. Different types of views such as front, rear, side, top, bottom, sections, and isometric views are defined to have access to every single area of the product.
- ✓ **Materials**. The exact material and grade (this is the commercial name from material manufacturers) are specified. Also, the color and any additional finish or post-process such as protective coating or paint are included in the drawing.
- ✓ **Detailed dimensions**. Most of the dimensions of the product and features are defined in the drawing as a reference.
- ✓ **Critical dimensions**. There are certain dimensions that are important for the design since they may affect the fit between components, mechanical movements or function of your product.
- ✓ **Tolerances**. All dimensions should have a range of tolerances, especially those defined as critical above. The manufacturing process usually drives the tolerance range achievable, but the geometry of the product affects as well.

Sometimes 2D drawings are used as a full product specification and may include other relevant information to help define assembly or inspection instructions among other useful data.

CAD Models

Computer-Aided Design (CAD) models are probably the most commonly used type of format nowadays and the one that is usually required to be able to fabricate the product and its components using machines.

CAD software allows designing the 3D digital representations of a product

In fact, the 2D Drawings described above are usually created after the 3D models. CAD software can quickly create those 2D digital versions from the 3D model and create a link between them so when you modify the 3D it will automatically update the 2D drawing.

These, again, are mostly created by Mechanical Engineers and will define volumes for the product and components. This is the main information that you can get from CAD models:

- ✓ **3D view.** Using a CAD software (or any available viewer) you can visualize the product in every orientation and in real-time. From 3D models, you can also get Renders which are photorealistic visualizations of your 3D model.
- ✓ **Dimensions.** While dimensions are not explicitly indicated in the model, you are able to measure any dimension that you want in the model with exact precision.
- ✓ **Assembly**. Most products are made of different parts, so CAD models let you visualize where components are located and how they fit with each other.
- ✓ **Simulations**. A very useful and powerful aspect of CAD models is the possibility to perform virtual simulations. You can check the performance of a component when loads are applied, the effects of temperature or check the dynamics of fluids and gases among many others.

CAD models are the main technical files used to fabricate prototypes and mass production. With these files, manufacturers can 3D print, design their own tools (also in CAD) and perform analysis to confirm that the product is ready for manufacturing.

Electronics Schematics

This is only relevant if your product has electronic boards on it, commonly known as Printed Circuit Boards Assembly (PCBA). In terms of dimensions and materials, as seen earlier, a 2D drawing of the boards will be used as well.

However, there are specific electronic files that will be produced to illustrate with a diagram the logic of how the electronic components interact with each other to achieve a particular function.

These files are created by an Electronic Engineer and they represent a less visual aspect of the product and instead explain how the product should function. An electronics schematics include the following elements:

- ✓ **Components**. The diagram uses symbols to represent the different electronic components such as resistors, capacitors, switches, transistors or Integrated Circuits among others.
- ✓ **Connections**. The schematics diagram indicates how components are wired together in a circuit by the means of lines and nodes.
- ✓ **Voltage**. It assigns each component to a specific voltage level.

This information will later help to build the physical board by knowing how each component will connect to each other. Also, it will help to define the actual location for each component on the board based on the diagram's logic and taking into account each component's size and other specific rules and regulations that need to be met.

PERFORM DRAWING AND SKETCHES TO WORKPLACE REQUIREMENTS

While most engineers enjoy the process of getting to the first working model, few employers view that as sufficient. Instead, engineers' efforts are useful only when the design has been captured in engineering drawings and supporting engineering data because:

- ✓ Engineering drawings describe how to consistently reproduce the design. Consistent reproduction is essential, since it forms the basis for product improvements and production efficiency.
- ✓ Engineering data proves that the product conforms to the original design goals. Proof of conformance is important to both internal stakeholders (marketing, accounting, production) and external groups (distributors, customers, service providers, regulatory agencies).

But simply creating engineering drawings and recording engineering data is insufficient. To be useful, engineering drawings and engineering data must be stored, reviewed and approved, published and maintained. In other words, engineering drawings and data require engineering document control.

Document control for engineering drawings

Document control for engineering drawings is comprised of both document attributes and a defined control process.

Engineering drawings, including technical documents such as specifications, procedures, will usually have these attributes:

- ✓ Owning organization, which is ultimately responsible for the document content.
- ✓ Document identification through the use of a document numbering system
- ✓ Title or description
- ✓ Document revision or other indication of a specific design iteration
- ✓ Author(s), reviewer(s) and/or others who created the information
- ✓ And, of course, the appropriate technical information necessary to fulfill their purpose

A document control process consists of a set of procedures for creating and maintaining the attributes of engineering drawings. Engineering drawing management processes include business rules that define:

- ✓ Which engineering drawing types are supported, and the contents and format of each type
- ✓ How engineering drawings are identified (e.g., owner, number, revision, title)
- ✓ Who is responsible for creating, reviewing and approving engineering drawings
- ✓ When engineering drawings may be released to interested parties

- ✓ The conditions under which existing engineering drawings are revised, replaced or canceled
- ✓ How obsolete engineering drawings are controlled, recalled or destroyed

Engineering drawings that reflect a consistent set of attributes, and are controlled using a documented set of procedures, significantly reduce product costs by simplifying design, sourcing, production, customer adoption and field service. PDXpert PLM software offers these precise advantages.

Engineering data management policies

In addition to managing the formal engineering drawings, a complete engineering document control system will manage the "background" information that is the basis for the engineering drawings. This engineering data may include a wide variety of electronic files which are saved in a file library (or "vault"):

- ✓ Product capabilities & functional requirements
- ✓ Budget estimates, production volume assumptions, and development schedules
- ✓ Suppliers' component datasheets
- ✓ Product performance tests and qualification results
- ✓ Alternative design data
- ✓ Notes, calculations and other written communications

A complete engineering drawing management environment encourages archiving as much "organizational knowledge" as possible. The ideal system captures all the data that would allow performance analysis, field diagnostics, and incremental design improvements over the entire product life cycle.

UNIT 06

PLAN TO UNDERTAKE A ROUTINE TASK

This unit covers a person planning their own work where tasks involve one or more steps or functions and are carried out routinely on a regular basis. It includes the concepts of following routine instructions, specifications and requirements

IDENTIFY TASK REQUIREMENTS

Task Analysis

A task analysis defines a job in terms of KSA necessary to perform daily tasks. It is a structured framework that dissects a job and arrives at a reliable method of describing it across time and people by composing a detailed listing of all the tasks. The first product of a task analysis is a task statement for each task on the list.

When writing the task statement, start each task with a verb, indicate how it is performed, and state the objective. For example, "Loads pallets using a forklift." One way of getting a comprehensive list is to have the employees prepare their own list, starting with the most important tasks. Then, compare these lists with yours. Finally, discuss any differences with the employees, and make changes where appropriate. This helps to ensure that you have accounted for all tasks and that they are accurate. It also gets them involved in the analysis activity.

Task or needs analysis should be performed whenever there are new processes or equipment, when job performance is below standards, or when requests for changes to current training or for new training are received. An analysis helps ensure that training is the appropriate solution, rather than another performance solution.

Once the task statement has been defined, the task analysis will then go into further detail by describing the:

- ✓ task frequency
- ✓ difficulty of learning
- ✓ importance to train
- ✓ task criticality
- ✓ task difficulty
- ✓ overall task importance

This in turn provides you with the information for identifying the KSA required for successful task performance. The analysis might also go into further detail by describing the task steps required to perform the task.

There are a wide variety of methods for performing a task analysis, such as observations, interviews, and questionnaires.

Task Statements

As mentioned earlier, a task statement is composed of an action and a result (product). For example, a couple of task statements for a fire person might be:

- ✓ *Determines manual ladder type and size needed at incident scene.* ("Determine" is the action while "identifying the correct ladder" is the result or product.)
- ✓ *Carries manual ladder from apparatus to incident scene.* ("Carries" is the action and the "ladder being placed at the scene" is the result of that action.)

Action can be mental, such as determining, or physical, such as carrying. Some other mental examples would be analyze, calculate, predict, and design. Physical examples might include, paint, dig, move, and operate. Actions can also deal with people such as counsel, mentor, teach, and explain. An example of a fire person doing a people task would be "Calms distressed individuals at emergency scene." Calms is the action being performed, while "producing a less stressed person" is the result or product of that action. It often helps to sort the task actions into People, Data, and Things for clarity. This helps to identify the main characteristics of the job.

Good task statements are not easy to write. They require some in-depth analysis of the job by observing and interviewing Subject Matter Experts (SME). When observing, you should have them slow down so that you can identify what they are performing. One way to do this is to have them speak out loud as they perform the task, explaining what they are doing and why as they perform the task. This is a must when documenting mental actions as you have no idea what the SME is thinking.

Also, unlike learning objectives, tasks can have more than one action word. For example, "Troubleshoot and repair a carburetor" might be an acceptable task statement whereas the two action words would make it unacceptable for a learning objective.

Task Steps

Task steps (also known as performance steps) are the step-by-step instructions for performing the process. They describe each step in sequence. You should ask, "What does the SME do first, second, third, and so on?" Take nothing for granted as experts may do some things so quickly that they are almost invisible. Often, they will not even be aware of the fact that they are performing something because they have done it so many times it just seems second nature to them.

Many task analysis do NOT require the recording of the task steps. Often, just the tasks will be recorded and the required KSA identified. Then, if any of the tasks requires training, rather it be formal, on-the-job, job aids, etc., then a second analysis will be performed to list the task steps. Although identifying and listing the steps can be a big help in defining a job, the cost of performing such a detailed analysis has to be weighed with other factors. Many processes, departments, and organizations are changing rapidly to stay competitive. If the task steps are not going to be used right away, you will need to determine if they will be valid at a later date.

However, the task steps for a learning program are almost always included, as the correct performance procedure needs to be documented. An example of a task for a Buyer with its steps might look like:

Orders manufacturing parts when the system flags a part as being low in stock.

1. Look up usage for the item for the previous 12 month period.
2. Calculate the average monthly use.
3. Add the planned growth rate for the product line.
4. Check parts catalogs or call the source for best buy rates.
5. Check with planned usage tables or the business unit to ensure that the part will not go out of specifications for the best calculated buy period.
6. Place purchase order.

There are four main methods for determining the steps in a task analysis:

- ✓ Hierarchical Task Analysis - arranging by order of actions
- ✓ IF and THEN Analysis - If and then relationship
- ✓ Model Based Analysis - possible actions listed
- ✓ Cognitive Task Analysis - critical decision based

Hierarchical Task Analysis

Most task analyses follow this method. Steps are arranged in the order they are performed. For example, a production worker might have the following task steps:
Package products as they come off the production line.

1. Place product in shrink-wrap.
2. Run product through heat-shrink.
3. Place product in package.
4. Glue ends of package together.
5. Place label on front of package.
6. Place on finished line.

It is not always easy to identify what a task step is as experts often group several steps into a larger one. For example, they might list "open the daily receiving spreadsheet file," instead of 1) start computer, 2) open spreadsheet program, 3) etc. If you are going to use the task steps for training purposes, then you are going to have to identify your target population. This will tell you how detailed the steps need to be. For example, if your target population is computer literate, then the expert's combined step might be appropriate, otherwise, you might have to break it into several smaller steps. There is no one right way to list steps as each circumstance will differ. This is why the first part of an analysis is crucial — to determine what type of information is needed and who your target population is.
If possible, steps should include the signs of success. This is how experts know when they've done something right. Carpenters look for edges to be aligned, while plumbers ensure there are no leaks. When you know this kind of event, you can help the learners ensure that they are doing things correctly.

If/Then Analysis

Often, the task performer's action depends upon a condition being satisfied. For example, think of using the delete function on a word processing program:

- ✓ IF text is a word THEN:
  - o move cursor to middle of word
  - o double-click mouse button
- ✓ IF text is a section of words or letters THEN:
  - o move cursor to beginning of text
  - o press mouse button down
  - o move cursor to end of text
  - o release mouse button
- ✓ THEN press [Ctrl-C], press delete button, or click on the cut icon.

An example for a supervisor's coaching task steps with certain conditions being met might look like this:
Coach employees to gain greater competence and to improve job performance.

- ✓ IF the employee is a beginner (cannot perform) THEN:
  - o Give lots of clear instructions (training) because the task is new.
  - o Give just a little bit of support (motivation) to calm the stress of change.
- ✓ IF the employee has had a little experience (can only perform with some guidance) THEN:

    - Allow the learner to experiment so that learning takes place from mistakes being made, but keep the level of guidance high so that these mistakes do not become learned.
    - Do NOT motivate too much as the employee needs to concentrate on mastering the new task (our brains can only take so many inputs. See Arousal).
- ✓ IF the employee can perform, but makes occasional mistakes or is slow (capable performer) THEN:
    - Drop instructional level to just a few pointers so that the learner can experiment with new skill.
    - Increase the amount of emotional support (motivation) to help increase the level of confidence.
- ✓ IF the employee performs correctly THEN:
    - Provide little coaching and support so that the employee can take ownership of job.
    - Delegate and encourage employee to take on new responsibilities and new assignments.
    - Start using mentoring on employee to help him or her grow.

Model Based Analysis

This method is often used for professional tasks as the steps for performing certain tasks can be extremely vague to define. Although performance is based on methodologies, there might not be any clear and cut guidelines for performing the task. For example, in going back to the task that has the supervisor coaching an employee, we might have this task and steps:

Uses one or more accelerated learning techniques to promote learning. Acceptable techniques include, but are not limited to:

- ✓ use examples of others
- ✓ have them form a picture in their minds of what they are trying to learn
- ✓ help them gain and understand necessary information
- ✓ apply the task to their job
- ✓ present information using visual, auditory, and kinesthetic methods
- ✓ practice the task

This method relies upon the task performer to determine what task steps are needed and then sequence those steps in order to accomplish the task in an efficient and effective manner.

Cognitive Task Analysis

Due to the rapid changes that are the major workings of many of today's organizations, a number of organizations are changing from task-based work to process-based. That is, they are becoming more knowledge-based. These jobs are no longer defined by a number of tasks, but by focusing on troubleshooting activities. In these cases, a cognitive task analysis may be more appropriate for identifying strategies involved in effective performance.

A Cognitive Task Analysis is directed at the psychological processes underlying the performance and the subtle cues that may depend on context and experience. The main goal of a cognitive task analysis is to define the actual decision requirements of the task by:

- ✓ Mapping out the task using task analysis (traditional task analysis).
- ✓ Identifying the critical decision points.
- ✓ Clustering and linking the decision points.
- ✓ Prioritizing the decision points.
- ✓ Diagnosing and characterizing the decisions as to the strategies used, cues signaling the decision points, and the inferences made regarding cues and decision points.

There is a key difference between a task analysis and cognitive task analysis. Task analysis focuses mainly on observable behavior and does not offer information on overall organization of knowledge. A cognitive task analysis is directed at the psychological processes underlying the behavior. Cognitive task analysis concentrates on the critical decisions and cognitive processes that separate the expert from the novice.

An example for an instructional designer might be (this example does not go into great detail due to space limitations):

Uses one or more accelerated learning techniques to promote learning.

- ✓ Map out the task using task analysis (traditional task analysis):
  - o use examples of others
  - o have them form a picture in their minds of what they are trying to learn
  - o help them gain and understand necessary information
  - o apply the task to their job
  - o present information with several examples to provide context
  - o practice the task
- ✓ Identify the critical decision points (what do experts ask themselves when deciding on what learning technique to use):
  - o What is the experience level of the learners?
  - o What do I need to ask them to show me they understand
- ✓ Cluster and link the decision points (Note: only the first decision point, "What is the experience level of the learners?" is shown):
  - o Ask learners for their experience level to gain a background.
  - o Ask questions that provide clues.
  - o Observe how they react to new and difficult information.
- ✓ Prioritize the decision points:
  - o Main decision point is asking for their experience level. Asking questions is then used to ensure that the trainer and the learner both understand each other and know where each other is coming from.
- ✓ Diagnose and characterize the decisions as to the strategies used, cues signaling the decision points, and the inferences made regarding cues and decision points.
  - o Asking the learners for their experience level builds a level of trust and rapport between them and the trainer. But, to prevent any form of misunderstanding, questioning techniques are used to verify their answers. With experience learners, the trainer can get right to the point. While less experienced learners need the material presented in a variety of formats.

Duties

Duties are a combination of related or like tasks. For example, an inventory control specialist might have two duties:

- ✓ Perform shipping duties:

    - Pull items using a letdown. (task)
    - Prepare items for shipment. (task)
- ✓ Perform receiving duties:
    - Unload trailers using a forklift. (task)
    - Receive the items into the computer database. (task)

As mentioned earlier, tasks should have a definite beginning and end and explain a process. This is the main clue for separating tasks from duties. For example, is the following a task or duty for a Fire person?

Stands watch to receive incoming alarms and information, answers phones, and monitors access to the station house.

This would be a duty as it would be extremely hard for someone to identify the process and note when it has started and when it has stopped. Clues that give this off as a duty are the multiple action verbs: stands, receive answer, and monitor. Also, if this was a task, then you would have to see all the actions performed when observing the task, e.g. when an alarm is received then the phone would have to be answered. Remember, a task stands alone as it has a definite start and an end.

The tasks performed while carrying out this duty might include:

- ✓ Receives notification of multiple alarms, downtown alarms, and other significant emergencies through the Fire Alarm Office. ("Receives" is the action while "being notified of the various alarms" is the result.)
- ✓ Notifies station personnel over public address system of incoming alarms and required response (e.g., everybody goes, truck only, engine only, etc.). ("Notifying" is the action while "the other fire persons being made aware of the required response" is the result.)

Knowledge, Skills, and Attitudes (KSA)

Knowing the tasks that have to be performed helps you to identify the KSA that the jobholder must possess in order to perform to standards. In some cases you will train some of the required KSA. But even then, you must determine the required entry behaviors (KSA required to be able to learn the new tasks). Some prerequisite skills may be difficult to recognize because they are too obscure, others may be too obvious.

For example, forklift operators need hand and eye coordination before they can be trained. A shipping and receiving specialist might need keyboarding skills, while a planner needs good math and organization skills. On the other end of the scale, you would expect an accountant to have math skills and receptionists to know that a ringing phone needs to be answered.

To help you extract the KSA from a task, you should be familiar with Bloom's Taxonomy or Learning Domains. The three learning domains used in Bloom's Taxonomy - cognitive, psychomotor, and affective; correspond to knowledge, skills, and attitude respectively.

For example, the task *"Create web pages"* has the action word "create. The chart showing the three learning domains has the word create as one of the key words in the *cognitive* domain. This is the next to highest category, so it tells you that it is high on the scale of knowledge skills. Some of the KSA required are "Builds a structure or pattern from diverse elements. Put parts together to form a whole, with emphasis on creating a new meaning or structure." Using this information, and with the input of SMEs, you might come up with something similar to:

"Create pages for the e-commerce web site."

- ✓ task frequency - performed daily as it is main job task.
- ✓ difficulty of learning - entry behavior requires computer, web, and design skills.
- ✓ importance to train - low as a qualified person can probably be hired
- ✓ task criticality - 5 on a scale of 1 to 5
- ✓ task difficulty - 4 on a scale of 1 to 5
- ✓ overall task importance - 5 on a scale of 1 to 5
- ✓ KSA required:
    - o Program in HTML (HyperText Markup Language).
    - o Design and build on-screen layout and messages using company templates.
    - o Use Dreamweaver or similar remote publishing tool.
    - o Works with others (teamwork) by interacting with the Merchandising department group.
    - o Constructs pictures using digital cameras and photo editing software.
    - o Communicates using both written and verbal skills.

Team Task Analysis

A team task analysis includes teamwork and individual task-work. This is often called a *collective task*. Teamwork consists of individuals interacting or coordinating tasks that are important to the team's goals, while task-work consists of individuals performing tasks. Like a job analysis, a team task analysis is important because it forms the foundation for team design, team performance measurement, and team training. The purpose of the team task analysis will dictate if the focus is to be upon team tasks, team processes, individual task-work, or some combination of the three.

A team can be defined as a group of individuals working together toward a common goal, product, or solution that requires the sharing of expertise, knowledge, and ideas in a cooperative and interdependent fashion. Some of the goals that they might be trying to achieve are:

- ✓ solving a problem
- ✓ designing a plan
- ✓ defining a process
- ✓ building a product
- ✓ executing a process

Individual tasks, are analyzed using the same methods as discussed earlier. They should, however, be reviewed by the other team-members in order to gauge their full impact. Teamwork, on the other hand, requires a slightly different approach. For example, some of the tasks that might be in teamwork are:

- ✓ Participate and share in the team's leadership.
- ✓ Achieve team roles and norms (focus is on the underlying team mechanics and operating rules).
- ✓ Participate by contributing data and knowledge.
- ✓ Coordinate task responsibilities.
- ✓ Share in the decision making process with the goal of reaching consensus.
- ✓ Communicate, provide feedback, and interact among the team members (openness in critiquing and trusting others).
- ✓ Accomplish goals (the team's ability to meet its milestones and time deadlines).

- ✓ Produce a quality product that will be accepted by the customer (either external or internal).
- ✓ Work efficiently and effectively as a team unit.

Teamwork becomes more difficult to analyze as it is performed collectively by the team. For example, how do you determine the amount of participation of the individuals in accomplishing a goal? Also, most of the team tasks include soft skills. A hard skill can easily be measured, such as *"Paint a door,"* while a soft skill is more difficult to measure, such as *"Share in the decision making process."*

Team tasks can best be analyzed by extracting task information from the team as a whole. It is only after getting agreement by the team on the task's frequency, criticality, difficulty, importance, and KSA that the complete significance of the teamwork task can be defined. Just as a team is responsible for achieving its goals, it should also have the major responsibility of defining the teamwork (team tasks) that empowers it. Although this requires that you become more of a facilitator than a task analyst, the payoff will be a team that has built and therefore will implement its defining structure.

PLAN STEPS REQUIRED TO COMPLETE TASK

Task management plans: the best way to stay organized at work

Getting and staying organized at work is really just a matter of making essential task management mechanisms a part of your work day environment.

In other words, the answer to how to organize tasks at work better is with a plan for accomplishing your goals that incorporates these basic criteria:

- ✓ time management,
- ✓ scheduling efficiency,
- ✓ data consolidation, and
- ✓ fluid communication

Whether you're working alone or as part of a bigger team project, you're far more likely to meet your deadlines – and help others meet theirs – with a personal task management plan in place.

Team task management plans, meanwhile, are ideal for helping project organizers and managers prioritize, assign, and track shared tasks and outcomes.

The bottom line is that arming yourself with a strategy for breaking large goals into bite-sized objectives will make your tasks easier to manage, measure, execute, and share. And a few fundamental planning components are all it takes to get a strategy like that working for you.

How to organize tasks at work from the foundation up

Advice on how to manage tasks in the workplace is everywhere. But like most cases of information overload, too much of a good thing can quickly become overwhelming. So we're going to stick with the basics.

Before we move forward, however, it's important to recognize that there's no true one-size-fits-all solution when it comes to task management. In most cases, the specific project in play – and your personal work style – will determine what works and what doesn't.

That said, the best ways to stay organized at work share four basic planning components:

- ✓ They help restructure big picture goals into smaller picture objectives.
- ✓ They break those objectives into individual tasks and subtasks.
- ✓ They lay out start dates, end dates, milestones, and timelines in a way that's easy to see and coordinate.
- ✓ They make use of efficiency and productivity tools.

Both personal and team task management plans can be built using this core foundation. So work through the components below and find out how you can construct a plan that will keep you on top of your daily and project objectives.

1. Rework big goals into small objectives

Restructuring large-scale goals into smaller, more actionable steps is the only way to map out a viable plan for organizing work and measuring progress.

By working with a mix of short-term and long-term objectives, you can:

- ✓ prioritize and arrange steps that will need to be taken, and
- ✓ see how each action fits into the whole

Let the complexity of your single, overriding goal determine whether you use pen and paper, text documents, spreadsheets, or diagramming software to sketch out a framework for breaking it into multiple mini-objectives.

Then flesh out and schedule or assign those objectives as individual, stepping-stone tasks.

2. Clarify objectives by converting them into a series of tasks

Organizing mini-objectives into tasks and subtasks lets you create a series of daily and weekly to-do's for yourself or team members. One advantage of knowing exactly what needs to get done and when is that you won't feel so overwhelmed by the bigger endgame.

As the breakdown of tasks, subtasks, and timelines grows more complicated, however, it's very possible that a simple "grocery list" of to-do's won't be enough to keep your work organized. So to stay on point, give your process a boost with flowcharts, planning templates, or task management software.

3. Lay out and manage task timelines visually

Managing multiple jobs – whether they're daily, weekly, or group project one-offs – is much less of a burden when you have a crystal-clear view of:

- ✓ the start date and end date for each task, and
- ✓ the various milestones along the way (these often take the form of subtasks)

You can achieve this clarity by using a visual timeline to plot key dates and targets.

Not only does visualizing your plan make it easier to review your own progress, it lets you see the status of shared tasks and amend or update pre-planned steps as needed. Consider using visual planning software and flexible project templates to organize, schedule, and oversee tasks.

4. Take advantage of visual task management tools

There's a very good reason why brightly colored sticky notes are so popular: visual task reminders work. And when you have specific goals to accomplish – and jobs you need to manage and organize – visual tools:

- ✓ help steer you through the most pressing objectives first,
- ✓ make it easy to see where you've been and where you're going, and

- ✓ shine a spotlight on potential roadblocks or bottlenecks so workaround routes can be planned

From online calendars to Gantt charts, visual and interactive task management tools encourage efficiency and promote productivity. They're also your best defense against procrastination at one end of the work duty spectrum – and temptations to multitask at the other.

You've discovered how to manage tasks better – now what?

Now that you have a firm grasp on how to manage tasks for better performance at work, how do you bring these basic components together?

It's not uncommon in our attempts to stay organized to introduce so many scheduling, time management, data, and communication aids into our work environment that they compete with each other for our limited attention.

Having determined that the best way to stay organized at work is with a personal or team task management plan, it should also be clear that the best way to create and implement that plan is with the help of one centralized system.

When you take advantage of a mind mapping platform like MindManager, for example, you can consolidate all your planning components in one place. Pre-built map templates make it easy to visually break goals into tasks, organize tasks into timelines, and keep an eye on the status of each action step – all in one fluid interface.

Whichever task management solution you choose, make sure the plan you create – and the tools you use to bring it to life – function *with* you, not *against* you, to keep you organized at work.

REVIEW PLAN

1. **Reviewing your plans helps limit decision fatigue**

A well-done plan helps you limit decision fatigue because a plan is a set of pre-made decisions. Thus, it's both a product of the most taxing thing we have to do *and* it helps us not have to do it all over again.

For instance, planning at broader levels of perspective enables us to not have to do so much decision-work at more narrow levels of perspective. If you set three big goals for the year, you already know that sometime during the quarters to follow, you need to be working towards those goals. You also know that during the months, you need to be working towards those quarterly goals. And so on and so forth, until you know that today's actions are moving you toward those three big goals. (Yes, this is baked right into our Digital Momentum Planner Pack. The Yearly Momentum Planner and Quarterly Momentum Planner that come with the premium set help you work down from the year.)

Many people don't think of it this way, but scheduling appointments is also a planning activity. An appointment at 3pm removes the decision about what you're going to do at 3pm, unless, of course, it's you telling yourself you're going to do something at 3pm. In those cases, most people start the decision process all over again, whereas when it comes to meeting with other people, we don't start the process all over again. Compare "Hey Pam, I know we had a 3pm today, but I decided that I want to do something else right now" to "I have on my calendar that I'm going to work out right now, but I'd rather process email." (Or maybe that's just me.)

We all are presented with too many decisions every day; there's no sense in doing the decision-work to make a plan and not use it.

2. **Reviewing your plans helps reveal assumptions that need to be adjusted**

Plans rest upon assumptions, whether you articulate those assumptions or not. Not having a plan rests upon many assumptions, with the most prominent one being that you don't need a plan.

For instance, setting a goal of finishing Project X by the end of the month assumes that finishing Project X by the end of the month is possible. Any plan that you make to accomplish that goal rests upon that goal. One way of looking at plans is that they help us make our assumptions true — we generally *are* capable of doing more than we think we can do but just don't focus our resources effectively. Plans help you do that.

When people talk of unrealistic goals and plans, largely what they mean is that the optimist's or deluded's assumptions about the way the world works don't match reality. The entrepreneur who starts a business with the goal of making a million dollars in their first year *usually* hasn't done sufficient research or doesn't have the experience to know that it takes a while to build up a market and production force to do that. There are outliers, of course, and it is *possible;* this goal rests upon a host of assumptions, though, any one of which can make that goal unachievable.

The more your projects involve other people, the more your assumptions are likely to be off. They can be off favorably, too; the right people bringing the right resources can shave months and years off of how long it takes you to do something.

Reviewing your plans, then, allows you to see which assumptions are better than others. The better your assumptions, the more likely you are to achieve your goals.

3. **Reviewing your plans helps you proactively problem-solve and coordinate**

It happens to the best of us. We assume that we can finish Project A in one day, but it takes two. Unfortunately, we've also assumed that we could start and finish Project B the next day. The miscalculation on Project A starts the project cascade, wherein one project displaces another project, which displaces another project, and so on down the line.

What I've seen most people do when the project cascade starts is just focus on catching up on whatever projects are starting to slip because they assume they'll catch up. A better option is to review your plans to see whom you need to proactively coordinate and communicate with.

If you're looking 15-20 days down the road, you have enough time to pull in additional people to help you finish the project. Or you have enough time to renegotiate some of your other projects so that you *can* double-down on it without losing face. The people you're working with can also adjust their plans to either alter the deadline, help with the project, or add additional resources to it.

In my experience, people are willing to help out if you give them advance notice. It's when you come up with a last-minute situation that frustrations occur. Continually reviewing your plans keeps you out of this last-minute hot water.

4. **Reviewing your plans helps you keep momentum on Big Projects**

Big Projects — which we call objectives around here — always contain a lot of smaller projects. Objectives can span quarters; rarely do we sustain our motivation that long. It can be challenging to stick with a project that you know isn't going to bear fruit for another three to six months.

Building your body of work is much like building a brick wall. You lay down one brick at a time, but as you're laying down that brick, it doesn't look like you've gotten anywhere. It's tedious and messy, too.

It's only when you take a step back from your work that you can truly appreciate that all those bricks are adding up to something. Yes, having an end in mind is nice and helps speed up your progress and I know many people who have built an incredible body of work almost accidentally. (This is especially true of connectors.)

I spent an entire spring building a retaining wall on our first home about six years ago. It was a curved wall on a double slope, so leveling the foundation stones took what seemed like forever for each one and I only had a few hours at a time. Leveling them required lying on the ground to read the level, adjusting a brick or two, reading the level, adjusting a brick or two, and so on. It was tedious and often demotivating to see that I'd spent my afternoon to lay two bricks.

At the end of it, though, we ended up with a bed to plant bushes and roses in. While I'm not in a hurry to do it again, it was worth it when I was done and paid for itself when we sold that home.

Reviewing your plans helps you see that the sum of each brick laid is greater than the brick itself.

5. **Reviewing your plans ultimately helps you save time**

The items listed above help you save time on their own, but the more you review your plans, the better you get at making plans that work. Whereas most people think effectiveness comes from world-mastery, the truth is that it comes from self-mastery. Systematically reviewing your plans helps you dial in your strengths and weaknesses such that you leverage your strengths and mitigate your weaknesses.

Successful people don't just know *that* they can accomplish something; they also know *why* they'll be able to accomplish it. Sometimes this is just an unconscious knowing, but what I've found is that the most successful people are the ones who intentionally sculpt their environments and conditions to favor their success. They don't just play the current set of games available — they create new ones that favor them.

Doing this requires you to know what works for you and what doesn't. Continually comparing your plans against your results sets up a continuous feedback loop that, done right, is the precursor to an upward spiral of success.

Why You're Not Reviewing Your Plans?

Over the years that I've been having conversations about planning and accomplishment, people have given me a few reasons why they're not reviewing their plans:

1. They don't have a plan to start with
2. They don't understand the value of doing so

3. They forget they've made the plan
4. They lose the plans they've made
5. They don't have time to do so

I'll be addressing each of these in future posts since, obviously, there's a lot to cover judging by the length of this post. I started here because it was easier to finish and it gives the "Why" of reviewing plans at the same time that it helps me address why your plans aren't working. Also, if you know something's valuable, you're less likely to forget it or lose it.

I'll address the time piece briefly now: if you don't have time to review your plan, you don't have time to *not* review your plan. If you don't have time to make a plan, you don't have time to *not* make a plan.

To be clear, plans can be fleshed out to different degrees of specificity. Simple goals and strategies can have simple plans; complex goals and strategies often need detailed plans.

While the planning process is itself more important than the plans that come from the process, it's also true that reviewing a well-made plan can enhance your success. Dust off those plans, adjust them, and move forward more intelligently!

UNIT 07

APPLY SCIENCE FOR WATER OPERATIONS

This unit of competency covers the ability to relate fundamental laws of science with routine tasks and work environment

APPLY PRINCIPALS AND THEORIES OF PHYSICS IN REAL WORLD

Scalar and Vector Quantities

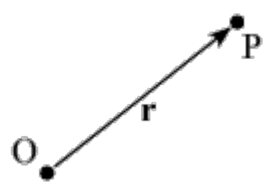
Scalars: Scalars are mathematical entities which have only a magnitude (and no direction). Physical examples include mass and energy.

Vectors: Vectors are mathematical entities which have both a magnitude and a direction. Note that the location of the vector (for example, on which point a specific vector force is acting, or where a car with a given vector velocity is located) is not part of the vector itself. Physical examples include forces, velocities, momenta and locations. Note that as we show below, not all entities having a magnitude and direction are necessarily vectors (as is elaborated below).

We can also define the following:
Scalar functions: The scalar function (aka a scalar field) is a function which returns a scalar at each location of space. Examples include the pressure field (i.e., the pressure at each point in your room), the energy density in an electric field, etc.

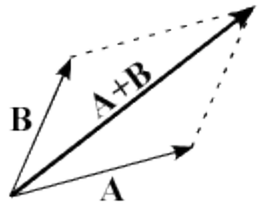
Vector functions: The vector function (aka a vector field) is a function which returns a vector at each location of space. Examples include the gravitational field (at each location we have a different vector defining the local acceleration of gravity), the electric field, the velocity field of a flow (e.g., the speed of the water in your bathtub, which depends on its location relative to the sinkhole, etc.)

Notation:
Scalar: Plain (or often italicized) letters: *a, k*, etc.
Vectors: Either bold letters: ***x,v*** (often used in books), or a small vector sign: $\vec{x}$
Magnitude of a vector: A≡|A|
Unit vector in the direction of A (a vector which has a unit magnitude and the direction of A): $\hat{A}$. Clearly, one has that $|\hat{A}| = 1$ and $A = \hat{A}|A|$.
Position vector (aka radius vector or location vector): The vector **r** is the vector connecting the origin (usually denoted as ***O***) to the location ***P*** of a given point.



Vector addition:

The sum of two vectors is defined as the diagonal of the parallelogram formed when the two vectors AA and BB are placed at the same point, as is described in the diagram. Evidently, we see that the addition is commutative, that is, the order is not important: A+B=B+A.

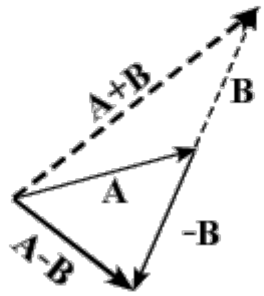


The negative of a vector:

The vector −A is defined to be the same as vector A, but with the opposite direction. Thus, when we add a vector and its negative we obtained that A+(−A)=0, as evident from the diagram.

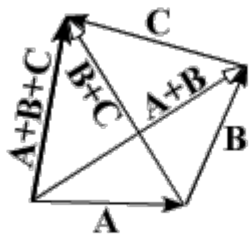
Vector subtraction:

Vector subtraction A−B is defined as: A+(−B), that is, adding the negative of the subtracted vector BB, as is apparent in the figure.



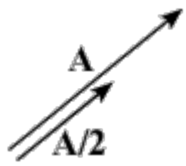
Vector distributivity:

The graphical definition of vector addition also implies a very important characteristic: Vector addition is distributive, that is A+(B+C)=(A+B)+C. In other words, when we add three vectors, it does not matter whether we add the first pair first, or the second pair first. This is demonstrated in the following figure.



Multiplication by a scaler:

Multiplying a vector by a scalar gives a new vector with the same direction but with a magnitude which is multiplied by the scaler. A negative scalar would yield a vector in the opposite direction as the original vector. For example: (−1)A=−A.



Examples of Vectors:

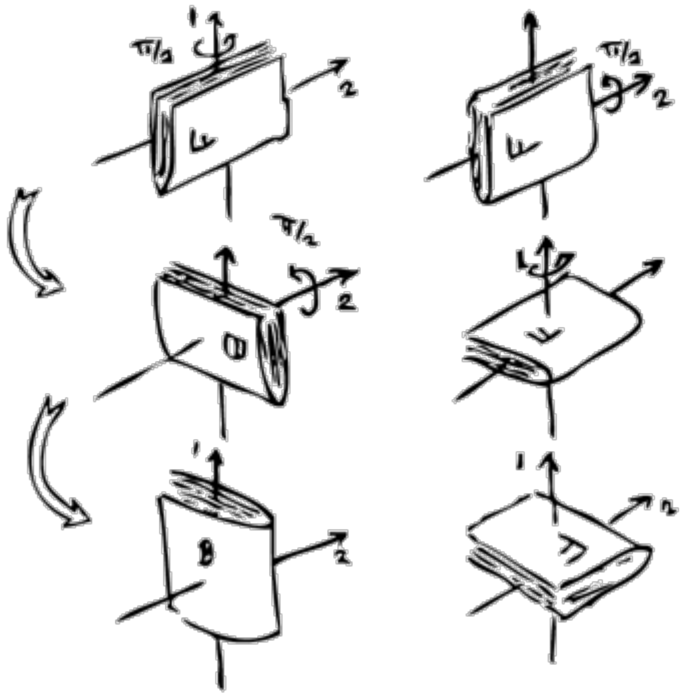
The following are examples of vectors, that is, entities which have both a magnitude and a direction, and which can be added following the parallelogram rule:

- ✓ Displacement vector (e.g., by how much a certain object moved) - the total displacement of an object satisfies the parallelogram definition of addition. If you first walk 1 mile east and then 1 mile north, you will end up at the same point as you would if you would first walk 1 mile north and then 1 mile east (assuming of course a flat earth!).
- ✓ Forces are vectors (e.g., opposite forces cancel each other, two perpendicular forces add up to a force 2–√2 larger and so forth).+

Examples of non-vectors:

Just as a precaution, it is worth noting that not every mathematical entity which has a magnitude and a direction is necessarily a vector. Two interesting examples include:

- ✓ The polarization of light - As first glance, one may think that the polarization of light can be described by a vector, that is, a direction and a magnitude. However, this is not the case. Polarization (and therefore polarizers) have the characteristic that if you rotate them by 180°, they return to their original state (have you ever tried rotating polarizer sunglasses by 90° and 180°? If you didn't look for such glasses and try it). This is in contrast to vectors which become their negative when rotated by 180°, and it is only after a 360° rotation that they return to their original state. Hence, polarization cannot be described by a vector (for the curious: you actually can, though not in real space but in the Poincaré sphere instead. More about it here).
- ✓ Finite angle rotations - Rotations are another example of a mathematical entity which seems to be describable as a vector. The direction is the axis of the rotation while the magnitude is the angle of rotation. However, it turns out (literally) that rotations are not commutative. That is, if you rotate by one rotation, and then by another, you do not end up in the same state as you would if you interchanged the order of the rotations. This is evident from the drawing below.

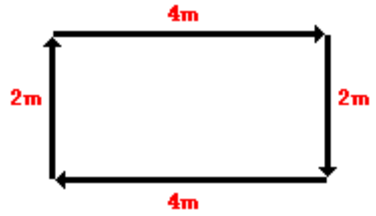


Rotations are not commutative and therefore cannot be described by vectors: Rotating around axis 1 by π/2 (i.e., 90°) and then around axis 2, is not the same as the net rotation obtained when first rotating around axis 2 and then around axis 1.

Kinematics

Distance and Displacement

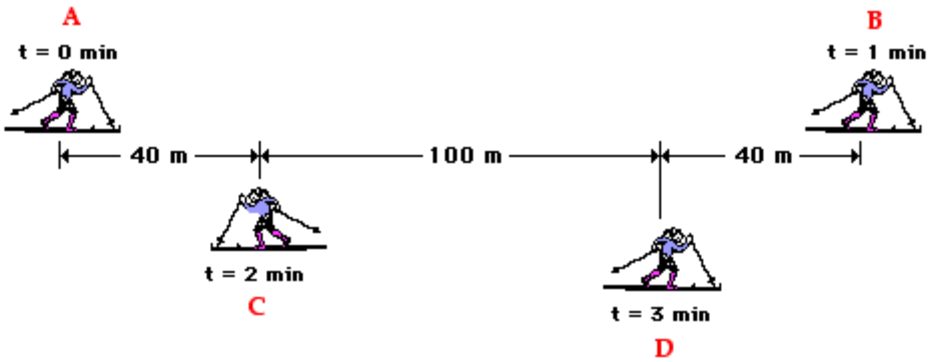
Distance and displacement are two quantities that may seem to mean the same thing yet have distinctly different definitions and meanings.
Distance is a scalar quantity that refers to "how much ground an object has covered" during its motion.
Displacement is a vector quantity that refers to "how far out of place an object is"; it is the object's overall change in position.
To test your understanding of this distinction, consider the motion depicted in the diagram below. A physics teacher walks 4 meters East, 2 meters South, 4 meters West, and finally 2 meters North.



Even though the physics teacher has walked a total distance of 12 meters, her displacement is 0 meters. During the course of her motion, she has "covered 12 meters of ground" (distance = 12 m). Yet when she is finished walking, she is not "out of place" - i.e., there is no displacement for her motion (displacement = 0 m). Displacement, being a vector quantity, must give attention to direction. The 4 meters east *cancels* the 4 meters west; and the 2

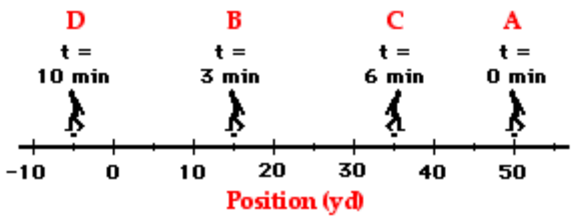
meters south *cancels* the 2 meters north. Vector quantities such as displacement are *direction aware*. Scalar quantities such as distance are ignorant of direction. In determining the overall distance traveled by the physics teachers, the various directions of motion can be ignored.
Now consider another example. The diagram below shows the position of a cross-country skier at various times. At each of the indicated times, the skier turns around and reverses the direction of travel. In other words, the skier moves from A to B to C to D.

Quick Quiz Use the diagram to determine the resulting displacement and the distance traveled by the skier during these three minutes. Then click the button to see the answer.



As a final example, consider a football coach pacing back and forth along the sidelines. The diagram below shows several of coach's positions at various times. At each marked position, the coach makes a "U-turn" and moves in the opposite direction. In other words, the coach moves from position A to B to C to D.

Quick Quiz What is the coach's resulting displacement and distance of travel? Click the button to see the answer.



To understand the distinction between distance and displacement, you must know the definitions. You must also know that a vector quantity such as displacement is *direction-aware* and a scalar quantity such as distance is *ignorant of direction*. When an object changes its direction of motion, displacement takes this direction change into account; heading the opposite direction effectively begins to *cancel* whatever displacement there once was.

Speed and Velocity

Just as distance and displacement have distinctly different meanings (despite their similarities), so do speed and velocity. Speed is a scalar quantity that refers to "how fast an object is moving." Speed can be thought of as the rate at which an object covers distance. A fast-moving object has a high speed and covers a relatively large distance in a short amount of time. Contrast this to a slow-moving object that has a low speed; it covers a relatively small amount of distance in the same amount of time. An object with no movement at all has a zero speed.

Velocity as a Vector Quantity

Velocity is a vector quantity that refers to "the rate at which an object changes its position." Imagine a person moving rapidly - one step forward and one step back - always returning to the original starting position. While this might result in a frenzy of activity, it would result in a zero velocity. Because the person always returns to the original position, the motion would never result in a change in position. Since velocity is defined as the rate at which the position changes, this motion results in zero velocity. If a person in motion wishes to maximize their velocity, then that person must make every effort to maximize the amount that they are displaced from their original position. Every step must go into moving that person further from where he or she started. For certain, the person should never change directions and begin to return to the starting position.

Velocity is a vector quantity. As such, velocity is direction aware. When evaluating the velocity of an object, one must keep track of direction. It would not be enough to say that an object has a velocity of 55 mi/hr. One must include direction information in order to fully describe the velocity of the object. For instance, you must describe an object's velocity as being 55 mi/hr, east. This is one of the essential differences between speed and velocity. Speed is a scalar quantity and does not keep track of direction; velocity is a vector quantity and is direction aware.

Determining the Direction of the Velocity Vector

The task of describing the direction of the velocity vector is easy. The direction of the velocity vector is simply the same as the direction that an object is moving. It would not matter whether the object is speeding up or slowing down. If an object is moving rightwards, then its velocity is described as being rightwards. If an object is moving downwards, then its velocity is described as being downwards. So an airplane moving towards the west with a speed of 300 mi/hr has a velocity of 300 mi/hr, west. Note that speed has no direction (it is a scalar) and the velocity at any instant is simply the speed value with a direction.

Calculating Average Speed and Average Velocity

As an object moves, it often undergoes changes in speed. For example, during an average trip to school, there are many changes in speed. Rather than the speed-o-meter maintaining a steady reading, the needle constantly moves up and down to reflect the stopping and starting and the accelerating and decelerating. One instant, the car may be moving at 50 mi/hr and another instant, it might be stopped (i.e., 0 mi/hr). Yet during the trip to school the person might average 32 mi/hr. The average speed during an entire motion can be thought of as the average of all speedometer readings. If the speedometer readings could be collected at 1-second intervals (or 0.1-second intervals or ...) and then averaged together, the average speed could be determined. Now that would be a lot of work. And fortunately, there is a shortcut. Read on.

The average speed during the course of a motion is often computed using the following formula:

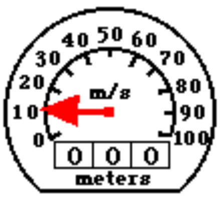
$$\text{Average Speed} = \frac{\text{Distance Traveled}}{\text{Time of Travel}}$$

In contrast, the average velocity is often computed using this formula

$$\text{Average Velocity} = \frac{\Delta\,\text{position}}{\text{time}} = \frac{\text{displacement}}{\text{time}}$$

Let's begin implementing our understanding of these formulas with the following problem:

Average Speed versus Instantaneous Speed



Since a moving object often changes its speed during its motion, it is common to distinguish between the average speed and the instantaneous speed. The distinction is as follows.

Instantaneous Speed - the speed at any given instant in time.

Average Speed - the average of all instantaneous speeds; found simply by a distance/time ratio.

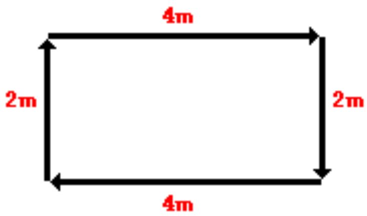
You might think of the instantaneous speed as the speed that the speedometer reads at any given instant in time and the average speed as the average of all the speedometer readings during the course of the trip. Since the task of averaging speedometer readings would be quite complicated (and maybe even dangerous), the average speed is more commonly calculated as the distance/time ratio.

Moving objects don't always travel with erratic and changing speeds. Occasionally, an object will move at a steady rate with a constant speed. That is, the object will cover the same distance every regular interval of time. For instance, a cross-country runner might be running with a constant speed of 6 m/s in a straight line for several minutes. If her speed is constant, then the distance traveled every second is the same. The runner would cover a distance of 6 meters every second. If we could measure her position (distance from an arbitrary starting point) each second, then we would note that the position would be changing by 6 meters each second. This would be in stark contrast to an object that is changing its speed. An object with a changing speed would be moving a different distance each second. The data tables below depict objects with constant and changing speed.

An object moving with a constant speed of 6 m/s	
Time (s)	Position (m)
0	0
1	6
2	12
3	18
4	24

An object moving with a changing speed	
Time (s)	Position (m)
0	0
1	1
2	4
3	9
4	16

Now let's consider the motion of that physics teacher again. The physics teacher walks 4 meters East, 2 meters South, 4 meters West, and finally 2 meters North. The entire motion lasted for 24 seconds. Determine the average speed and the average velocity.



The physics teacher walked a distance of 12 meters in 24 seconds; thus, her average speed was 0.50 m/s. However, since her displacement is 0 meters, her average velocity is 0 m/s. Remember that the displacement refers to the change in position and the velocity is based upon this position change. In this case of the teacher's motion, there is a position change of 0 meters and thus an average velocity of 0 m/s.

Acceleration

An often confused quantity, acceleration has a meaning much different than the meaning associated with it by sports announcers and other individuals. The definition of acceleration is:

Acceleration is a vector quantity that is defined as the rate at which an object changes its velocity. An object is accelerating if it is changing its velocity.

Time	Velocity
0 s	0 m/s, No
1 s	10 m/s, No
2 s	20 m/s, No
3 s	30 m/s, No
4 s	40 m/s, No
5 s	50 m/s, No

Sports announcers will occasionally say that a person is accelerating if he/she is moving fast. Yet acceleration has nothing to do with going fast. A person can be moving very fast and still not be accelerating. Acceleration has to do with changing how fast an object is moving. If an object is not changing its velocity, then the object is not accelerating. The data at the right are representative of a northward-moving accelerating object. The velocity is changing over the course of time. In fact, the velocity is changing by a constant amount - 10 m/s - in each second of time. Anytime an object's velocity is changing, the object is said to be accelerating; it has an acceleration.

The Meaning of Constant Acceleration

Sometimes an accelerating object will change its velocity by the same amount each second. As mentioned in the previous paragraph, the data table above show an object changing its velocity by 10 m/s in each consecutive second. This is referred to as a constant acceleration since the velocity is changing by a constant amount each second. An object with a constant acceleration should not be confused with an object with a constant velocity. Don't be fooled! If an object is changing its velocity -whether by a constant amount or a varying amount - then it is an accelerating object. And an object with a constant velocity is not accelerating. The data tables below depict motions of objects with a constant acceleration and a changing acceleration. Note that each object has a changing velocity.

Accelerating Objects are Changing Their Velocity ...

... by a constant amount each second ...

Time (s)	Velocity (m/s)
0	0
1	4
2	8
3	12
4	16

...in which case, it is referred to as a constant acceleration.

... or by a changing amount each second ...

Time (s)	Velocity (m/s)
0	0
1	1
2	4
3	5
4	7

...in which case, it is referred to as a non-constant acceleration.

Since accelerating objects are constantly changing their velocity, one can say that the distance traveled/time is not a constant value. A falling object for instance usually accelerates as it falls. If we were to observe the motion of a free-falling object (free fall motion will be discussed in detail later), we would observe that the object averages a velocity of approximately 5 m/s in the first second, approximately 15 m/s in the second second, approximately 25 m/s in the third second, approximately 35 m/s in the fourth second, etc. Our free-falling object would be constantly accelerating. Given these average velocity values during each consecutive 1-second time interval, we could say that the object would fall 5 meters in the first second, 15 meters in the second second (for a total distance of 20 meters), 25 meters in the third second (for a total distance of 45 meters), 35 meters in the fourth second (for a total distance of 80 meters after four seconds). These numbers are summarized in the table below.

Time Interval	Velocity Change During Interval	Ave. Velocity During Interval	Distance Traveled During Interval	Total Distance Traveled from 0 s to End of Interval
0 – 1.0 s	0 to ~10 m/s	~5 m/s	~5 m	~5 m
1.0 – 2.0 s	~10 to 20 m/s	~15 m/s	~15 m	~20 m
2.0 – 3.0 s	~20 to 30 m/s	~25 m/s	~25 m	~45 m
3.0 – 4.0 s	~30 to 40 m/s	~35 m/s	~35 m	~80 m

Note: The ~ symbol as used here means approximately.

This discussion illustrates that a free-falling object that is accelerating at a constant rate will cover different distances in each consecutive second. Further analysis of the first and last columns of the data above reveal that there is a square relationship between the total distance traveled and the time of travel for an object starting from rest and moving with a constant acceleration. The total distance traveled is directly proportional to the square of the time. As such, if an object travels for twice the time, it will cover four times (2^2) the distance; the total distance traveled after two seconds is four times the total distance traveled after one second. If an object travels for three times the time, then it will cover nine times (3^2) the distance; the distance traveled after three seconds is nine times the distance traveled after one second. Finally, if an object travels for four times the time, then it will cover 16 times (4^2) the distance; the distance traveled after four seconds is 16 times the distance traveled after one second. For objects with a constant acceleration, the distance of travel is directly proportional to the square of the time of travel.

Calculating the Average Acceleration

The average acceleration (a) of any object over a given interval of time (t) can be calculated using the equation

$$\text{Ave. acceleration} = \frac{\Delta \text{velocity}}{\text{time}} = \frac{v_f - v_i}{t}$$

This equation can be used to calculate the acceleration of the object whose motion is depicted by the velocity-time data table above. The velocity-time data in the table shows that the object has an acceleration of 10 m/s/s. The calculation is shown below.

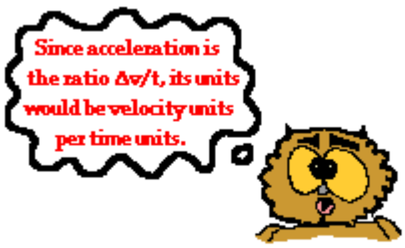
$$a = \frac{v_f - v_i}{t} = \frac{50\text{ m/s} - 0\text{ m/s}}{5\text{ s}} = \frac{10\text{ m/s}}{1\text{ s}}$$

Acceleration values are expressed in units of velocity/time. Typical acceleration units include the following:

m/s/s

mi/hr/s

km/hr/s



m/s2

These units may seem a little awkward to a beginning physics student. Yet they are very reasonable units when you begin to consider the definition and equation for acceleration. The reason for the units becomes obvious upon examination of the acceleration equation.

$$a = \frac{\Delta \text{velocity}}{\text{time}}$$

Since acceleration is a velocity change over a time, the units on acceleration are velocity units divided by time units - thus (m/s)/s or (mi/hr)/s. The (m/s)/s unit can be mathematically simplified to m/s^2.

Circular motion and governing equations

Any moving object can be described using the kinematic concepts. The motion of a moving object can be explained using either Newton's Laws and vector principles or by means of the Work-Energy Theorem. The same concepts and principles used to describe and explain the motion of an object can be used to describe and explain the parabolic motion of a projectile. In this unit, we will see that these same concepts and principles can also be used to describe and explain the motion of objects that either move in circles or can be approximated to be moving in circles. Kinematic concepts and motion principles will be applied to the motion of objects in circles and then extended to analyze the motion of such objects as roller coaster cars, a football player making a circular turn, and a planet orbiting the sun. We will see that the beauty and power of physics lies in the fact that a few simple concepts and principles can be used to explain the mechanics of the entire universe. Lesson 1 of this study will begin with the development of kinematic and dynamic ideas that can be used to describe and explain the motion of objects in circles.

Suppose that you were driving a car with the steering wheel turned in such a manner that your car followed the path of a perfect circle with a constant radius. And suppose that as you drove, your speedometer maintained a constant reading of 10 mi/hr. In such a situation as this, the motion of your car could be described as experiencing uniform circular motion. Uniform circular motion is the motion of an object in a circle with a constant or uniform speed.

Calculation of the Average Speed

Uniform circular motion - circular motion at a constant speed - is one of many forms of circular motion. An object moving in uniform circular motion would cover the same linear distance in each second of time. When moving in a circle, an object traverses a distance around the perimeter of the circle. So if your car were to move in a circle with a constant speed of 5 m/s, then the car would travel 5 meters along the perimeter of the circle in each second of time. The distance of one complete cycle around the perimeter of a circle is known as the circumference. With a uniform speed of 5 m/s, a car could make a complete cycle around a circle that had a circumference of 5 meters. At this uniform speed of 5 m/s, each cycle around the 5-m circumference circle would require 1 second. At 5 m/s, a circle with a circumference of 20 meters could be made in 4 seconds; and at this uniform speed, every cycle around the 20-m circumference of the circle would take the same time period of 4 seconds. This relationship between the circumference of a circle, the time to complete one cycle around the circle, and the speed of the object is merely an extension of the average speed equation.

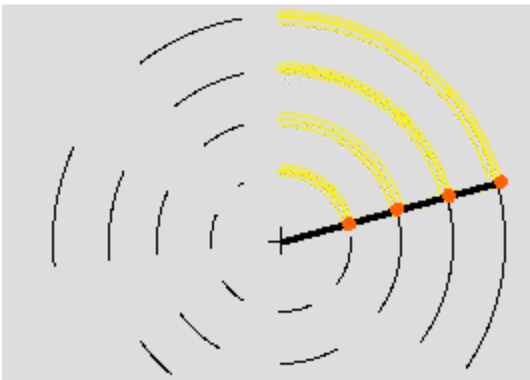
$$\text{Average Speed} = \frac{\text{distance}}{\text{time}} = \frac{\text{circumference}}{\text{time}}$$

The circumference of any circle can be computed using from the radius according to the equation

Circumference = 2*pi*Radius

Combining these two equations above will lead to a new equation relating the speed of an object moving in uniform circular motion to the radius of the circle and the time to make one cycle around the circle (period).

$$\text{Average Speed} = \frac{2 \cdot \pi \cdot R}{T}$$

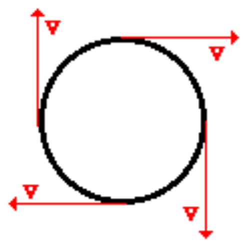


Each bulb on the wire moves around the perimeter of the circle in the same amount of time; but the larger the radius of the circle, the greater the speed.

where R represents the radius of the circle and T represents the period. This equation, like all equations, can be used as an algebraic recipe for problem solving. It also can be used to guide our thinking about the variables in the equation relate to each other. For instance, the equation suggests that for objects moving around circles of different radius in the same period, the object traversing the circle of larger radius must be traveling with the greatest speed. In fact, the average speed and the radius of the circle are directly proportional. A twofold increase in radius corresponds to a twofold increase in speed; a threefold increase in radius corresponds to a three--fold increase in speed; and so on. To illustrate, consider a strand of four LED lights positioned at various locations along the strand. The strand is held at one end and spun rapidly in a circle. Each LED light traverses a circle of different radius. Yet since they are connected to the same wire, their period of rotation is the same. Subsequently, the LEDs that are further from the center of the circle are traveling faster in order to sweep out the circumference of the larger circle in the same amount of time. If the room lights are turned off, the LEDs created an arc that could be perceived to be longer for those LEDs that were traveling faster - the LEDs with the greatest radius. This is illustrated in the diagram at the right.

The Direction of the Velocity Vector

Objects moving in uniform circular motion will have a constant speed. But does this mean that they will have a constant velocity? Recall from Scalar and Vectors that speed and velocity refer to two distinctly different quantities. Speed is a scalar quantity and velocity is a vector quantity. Velocity, being a vector, has both a magnitude and a direction. The magnitude of the velocity vector is the instantaneous speed of the object. The direction of the velocity vector is directed in the same direction that the object moves. Since an object is moving in a circle, its direction is continuously changing. At one moment, the object is moving northward such that the velocity vector is directed northward. One quarter of a cycle later, the object would be moving eastward such that the velocity vector is directed eastward. As the object rounds the circle, the direction of the velocity vector is different than it was the instant before. So while the magnitude of the velocity vector may be constant, the direction of the velocity vector is changing. The best word that can be used to describe the direction of the velocity vector is the word tangential. The direction of the velocity vector at any instant is in the direction of a tangent line drawn to the circle at the object's location. (A tangent line is a line that touches a circle at one point but does not intersect it.) The diagram at the right shows the direction of the velocity vector at four different points for an object moving in a clockwise direction around a circle. While the actual direction of the object (and thus, of the velocity vector) is changing, its direction is always tangent to the circle.



The direction of the velocity vector at every instant is in a direction tangent to the circle.

To summarize, an object moving in uniform circular motion is moving around the perimeter of the circle with a constant speed. While the speed of the object is constant, its velocity is changing. Velocity, being a vector, has a constant magnitude but a changing direction. The direction is always directed tangent to the circle and as the object turns the circle, the tangent line is always pointing in a new direction.

Acceleration

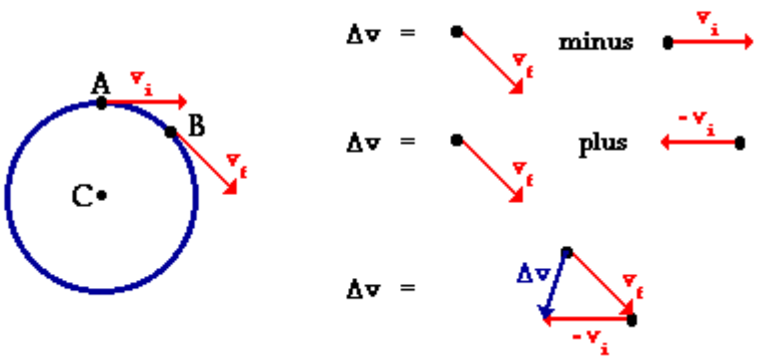
As mentioned earlier, an object moving in uniform circular motion is moving in a circle with a uniform or constant speed. The velocity vector is constant in magnitude but changing in direction. Because the speed is constant for such a motion, many students have the misconception that there is no acceleration. "After all," they might say, "if I were driving a car in a circle at a constant speed of 20 mi/hr, then the speed is neither decreasing nor increasing; therefore there must not be an acceleration." At the center of this common student misconception is the wrong belief that acceleration has to do with speed and not with velocity. But the fact is that an accelerating object is an object that is changing its velocity. And since velocity is a vector that has both magnitude and direction, a change in either the magnitude or the direction constitutes a change in the velocity. For this reason, it can be safely concluded that an object moving in a circle at constant speed is indeed accelerating. It is accelerating because the direction of the velocity vector is changing.

Geometric Proof of Inward Acceleration

To understand this at a deeper level, we will have to combine the definition of acceleration with a review of some basic vector principles. Recall from earlier that acceleration as a quantity was defined as the rate at which the velocity of an object changes. As such, it is calculated using the following equation:

$$\text{Ave. acceleration} = \frac{\Delta\text{velocity}}{\text{time}} = \frac{v_f - v_i}{t}$$

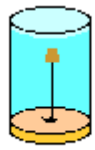
where v_i represents the initial velocity and v_f represents the final velocity after some time of t. The numerator of the equation is found by subtracting one vector (v_i) from a second vector (v_f). But the addition and subtraction of vectors from each other is done in a manner much different than the addition and subtraction of scalar quantities. Consider the case of an object moving in a circle about point C as shown in the diagram below. In a time of t seconds, the object has moved from point A to point B. In this time, the velocity has changed from v_i to v_f. The process of subtracting v_i from v_f is shown in the vector diagram; this process yields the change in velocity.



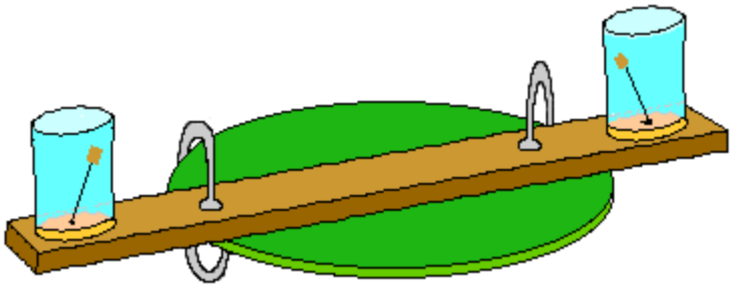
Direction of the Acceleration Vector

Note in the diagram above that there is a velocity change for an object moving in a circle with a constant speed. A careful inspection of the velocity change vector in the above diagram shows that it points down and to the left. At the midpoint along the arc connecting points A and B, the velocity change is directed towards point C - the center of the circle. The acceleration of the object is dependent upon this velocity change and is in the same direction as this velocity change. The acceleration of the object is in the same direction as the velocity change vector; the acceleration is directed towards point C as well - the center of the circle. Objects moving in circles at a constant speed accelerate towards the center of the circle.

The acceleration of an object is often measured using a device known as an accelerometer. A simple accelerometer consists of an object immersed in a fluid such as water. Consider a sealed jar that is filled with water. A cork attached to the lid by a string can serve as an accelerometer. To test the direction of acceleration for an object moving in a circle, the jar can be inverted and attached to the end of a short section of a wooden 2x4. A second accelerometer constructed in the same manner can be attached to the opposite end of the 2x4. If the 2x4 and accelerometers are clamped to a rotating platform and spun in a circle, the direction of the acceleration can be clearly seen by the direction of lean of the corks. As the cork-water combination spins in a circle, the cork leans towards the center of the circle. The least massive of the two objects always leans in the direction of the acceleration. In the case of the cork and the water, the cork is less massive (on a per mL basis) and thus it experiences the greater acceleration. Having less inertia (owing to its smaller mass on a per mL basis), the cork resists the acceleration the least and thus leans to the inside of the jar towards the center of the circle. This is observable evidence that an object moving in circular motion at constant speed experiences an acceleration that is directed towards the center of the circle.



Cork Accelerometer



The cork of a water accelerometer points inward towards the center of the circle when placed upon a rotating platform, thus indicating an inward acceleration for circular motion.

Another simple homemade accelerometer involves a lit candle centered vertically in the middle of an open-air glass. If the glass is held level and at rest (such that there is no acceleration), then the candle flame extends in an upward direction. However, if you hold the glass-candle system with an outstretched arm and spin in a circle at a constant rate (such that the flame experiences an acceleration), then the candle flame will no longer extend vertically upwards. Instead the flame deflects from its upright position. This signifies that there is an acceleration when the flame moves in a circular path at constant speed. The deflection of the flame will be in the direction of the acceleration. This can be explained by asserting that the hot gases of the flame are less massive (on a per mL basis) and thus have less inertia than the cooler gases that surround it. Subsequently, the hotter and lighter gases of the flame experience the greater acceleration and will lean in the direction of the acceleration. A careful examination of the flame reveals that the flame will point towards the center of the circle, thus indicating that not only is there an acceleration; but that there is an inward acceleration. This is one more piece of observable evidence that indicates that objects moving in a circle at a constant speed experience an acceleration that is directed towards the center of the circle.

So thus far, we have seen a geometric proof and two real-world demonstrations of this inward acceleration. At this point it becomes the decision of the student to believe or to not believe. Is it sensible that an object moving in a circle experiences an acceleration that is directed towards the center of the circle? Can you think of a logical reason to believe in say no acceleration or even an outward acceleration experienced by an object moving in uniform circular motion?

The Centripetal Force Requirement

As mentioned earlier in this lesson, an object moving in a circle is experiencing an acceleration. Even if moving around the perimeter of the circle with a constant speed, there is still a change in velocity and subsequently an acceleration. This acceleration is directed towards the center of the circle. And in accord with Newton's second law of motion, an object which experiences an acceleration must also be experiencing a net force. The direction of the net force is in the same direction as the acceleration. So for an object moving in a circle, there must be an inward force acting upon it in order to cause its inward acceleration. This is sometimes referred to as the centripetal force requirement. The word centripetal (not to be confused with the F-word centrifugal) means center seeking. For object's moving in circular motion, there is a net force acting towards the center which causes the object to seek the center.

To understand the importance of a centripetal force, it is important to have a sturdy understanding of the Newton's first law of motion - the law of inertia. The law of inertia states that ...

....objects in motion tend to stay in motion with the same speed and the same direction unless acted upon by an unbalanced force.

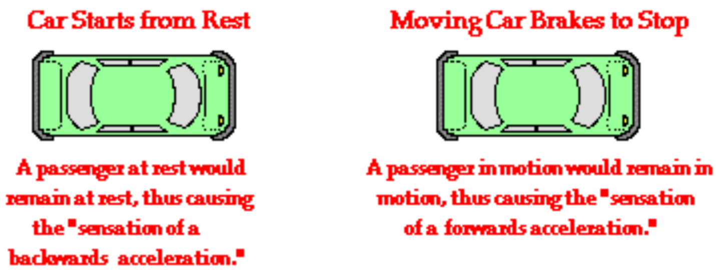
According to Newton's first law of motion, it is the natural tendency of all moving objects to continue in motion in the same direction that they are moving ... unless some form of unbalanced force acts upon the object to deviate its motion from its straight-line path. Moving objects will tend to naturally travel in straight lines; an unbalanced force is only required to cause it to turn. Thus, the presence of an unbalanced force is required for objects to move in circles.

Inertia, Force and Acceleration for an Automobile Passenger

The idea expressed by Newton's law of inertia should not be surprising to us. We experience this phenomenon of inertia nearly everyday when we drive our automobile. For example, imagine that you are a passenger in a car at a traffic light. The light turns green and the driver accelerates from rest. The car begins to accelerate forward, yet relative to the seat which you are on your body begins to lean backwards. Your body being at rest tends to stay at rest. This is one aspect of the law of inertia - "objects at rest tend to stay at rest." As the wheels of the car spin to generate a forward force upon the car and cause a forward acceleration, your body tends to stay in place. It certainly might seem to you as though your body were experiencing a backwards force causing it to accelerate backwards. Yet you would have a difficult time identifying such a backwards force on your body. Indeed there isn't one. The feeling of being thrown backwards is merely the tendency of your body to resist the acceleration and to remain in its state of rest. The car is accelerating out from under your body, leaving you with the false feeling of being pushed backwards.

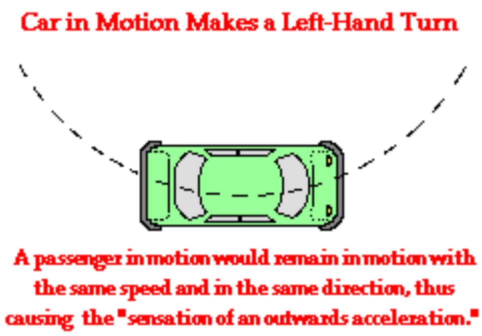
Now imagine that you are in the same car moving along at a constant speed approaching a stoplight. The driver applies the brakes, the wheels of the car lock, and the car begins to skid to a stop. There is a backwards force upon the forward moving car and subsequently a backwards acceleration on the car. However, your body, being in motion, tends to continue in motion while the car is skidding to a stop. It certainly might seem to you as though your body were experiencing a forwards force causing it to accelerate forwards. Yet you would once more have a difficult time identifying such a forwards force on your body. Indeed there is no physical object accelerating you forwards. The feeling of being thrown forwards is merely the tendency of your body to resist the deceleration and to remain in its state of forward motion. This is the second aspect of Newton's law of inertia - "an object in motion tends to stay in motion with the same speed and in the same direction... ." The unbalanced force acting upon the car causes the car to slow down while your body continues in its forward motion. You are once more left with the false feeling of being pushed in a direction which is opposite your acceleration.

These two driving scenarios are summarized by the following graphic.



In each case - the car starting from rest and the moving car braking to a stop - the direction which the passengers lean is opposite the direction of the acceleration. This is merely the result of the passenger's inertia - the tendency to resist acceleration. The passenger's lean is not an acceleration in itself but rather the tendency to maintain the state of motion while the car does the acceleration. The tendency of a passenger's body to maintain its state of rest or motion while the surroundings (the car) accelerate is often misconstrued as an acceleration. This becomes particularly problematic when we consider the third possible inertia experience of a passenger in a moving automobile - the left hand turn.

Suppose that on the next part of your travels the driver of the car makes a sharp turn to the left at constant speed. During the turn, the car travels in a circular-type path. That is, the car sweeps out one-quarter of a circle. The friction force acting upon the turned wheels of the car causes an unbalanced force upon the car and a



subsequent acceleration. The unbalanced force and the acceleration are both directed towards the center of the circle about which the car is turning. Your body however is in motion and tends to stay in motion. It is the inertia of your body - the tendency to resist acceleration - that causes it to continue in its forward motion. While the car is accelerating inward, you continue in a straight line. If you are sitting on the passenger side of the car, then eventually the outside door of the car will hit you as the car turns inward. This phenomenon might cause you to think that you are being accelerated outwards away from the center of the circle. In reality, you are continuing in your straight-line inertial path tangent to the circle while the car is accelerating out from under you. The sensation of an outward force and an outward acceleration is a false sensation. There is no physical object capable of pushing you outwards. You are merely experiencing the tendency of your body to continue in its path tangent to the circular path along which the car is turning. You are once more left with the false feeling of being pushed in a direction that is opposite your acceleration.

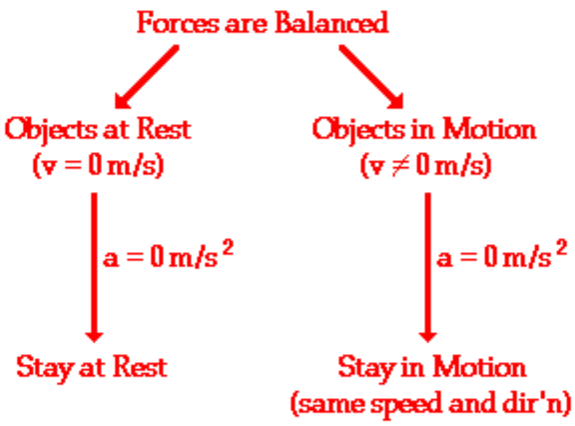
Laws of Forces

Newton's First Law

Newton's first law of motion is often stated as
An object at rest stays at rest and an object in motion stays in motion with the same speed and in the same direction unless acted upon by an unbalanced force.

Two Clauses and a Condition

There are two clauses or parts to this statement - one that predicts the behavior of stationary objects and the other that predicts the behavior of moving objects. The two parts are summarized in the following diagram.



The behavior of all objects can be described by saying that objects tend to "keep on doing what they're doing" (unless acted upon by an unbalanced force). If at rest, they will continue in this same state of rest. If in motion with an eastward velocity of 5 m/s, they will continue in this same state of motion (5 m/s, East). If in motion with a leftward velocity of 2 m/s, they will continue in this same state of motion (2 m/s, left). The state of motion of an object is maintained as long as the object is not acted upon by an unbalanced force. All objects resist changes in their state of motion - they tend to "keep on doing what they're doing."

There is an important condition that must be met in order for the first law to be applicable to any given motion. The condition is described by the phrase "... unless acted upon by an unbalanced force." As the long as the forces are not unbalanced - that is, as long as the forces are balanced - the first law of motion applies. This concept of a balanced versus and unbalanced force will be discussed in more detail later.

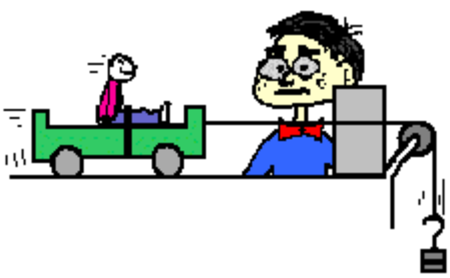
Suppose that you filled a baking dish to the rim with water and walked around an oval track making an attempt to complete a lap in the least amount of time. The water would have a tendency to spill from the container during specific locations on the track. In general the water spilled when:

- ✓ the container was at rest and you attempted to move it
- ✓ the container was in motion and you attempted to stop it
- ✓ the container was moving in one direction and you attempted to change its direction.

The water spills whenever the state of motion of the container is changed. The water resisted this change in its own state of motion. The water tended to "keep on doing what it was doing." The container was moved from rest to a high speed at the starting line; the water remained at rest and spilled onto the table. The container was stopped near the finish line; the water kept moving and spilled over container's leading edge. The container was forced to move in a different direction to make it around a curve; the water kept moving in the same direction and spilled over its edge. The behavior of the water during the lap around the track can be explained by Newton's first law of motion.

Everyday Applications of Newton's First Law

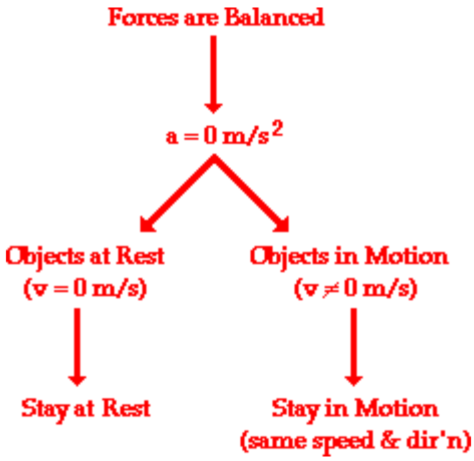
There are many applications of Newton's first law of motion. Consider some of your experiences in an automobile. Have you ever observed the behavior of coffee in a coffee cup filled to the rim while starting a car from rest or while bringing a car to rest from a state of motion? Coffee "keeps on doing what it is doing." When you accelerate a car from rest, the road provides an unbalanced force on the spinning wheels to push the car forward; yet the coffee (that was at rest) wants to stay at rest. While the car accelerates forward, the coffee remains in the same position; subsequently, the car accelerates out from under the coffee and the coffee spills in your lap. On the other hand, when braking from a state of motion the coffee continues forward with the same speed and in the same direction, ultimately hitting the windshield or the dash. Coffee in motion stays in motion.



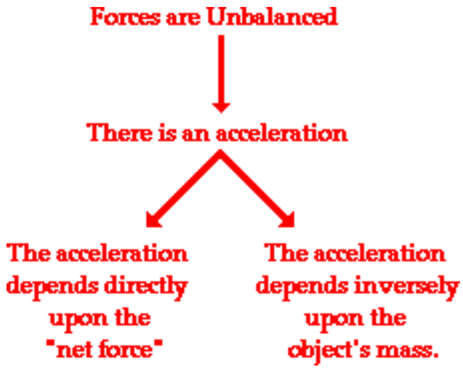
Have you ever experienced inertia (resisting changes in your state of motion) in an automobile while it is braking to a stop? The force of the road on the locked wheels provides the unbalanced force to change the car's state of motion, yet there is no unbalanced force to change your own state of motion. Thus, you continue in motion, sliding along the seat in forward motion. A person in motion stays in motion with the same speed and in the same direction ... unless acted upon by the unbalanced force of a seat belt. Yes! Seat belts are used to provide safety for passengers whose motion is governed by Newton's laws. The seat belt provides the unbalanced force that brings you from a state of motion to a state of rest. Perhaps you could speculate what would occur when no seat belt is used.

Newton's Second Law

Newton's first law of motion predicts the behavior of objects for which all existing forces are balanced. The first law - sometimes referred to as the law of inertia - states that if the forces acting upon an object are balanced, then the acceleration of that object will be 0 m/s/s. Objects at equilibrium (the condition in which all forces balance) will not accelerate. According to Newton, an object will only accelerate if there is a net or unbalanced force acting upon it. The presence of an unbalanced force will accelerate an object - changing its speed, its direction, or both its speed and direction.



Newton's second law of motion pertains to the behavior of objects for which all existing forces are not balanced. The second law states that the acceleration of an object is dependent upon two variables - the net force acting upon the object and the mass of the object. The acceleration of an object depends directly upon the net force acting upon the object, and inversely upon the mass of the object. As the force acting upon an object is increased, the acceleration of the object is increased. As the mass of an object is increased, the acceleration of the object is decreased.



The BIG Equation

Newton's second law of motion can be formally stated as follows:
The acceleration of an object as produced by a net force is directly proportional to the magnitude of the net force, in the same direction as the net force, and inversely proportional to the mass of the object.
This verbal statement can be expressed in equation form as follows:

$$a = F_{net} / m$$

The above equation is often rearranged to a more familiar form as shown below. The net force is equated to the product of the mass times the acceleration.

$$F_{net} = m \bullet a$$

In this entire discussion, the emphasis has been on the *net force*. The acceleration is directly proportional to the *net force*; the *net force* equals mass times acceleration; the acceleration in the same direction as the *net force*; an acceleration is produced by a *net force*. The NET FORCE. It is important to remember this distinction. Do not use the value of merely "any 'ole force" in the above equation. It is the net force that is related to acceleration. As discussed in an earlier lesson, the net force is the vector sum of all the forces. If all the individual forces acting upon an object are known, then the net force can be determined.

Consistent with the above equation, a unit of force is equal to a unit of mass times a unit of acceleration. By substituting standard metric units for force, mass, and acceleration into the above equation, the following unit equivalency can be written.

$$1 \text{ Newton} = 1 \text{ kg} \bullet \text{m/s}^2$$

The definition of the standard metric unit of force is stated by the above equation. One Newton is defined as the amount of force required to give a 1-kg mass an acceleration of 1 m/s/s.

Newton's Third Law

A force is a push or a pull that acts upon an object as a results of its interaction with another object. Forces result from interactions! As discussed earlier, some forces result from *contact interactions* (normal, frictional, tensional, and applied forces are examples of contact forces) and other forces are the result of action-at-a-distance interactions (gravitational, electrical, and magnetic forces). According to Newton, whenever objects A and B interact with each other, they exert forces upon each other. When you sit in your chair, your body exerts a downward force on the chair and the chair exerts an upward force on your body. There are two forces resulting from this interaction - a force on the chair and a force on your body. These two forces are called *action* and *reaction* forces and are the subject of Newton's third law of motion. Formally stated, Newton's third law is:

For every action, there is an equal and opposite reaction.

The statement means that in every interaction, there is a pair of forces acting on the two interacting objects. The size of the forces on the first object equals the size of the force on the second object. The direction of the force on the first object is opposite to the direction of the force on the second object. Forces always come in pairs - equal and opposite action-reaction force pairs.

Examples of Interaction Force Pairs

A variety of action-reaction force pairs are evident in nature. Consider the propulsion of a fish through the water. A fish uses its fins to push water backwards. But a push on the water will only serve to accelerate the water. Since forces result from mutual interactions, the water must also be pushing the fish forwards, propelling the fish through the water. The size of the force on the water equals the size of the force on the fish; the direction of the force on the water (backwards) is opposite the direction of the force on the fish (forwards). For every action, there is an equal (in size) and opposite (in direction) reaction force. Action-reaction force pairs make it possible for fish to swim.

Consider the flying motion of birds. A bird flies by use of its wings. The wings of a bird push air downwards. Since forces result from mutual interactions, the air must also be pushing the bird upwards. The size of the force on the air equals the size of the force on the bird; the direction of the force on the air (downwards) is opposite the direction of the force on the bird (upwards). For every action, there is an equal (in size) and opposite (in direction) reaction. Action-reaction force pairs make it possible for birds to fly.

Consider the motion of a car on the way to school. A car is equipped with wheels that spin. As the wheels spin, they grip the road and push the road backwards. Since forces result from mutual interactions, the road must also be pushing the wheels forward. The size of the force on the road equals the size of the force on the wheels (or car); the direction of the force on the road (backwards) is opposite the direction of the force on the wheels (forwards). For every action, there is an equal (in size) and opposite (in direction) reaction. Action-reaction force pairs make it possible for cars to move along a roadway surface.

Energy

The simplest definition of energy is "the ability to do work". Energy is how things change and move. It's everywhere around us and takes all sorts of forms. It takes energy to cook food, to drive to school, and to jump in the air.

Different forms of Energy

- ✓ Energy can take a number of different forms. Here are some examples:

- ✓ Chemical - Chemical energy comes from atoms and molecules and how they interact.
- ✓ Electrical - Electrical energy is generated by the movement of electrons.
- ✓ Gravitational - Large objects such as the Earth and the Sun create gravity and gravitational energy.
- ✓ Heat - Heat energy is also called thermal energy. It comes from molecules of different temperatures interacting.
- ✓ Light - Light is called radiant energy. The Earth gets a lot of its energy from the light of the Sun.
- ✓ Motion - Anything that is moving has energy. This is also called kinetic energy.
- ✓ Nuclear - Huge amounts of nuclear energy can be generated by splitting atoms.
- ✓ Potential - Potential energy is energy that is stored. One example of this is a spring that is pressed all the way down. Another example is a book sitting high on a shelf.

Units of Measure for Energy

In physics, the standard unit of measure for energy is the joule which is abbreviated as J. There are other units of measure for energy that are used throughout the world including kilowatt-hours, calories, newton-meters, therms, and foot-pounds.

Law of Conservation of Energy

This law states that energy is never created or destroyed, it is only changed from one state to another. One example is the chemical energy in food that we turn into kinetic energy when we move.

Renewable and Nonrenewable

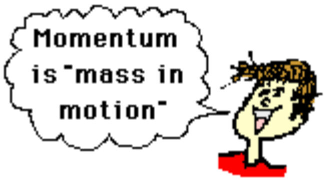
As humans we use a lot of energy to drive our cars, heat and cool our houses, watch TV, and more. This energy comes from a variety of places and in a number of forms. Conservationists classify the energy we use into two types: renewable and nonrenewable. Nonrenewable energy uses up resources that we cannot recreate. Some examples of this are gas to run our car and coal burned in power plants. Once they are used, they are gone forever. A renewable energy source is one that can be replenished. Examples of this include hydropower from turbines in a dam, wind power from windmills, and solar power from the sun. The more renewable power we use the better for our planet and for future generations as they won't run out of resources someday.

Fun Facts about Energy

- ✓ In 2008 about 7% of the energy used in the United States was from renewable sources.
- ✓ A modern windmill or turbine can generate enough electricity to power around 300 homes.
- ✓ People have used waterpower to grind grain for over 2,000 years. Geothermal power uses energy from geysers, hot springs, and volcanoes.
- ✓ The entire world could be powered for a year from the energy from the sun that falls on the Earth's surface in one hour. We just need to figure out how to harness it!

Momentum

Momentum is a commonly used term in sports. A team that has the momentum is on *the move* and is going to take some effort to stop. A team that has a lot of momentum is really *on the move* and is going to be *hard to stop*. Momentum is a physics term; it refers to the quantity of motion that an object has. A sports team that is *on the move* has the momentum. If an object is in motion (*on the move*) then it has momentum.



Momentum can be defined as "mass in motion." All objects have mass; so if an object is moving, then it has momentum - it has its mass in motion. The amount of momentum that an object has is dependent upon two variables: how much *stuff* is moving and how fast the *stuff* is moving. Momentum depends upon the variables mass and velocity. In terms of an equation, the momentum of an object is equal to the mass of the object times the velocity of the object.

Momentum = mass • velocity

In physics, the symbol for the quantity momentum is the lower case **p**. Thus, the above equation can be rewritten as

$$p = m \bullet v$$

where **m** is the mass and **v** is the velocity. The equation illustrates that momentum is directly proportional to an object's mass and directly proportional to the object's velocity.
The units for momentum would be mass units times velocity units. The standard metric unit of momentum is the kg•m/s. While the kg•m/s is the standard metric unit of momentum, there are a variety of other units that are acceptable (though not conventional) units of momentum. Examples include kg•mi/hr, kg•km/hr, and g•cm/s. In each of these examples, a mass unit is multiplied by a velocity unit to provide a momentum unit. This is consistent with the equation for momentum.

Impulse

These concepts are merely an outgrowth of Newton's second law as discussed in an earlier unit. Newton's second law ($F_{net} = m \bullet a$) stated that the acceleration of an object is directly proportional to the net force acting upon the object and inversely proportional to the mass of the object. When combined with the definition of acceleration (a = change in velocity / time), the following equalities result.

$$F = m \bullet a$$

or

$$F = m \bullet \Delta v / t$$

If both sides of the above equation are multiplied by the quantity t, a new equation results.

$$F \bullet t = m \bullet \Delta v$$

This equation represents one of two primary principles to be used in the analysis of collisions during this unit. To truly understand the equation, it is important to understand its meaning in words. In words, it could be said that the force times the time equals the mass times the change in velocity. In physics, the quantity Force • time is known as **impulse**. And since the quantity m•v is the momentum, the quantity m•Δv must be the **change in momentum**. The equation really says that the

Impulse = Change in momentum

One focus of this unit is to understand the physics of collisions. The physics of collisions are governed by the laws of momentum; and the first law that we discuss in this unit is expressed in the above equation. The equation is known as the impulse-momentum change equation. The law can be expressed this way:

In a collision, an object experiences a force for a specific amount of time that results in a change in momentum. The result of the force acting for the given amount of time is that the object's mass either speeds up or slows down (or changes direction). The impulse experienced by the object equals the change in momentum of the object. In equation form, F • t = m • Δ v.

In a collision, objects experience an impulse; the impulse causes and is equal to the change in momentum. Consider a football halfback running down the football field and encountering a collision with a defensive back. The collision would change the halfback's speed and thus his momentum. If the motion was represented by a ticker tape diagram, it might appear as follows:

At approximately the tenth dot on the diagram, the collision occurs and lasts for a certain amount of time; in terms of dots, the collision lasts for a time equivalent to approximately *nine dots*. In the halfback-defensive back collision, the halfback experiences a force that lasts for a certain amount of time to change his momentum. Since the collision causes the rightward-moving halfback to slow down, the force on the halfback must have been directed leftward. If the halfback experienced a force of 800 N for 0.9 seconds, then we could say that the impulse was 720 N•s. This impulse would cause a momentum change of 720 kg•m/s. In a collision, the impulse experienced by an object is always equal to the momentum change.

Waves

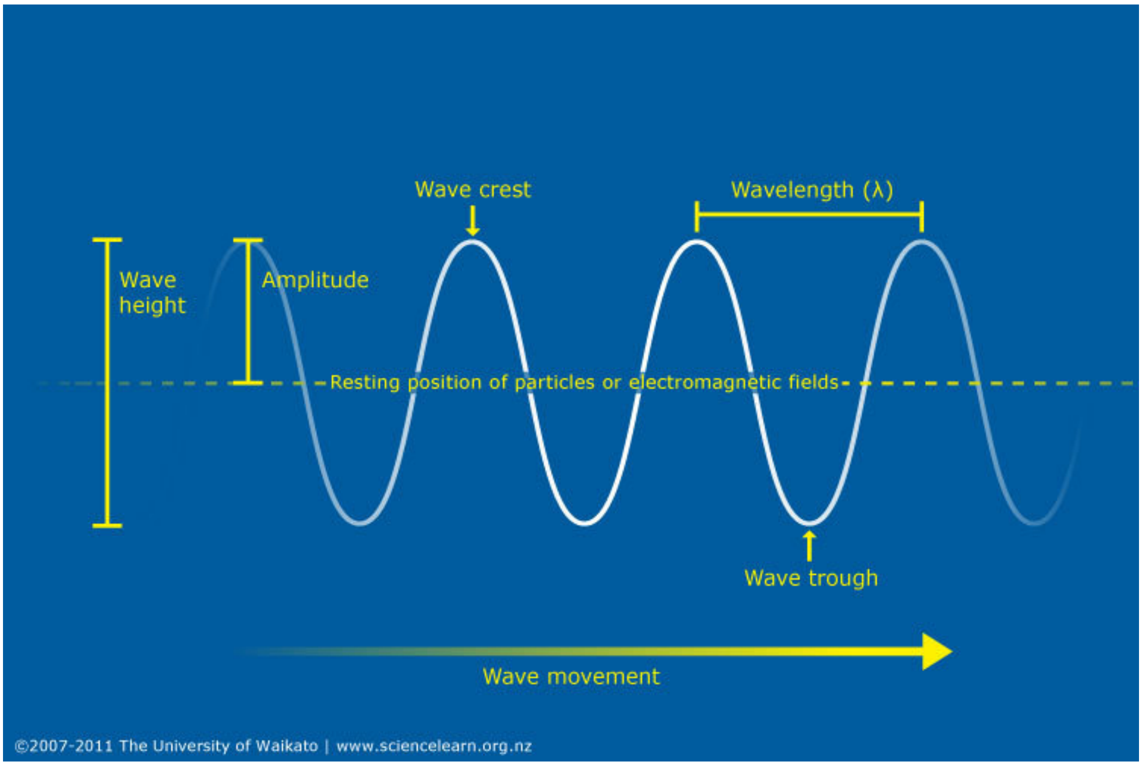
Seeing, hearing, feeling warmth, surfing, tuning the radio, using a cellphone – these and many more activities involve waves. But what is a wave? In this article, we get to grips with the different kinds of waves and look at the key characteristics of all waves – their wavelength, period, frequency, speed and amplitude. These concepts are important for describing waves of all kinds.

Different waves, same properties

Water waves are the focus of our Tsunamis and surf resources, but many other kinds of wave exist. These include sound waves, light waves, radio waves, microwaves and others. All kinds of waves have the same fundamental properties of reflection, refraction, diffraction and interference, and all waves have a wavelength, frequency, speed and amplitude.

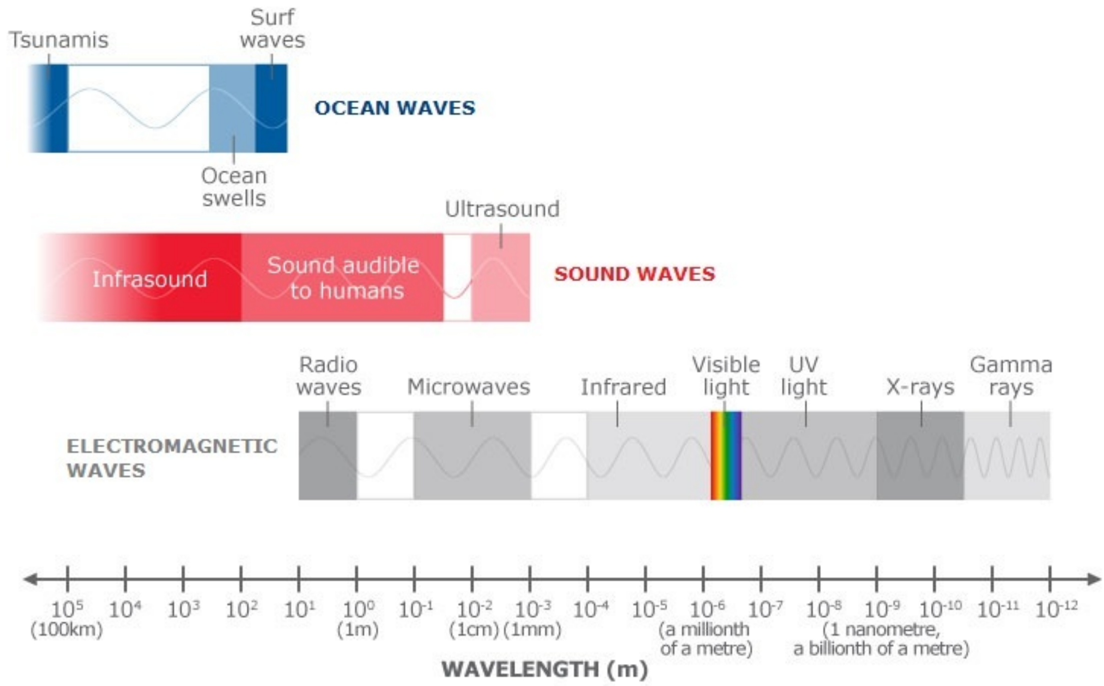
All waves can be thought of as a disturbance that transfers energy.

Some waves (water waves and sound waves) are formed through the vibration of particles. Waves form because water molecules are disturbed, and sound waves are formed by the disturbance of air particles or particles in an object through which sound is travelling, like a door.
Electromagnetic waves (such as light waves, UV radiation, microwaves and others) are formed through oscillating electric and magnetic fields.



Waves have a defined wavelength

Every wave has a specific wavelength. This is defined as the length from one wave crest to the next.
Different kinds of waves have widely varying wavelengths. In water, surf waves have wavelengths of 30–50 m, and tsunamis have much longer wavelengths (about 100km). Sound waves vary in wavelength according to the pitch of the sound – humans can hear sound with wavelengths between 70 mm and 70 m. Different kinds of electromagnetic waves vary greatly in wavelength, from the long wavelength of radio waves (about 10 m) to the much shorter wavelengths of visible light (less than a millionth of a metre – usually described as hundreds of nanometres) and X-rays (less than a billionth of a metre).



Waves have a defined frequency

As well as a defined speed, every wave has a frequency. This is the number of wavelengths that travel past a point in 1 second of time. Frequency is measured in hertz (waves per second). For each type of wave, a longer wavelength means a lower frequency – for electromagnetic waves, for example, microwaves have a much lower frequency than UV waves.

Waves also have a defined period. This is the time it takes for the wave to undergo one complete oscillation or one complete motion. The wave period is inversely proportional to the frequency – the longer the period, the lower the frequency.

Wave speed is related to frequency and wavelength

Every wave travels at a particular speed. Water waves are unusual because waves can have different speeds – wave speed depends on how the wave is formed, which is why tsunamis travel much faster than surf waves. Unlike water waves, electromagnetic waves always travel at the same speed (3 hundred million metres per second) and sound waves all travel at the same speed in a given medium (for example, approximately 340 metres per second in air).

The speed of a wave is related to both its frequency and wavelength. The equation $v = f \times \lambda$ (speed = frequency x wavelength) describes this relationship and is useful for predicting the unknown characteristics of a wave.

For waves that always travel at the same speed (like electromagnetic waves), the equation can be used to work out the frequency or wavelength. High-frequency EM waves will have a short wavelength, and low-frequency waves will have longer wavelengths. For waves with a variable speed (such as water waves), the equation can be used to work out the speed from the frequency and wavelength.

All waves have an amplitude

The amplitude of a wave is normally defined as the maximum displacement of the particles within the wave from their normal equilibrium positions. For water waves, the amplitude of a wave is the distance between the wave crest and the normal water level.
People sometimes talk about the wave height, which is the vertical distance from the wave crest to the wave trough, instead of amplitude.

Vibration Motion

Things wiggle. They do the back and forth. They vibrate; they shake; they oscillate. These phrases describe the motion of a variety of objects. They even describe the motion of matter at the atomic level. Even atoms wiggle - they do the back and forth. Wiggles, vibrations, and oscillations are an inseparable part of nature. In this chapter of The Physics Classroom Tutorial, we will make an effort to understand vibrational motion and its relationship to waves. An understanding of vibrations and waves is essential to understanding our physical world. Much of what we see and hear is only possible because of vibrations and waves. We see the world around us because of light waves. And we hear the world around us because of sound waves. If we can understand waves, then we will be able to understand the world of sight and sound.

Bobblehead Dolls - An Example of a Vibrating Object

To begin our ponderings of vibrations and waves, consider one of those crazy bobblehead dolls that you've likely seen at baseball stadiums or novelty shops. A bobblehead doll consists of an oversized replica of a person's head attached by a spring to a body and a stand. A light tap to the oversized head causes it to bobble. The head wiggles; it vibrates; it oscillates. When pushed or somehow disturbed, the head does *the back and forth*. The back and forth doesn't happen forever. Over time, the vibrations tend to *die off* and the bobblehead stops bobbing and finally assumes its usual resting position.
The bobblehead doll is a good illustration of many of the principles of vibrational motion. Think about how you would describe the back and forth motion of the oversized head of a bobblehead doll. What words would you use to describe such a motion? How does the motion of the bobblehead change over time? How does the motion of one bobblehead differ from the motion of another bobblehead? What quantities could you measure to describe the motion and so distinguish one motion from another motion? How would you explain the cause of such a motion? Why does the back and forth motion of the bobblehead finally stop? These are all questions worth pondering and answering if we are to understand vibrational motion. These are the questions we will attempt to answer in Section 1 of this chapter.

What Causes Objects to Vibrate?

Like any object that undergoes vibrational motion, the bobblehead has a resting position. The resting position is the position assumed by the bobblehead when it is not vibrating. The resting position is sometimes referred to as the equilibrium position. When an object is positioned at its equilibrium position, it is in a state of equilibrium. As discussed in the Newton's Law, an object which is in a state of equilibrium is experiencing a balance of forces. All the individual forces - gravity, spring, etc. - are balanced or add up to an overall net force of 0 Newtons. When a bobblehead is at the equilibrium position, the forces on the bobblehead are balanced. The bobblehead will remain in this position until somehow disturbed from its equilibrium.

When in its resting position, the bobblehead is at equilibrium; all the forces acting upon it are balanced. When a force is applied to the bobblehead, it is displaced from its equilibrium position. This force disturbs the equilibrium and is the cause of the bobblehead's vibration.

If a force is applied to the bobblehead, the equilibrium will be disturbed and the bobblehead will begin vibrating. We could use the phrase forced vibration to describe the force which sets the otherwise resting bobblehead into motion. In this case, the force is a short-lived, momentary force that begins the motion. The bobblehead does its back and forth, repeating the motion over and over. Each repetition of its back and forth motion is a little less vigorous than its previous repetition. If the head sways 3 cm to the right of its equilibrium position during the first repetition, it may only sway 2.5 cm to the right of its equilibrium position during the second repetition. And it may only sway 2.0 cm to the right of its equilibrium position during the third repetition. And so on. The extent of its displacement from the equilibrium position becomes less and less over time. Because the forced vibration that initiated the motion is a single instance of a short-lived, momentary force, the vibrations ultimately cease. The bobblehead is said to experience damping. Damping is the tendency of a vibrating object to lose or to dissipate its energy over time. The mechanical energy of the bobbing head is lost to other objects. Without a *sustained* forced vibration, the back and forth motion of the bobblehead eventually ceases as energy is dissipated to other objects. A sustained input of energy would be required to keep the back and forth motion going. After all, if the vibrating object naturally loses energy, then it must continuously be put back into the system through a forced vibration in order to sustain the vibration.

Properties of Periodic Motion

A vibrating object is wiggling about a fixed position. Like the mass on a spring in the animation at the right, a vibrating object is moving over the same path over the course of time. Its motion repeats itself over and over again. If it were not for damping, the vibrations would endure forever (or at least until someone catches the mass and brings it to rest). The mass on the spring not only repeats the same motion, it does so in a regular fashion. The time it takes to complete one back and forth cycle is always the same amount of time. If it takes the mass 3.2 seconds for the mass to complete the first back and forth cycle, then it will take 3.2 seconds to complete the seventh back and forth cycle. It's like clockwork. It's so predictable that you could set your watch by it. In Physics, a motion that is regular and repeating is referred to as a periodic motion. Most objects that vibrate do so in a regular and repeated fashion; their vibrations are periodic.

APPLY PRINCIPALS AND THEORIES OF CHEMISTRY IN REAL WORLD EXAMPLES

States of Matter

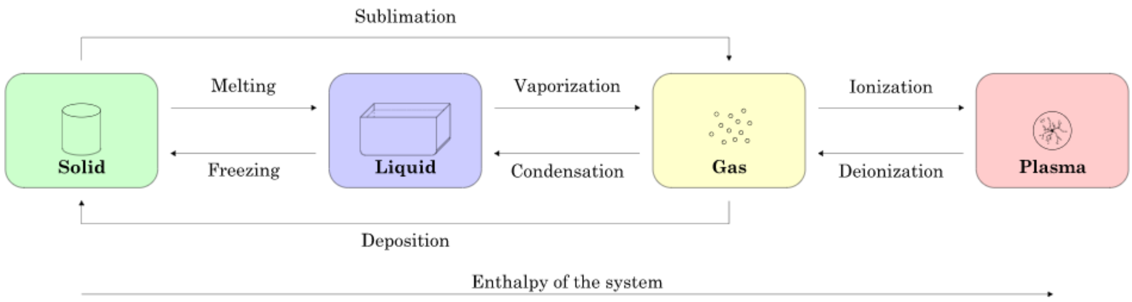
Key Points

- ✓ Matter can exist in one of three main states: solid, liquid, or gas.
- ✓ Solid matter is composed of tightly packed particles. A solid will retain its shape; the particles are not free to move around.
- ✓ Liquid matter is made of more loosely packed particles. It will take the shape of its container. Particles can move about within a liquid, but they are packed densely enough that volume is maintained.
- ✓ Gaseous matter is composed of particles packed so loosely that it has neither a defined shape nor a defined volume. A gas can be compressed.

Terms

- ✓ solidA substance that retains its size and shape without a container; a substance whose molecules cannot move freely except to vibrate.
- ✓ gasA substance that can only be contained if it is fully surrounded by a container (or held together by gravitational pull); a substance whose molecules have negligible intermolecular interactions and can move freely.
- ✓ liquidA substance that flows and keeps no definite shape because its molecules are loosely packed and constantly moving. It takes the shape of its container but maintains constant volume.

The three states of matter are the three distinct physical forms that matter can take in most environments: solid, liquid, and gas. In extreme environments, other states may be present, such as plasma, Bose-Einstein condensates, and neutron stars. Further states, such as quark-gluon plasmas, are also believed to be possible. Much of the atomic matter of the universe is hot plasma in the form of rarefied interstellar medium and dense stars.
Historically, the states of matter were distinguished based on qualitative differences in their bulk properties. Solid is the state in which matter maintains a fixed volume and shape; liquid is the state in which matter adapts to the shape of its container but varies only slightly in volume; and gas is the state in which matter expands to occupy the volume and shape of its container. Each of these three classical states of matter can transition directly into either of the other two classical states.



Solids

A solid's particles are packed closely together. The forces between the particles are strong enough that the particles cannot move freely; they can only vibrate. As a result, a solid has a stable, definite shape and a definite volume. Solids can only change shape under force, as when broken or cut.

In crystalline solids, particles are packed in a regularly ordered, repeating pattern. There are many different crystal structures, and the same substance can have more than one structure. For example, iron has a body-centered cubic structure at temperatures below 912 °C and a face-centered cubic structure between 912 and 1394 °C. Ice has fifteen known crystal structures, each of which exists at a different temperature and pressure.

A solid can transform into a liquid through melting, and a liquid can transform into a solid through freezing. A solid can also change directly into a gas through a process called sublimation.

Liquids

A liquid is a fluid that conforms to the shape of its container but that retains a nearly constant volume independent of pressure. The volume is definite (does not change) if the temperature and pressure are constant. When a solid is heated above its melting point, it becomes liquid because the pressure is higher than the triple point of the substance. Intermolecular (or interatomic or interionic) forces are still important, but the molecules have enough energy to move around, which makes the structure mobile. This means that a liquid is not definite in shape but rather conforms to the shape of its container. Its volume is usually greater than that of its corresponding solid (water is a well-known exception to this rule). The highest temperature at which a particular liquid can exist is called its critical temperature.

A liquid can be converted to a gas through heating at constant pressure to the substance's boiling point or through reduction of pressure at constant temperature. This process of a liquid changing to a gas is called evaporation.

Gases

Gas molecules have either very weak bonds or no bonds at all, so they can move freely and quickly. Because of this, not only will a gas conform to the shape of its container, it will also expand to completely fill the container. Gas molecules have enough kinetic energy that the effect of intermolecular forces is small (or zero, for an ideal gas), and they are spaced very far apart from each other; the typical distance between neighboring molecules is much greater than the size of the molecules themselves.

A gas at a temperature below its critical temperature can also be called a vapor. A vapor can be liquefied through compression without cooling. It can also exist in equilibrium with a liquid (or solid), in which case the gas pressure equals the vapor pressure of the liquid (or solid).
A supercritical fluid (SCF) is a gas whose temperature and pressure are greater than the critical temperature and critical pressure. In this state, the distinction between liquid and gas disappears. A supercritical fluid has the physical properties of a gas, but its high density lends it the properties of a solvent in some cases. This can be useful in several applications. For example, supercritical carbon dioxide is used to extract caffeine in the manufacturing of decaffeinated coffee.

Physical and Chemical Changes

Physical Changes

Another way to think about this is that a physical change does not cause a substance to become a fundamentally different substance but a chemical change causes a substance to change into something chemically new. Blending a smoothie, for example, involves two physical changes: the change in shape of each fruit and the mixing together of many different pieces of fruit. Because none of the chemicals in the smoothie components are changed during blending (the water and vitamins from the fruit are unchanged, for example), we know that no chemical changes are involved.

Physical change blending a smoothie involves physical changes but no chemical changes.
Cutting, tearing, shattering, grinding, and mixing are further types of physical changes because they change the form but not the composition of a material. For example, mixing salt and pepper creates a new substance without changing the chemical makeup of either component.
Phase changes are changes that occur when substances are melted, frozen, boiled, condensed, sublimated, or deposited. They are also physical changes because they do not change the nature of the substance.
Boiling water boiling water is an example of a physical change and not a chemical change because the water vapor still has the same molecular structure as liquid water (H2O). If the

bubbles were caused by the decomposition of a molecule into a gas (such as $H_2O \rightarrow H_2$ and O_2), then boiling would be a chemical change.

Chemical Changes

Chemical changes are also known as chemical reactions. The "ingredients" of a reaction are called the reactants, and the end results are called the products. The change from reactants to products is signified by an arrow:
Reactants → Products
The formation of gas bubbles is often the result of a chemical change (except in the case of boiling, which is a physical change). A chemical change might also result in the formation of a precipitate, such as the appearance of a cloudy material when dissolved substances are mixed.
Rotting, burning, cooking, and rusting are all further types of chemical changes because they produce substances that are entirely new chemical compounds. For example, burned wood becomes ash, carbon dioxide, and water. When exposed to water, iron becomes a mixture of several hydrated iron oxides and hydroxides. Yeast carries out fermentation to produce alcohol from sugar.
An unexpected color change or release of odor also often indicates a chemical change. For example, the color of the element chromium is determined by its oxidation state; a single chromium compound will only change color if it undergoes an oxidation or reduction reaction. The heat from cooking an egg changes the interactions and shapes of the proteins in the egg white, thereby changing its molecular structure and converting the egg white from translucent to opaque.
The best way to be completely certain whether a change is physical or chemical is to perform chemical analyses, such as mass spectroscopy, on the substance to determine its composition before and after a reaction.

Atoms

Everyday experience should convince you that matter is found in myriad forms, yet all the matter you have ever seen is made of atoms, or atoms stuck together in configurations of dizzying complexity. A chemical element is a substance that cannot be made into a simpler form by ordinary chemical means. The smallest unit of a chemical element is an atom, and all atoms of a particular element are identical.

Molecules

In the previous section we said that many atoms are more stable when they have a net charge: they are more stable as ions. When a cation gets close to an anion, they link up because of their different net charges — positive charges attract negative charges and vice versa. When two or more atoms link up, they create a molecule. A molecule of water is made of two atoms of hydrogen (H) and one atom of oxygen (O). The molecular mass is the sum of the masses of all the atoms in the molecule. A collection of molecules is called a compound.

Elements

A chemical element is a pure substance that consists of one type of atom. Each atom has an atomic number, which represents the number of protons that are in the nucleus of a single atom of that element. The periodic table of elements is ordered by ascending atomic number.

The chemical elements are divided into the metals, the metalloids, and the non-metals. Metals, typically found on the left side of the periodic table, are:

- ✓ often conductive to electricity
- ✓ malleable
- ✓ shiny
- ✓ sometimes magnetic.

Aluminum, iron, copper, gold, mercury and lead are metals.

In contrast, non-metals, found on the right side of the periodic table (to the right of the staircase), are:

- ✓ typically not conductive
- ✓ not malleable
- ✓ dull (not shiny)
- ✓ not magnetic.

Examples of elemental non-metals include carbon and oxygen.

Metalloids have some characteristics of metals and some characteristics of non-metals. Silicon and arsenic are metalloids.

As of November, 2011, 118 elements have been identified (the most recently identified was ununseptium, in 2010). Of these 118 known elements, only the first 98 are known to occur naturally on Earth. The elements that do not occur naturally on Earth are the synthetic products of man-made nuclear reactions. 80 of the 98 naturally-occurring elements are stable; the rest are radioactive, which means they decay into lighter elements over timescales ranging from fractions of a second to billions of years.

Compounds

Pure samples of isolated elements are uncommon in nature. While the 98 naturally occurring elements have all been identified in mineral samples from the Earth's crust, only a small minority of them can be found as recognizable, relatively pure minerals. Among the more common of such "native elements" are copper, silver, gold, and sulfur. Carbon is also commonly found in the form of coal, graphite, and diamonds. The noble gases (e.g., neon) and noble metals (e.g., mercury) can also be found in their pure, non-bonded forms in nature. Still, most of these elements are found in mixtures.

When two distinct elements are chemically combined—i.e., chemical bonds form between their atoms—the result is called a chemical compound. Most elements on Earth bond with other elements to form chemical compounds, such as sodium (Na) and Chloride (Cl), which combine to form table salt (NaCl). Water is another example of a chemical compound. The two or more component elements of a compound can be separated through chemical reactions.

Chemical compounds have a unique and defined structure, which consists of a fixed ratio of atoms held together in a defined spatial arrangement by chemical bonds. Chemical compounds can be:

- ✓ molecular compounds held together by covalent bonds
- ✓ salts held together by ionic bonds

- ✓ intermetallic compounds held together by metallic bonds
- ✓ complexes held together by coordinate covalent bonds.

Pure chemical elements are not considered chemical compounds, even if they consist of diatomic or polyatomic molecules (molecules that contain only multiple atoms of a single element, such as H2 or S8).

Mixture

A mixture is made by simply mixing together elements and compounds. No new chemical bonds are formed. Mixtures can be separated using techniques such as filtration, chromatography, evaporation, magnetisation, flotation and distillation.

Solute, solvent, solution definition with examples

A **solution** in chemistry is a **homogenous mixture** of two or more substances.

- ✓ The substance which is dissolved is called a **solute**.
- ✓ The substance in which the solute is dissolved is called a **solvent**.

Main characteristics of a solution

Solution is homogenous

That the solution is a homogenous mixture means that it forms a single phase. You cannot differentiate one substance from another within the solution. Characteristics of a solution are identically distributed through it. For an easy example, if you dissolve sugar in water but some of the sugar is still visibly laying on the bottom of the container (or even floating moved by movement of water) then this not part of a solution - only the dissolved "invisible" sugar is.
You cannot see a solute inside a solvent, nor can you mechanically take one out of another (e.g. taking dissolved sugar from water is impossible with a sifter or another mechanical method).

Solution is stable

A solution is stable in given conditions. E.g. in a particular temperature and pressure it does not require stirring or other methods to remain homogenous.

Solution is in one phase

That the whole solution is on one phase means that the whole of it is either gaseous, liquid or solid.

Which is the solute and which is the solvent?

Usually it is easy to determine which substance is a solute and which is a solvent. The **solute** when dissolved takes on the characteristics of the **solvent**. A solution is composed in majority of a solvent (there is more of it then the solute). A sugar dissolved in water seems to take on its characteristics and there is more water than sugar in the solution.

Examples of solutions

Common example of a solution in everyday life is salt or sugar (solute) dissolved in water (solvent). Below you can find links to further examples of various types of solutions with a more detailed explanation.

Solubility Basics - What is solubility?

In General

In general, **SOLUBILITY** is an ability of a substance to dissolve. In the process of dissolving, the substance which is being dissolved is called a **solute** and the substance in which the solute is dissolved is called a **solvent.** A mixture of solute and solvent is called a **solution.**

To put it in simple words:

When we insert sugar into water it will dissolve. In this process:

- ✓ sugar is the **solute**
- ✓ water is the **solvent**

One of the characteristics of table sugar is its **solubility in water**

That was a definition of solubility as it is used in a common language. Now let's see **solubility as chemists understand it:**

Chemist's understanding of Solubility

A chemist understands solubility as a measure. A chemist would say that:

SOLUBILITY is understood as a maximum amount of solute that dissolves in a solvent at so called **equilibrium**. In chemistry an equilibrium is a state where reactants and products reach a balance - no more solute can be dissolved in the solvent in the set conditions (temperature, pressure). Such a solution is called a **saturated solution**.

To put it in simple words: If you take one liter of water and you start dissolving table salt in it (chemical formula of salt is **NaCl**) and:

- ✓ temperature of water is 25°C
- ✓ pressure is 1 ATM (Atmosphere - standard pressure in the open air on Earth)

you should be able to dissolve exactly 357.00 grams and not a gram more. The rest of the salt will stay on the bottom as residue and will not dissolve. **Solubility of salt in water is therefore 357.00g/L.** When this amount of salt is dissolved the solution reaches its equilibrium. Every chemical substance which dissolves in water has a fixed solubility. If it does not dissolve - its solubility is zero. Many of these solubilities have been measured and special charts are produced displaying solubility of many substances at once.

HERE you can check out our solubility table which is one of the biggest available on the web.

To complete our introduction to solubility, we will describe two groups of substances in case of which solubility measure cannot be applied. These are miscible and immiscible substances

Miscible and immiscible substances

Some substances, like water and alcohol, can be mixed together and create a homogenous phase in any proportion. A solubility measure cannot be applied to such two substances. Such substances are called **miscible.** On the other hand if two substances cannot be mixed together (like water and oil), they are called **immiscible**.
Now, when you know what solubility really is, you can check out 'why do things dissolve', where we explain in detail why some things dissolve and some do not.

UNIT 08

STORE FLUIDS IN BULK

This competency covers the storage and transfer of fluids to and from tanks. In a typical scenario the plant technician will manage a series of liquid storage tanks for raw materials and finished product as part of the production process

PREPARE FOR WORK

Hazard Identification and Assessment

One of the "root causes" of workplace injuries, illnesses, and incidents is the failure to identify or recognize hazards that are present, or that could have been anticipated. A critical element of any effective safety and health program is a proactive, ongoing process to identify and assess such hazards.

To identify and assess hazards, employers and workers:

- ✓ Collect and review information about the hazards present or likely to be present in the workplace.
- ✓ Conduct initial and periodic workplace inspections of the workplace to identify new or recurring hazards.
- ✓ Investigate injuries, illnesses, incidents, and close calls/near misses to determine the underlying hazards, their causes, and safety and health program shortcomings.
- ✓ Group similar incidents and identify trends in injuries, illnesses, and hazards reported.
- ✓ Consider hazards associated with emergency or nonroutine situations.
- ✓ Determine the severity and likelihood of incidents that could result for each hazard identified, and use this information to prioritize corrective actions.

Some hazards, such as housekeeping and tripping hazards, can and should be fixed as they are found. Fixing hazards on the spot emphasizes the importance of safety and health and takes advantage of a safety leadership opportunity. To learn more about fixing other hazards identified using the processes described here, see "Hazard Prevention and Control."

Action item 1: Collect existing information about workplace hazards

Information on workplace hazards may already be available to employers and workers, from both internal and external sources.

How to accomplish it

Collect, organize, and review information with workers to determine what types of hazards may be present and which workers may be exposed or potentially exposed. Information available in the workplace may include:

- ✓ Equipment and machinery operating manuals.
- ✓ Safety Data Sheets (SDS) provided by chemical manufacturers.
- ✓ Self-inspection reports and inspection reports from insurance carriers, government agencies, and consultants.
- ✓ Records of previous injuries and illnesses, such as OSHA 300 and 301 logs and reports of incident investigations.
- ✓ Workers' compensation records and reports.
- ✓ Patterns of frequently-occurring injuries and illnesses.
- ✓ Exposure monitoring results, industrial hygiene assessments, and medical records (appropriately redacted to ensure patient/worker privacy).
- ✓ Existing safety and health programs (lockout/tagout, confined spaces, process safety management, personal protective equipment, etc.).

- ✓ Input from workers, including surveys or minutes from safety and health committee meetings.
- ✓ Results of job hazard analyses, also known as job safety analyses.

Information about hazards may be available from outside sources, such as:

- ✓ OSHA, National Institute for Occupational Safety and Health (NIOSH), and Centers for Disease Control and Prevention (CDC) websites, publications, and alerts.
- ✓ Trade associations.
- ✓ Labor unions, state and local occupational safety and health committees/coalitions ("COSH groups"), and worker advocacy groups.
- ✓ Safety and health consultants.

Action item 2: Inspect the workplace for safety hazards

Hazards can be introduced over time as workstations and processes change, equipment or tools become worn, maintenance is neglected, or housekeeping practices decline. Setting aside time to regularly inspect the workplace for hazards can help identify shortcomings so that they can be addressed before an incident occurs.

How to accomplish it

- ✓ Conduct regular inspections of all operations, equipment, work areas and facilities. Have workers participate on the inspection team and talk to them about hazards that they see or report.
- ✓ Be sure to document inspections so you can later verify that hazardous conditions are corrected. Take photos or video of problem areas to facilitate later discussion and brainstorming about how to control them, and for use as learning aids.
- ✓ Include all areas and activities in these inspections, such as storage and warehousing, facility and equipment maintenance, purchasing and office functions, and the activities of on-site contractors, subcontractors, and temporary employees.
- ✓ Regularly inspect both plant vehicles (e.g., forklifts, powered industrial trucks) and transportation vehicles (e.g., cars, trucks).
- ✓ Use checklists that highlight things to look for. Typical hazards fall into several major categories, such as those listed below; each workplace will have its own list:
    - o General housekeeping
    - o Slip, trip, and fall hazards
    - o Electrical hazards
    - o Equipment operation
    - o Equipment maintenance
    - o Fire protection
    - o Work organization and process flow (including staffing and scheduling)
    - o Work practices
    - o Workplace violence
    - o Ergonomic problems
    - o Lack of emergency procedures

- ✓ Before changing operations, workstations, or workflow; making major organizational changes; or introducing new equipment, materials, or processes, seek the input of workers and evaluate the planned changes for potential hazards and related risks.

Note: Many hazards can be identified using common knowledge and available tools. For example, you can easily identify and correct hazards associated with broken stair rails and frayed electrical cords. Workers can be a very useful internal resource, especially if they are trained in how to identify and assess risks.

Action item 3: Identify health hazards

Identifying workers' exposure to health hazards is typically more complex than identifying physical safety hazards. For example, gases and vapors may be invisible, often have no odor, and may not have an immediately noticeable harmful health effect. Health hazards include chemical hazards (solvents, adhesives, paints, toxic dusts, etc.), physical hazards (noise, radiation, heat, etc.), biological hazards (infectious diseases), and ergonomic risk factors (heavy lifting, repetitive motions, vibration). Reviewing workers' medical records (appropriately redacted to ensure patient/worker privacy) can be useful in identifying health hazards associated with workplace exposures.

How to accomplish it

- ✓ Identify chemical hazards –review SDS and product labels to identify chemicals in your workplace that have low exposure limits, are highly volatile, or are used in large quantities or in unventilated spaces. Identify activities that may result in skin exposure to chemicals.
- ✓ Identify physical hazards –identify any exposures to excessive noise (areas where you must raise your voice to be heard by others), elevated heat (indoor and outdoor), or sources of radiation (radioactive materials, X-rays, or radiofrequency radiation).
- ✓ Identify biological hazards –determine whether workers may be exposed to sources of infectious diseases, molds, toxic or poisonous plants, or animal materials (fur or scat) capable of causing allergic reactions or occupational asthma.
- ✓ Identify ergonomic risk factors –examine work activities that require heavy lifting, work above shoulder height, repetitive motions, or tasks with significant vibration.
- ✓ Conduct quantitative exposure assessments –when possible, using air sampling or direct reading instruments.
- ✓ Review medical records –to identify cases of musculoskeletal injuries, skin irritation or dermatitis, hearing loss, or lung disease that may be related to workplace exposures.

Note: Identifying and assessing health hazards may require specialized knowledge. Small businesses can obtain free and confidential occupational safety and health advice services, including help identifying and assessing workplace hazards, through OSHA's On-site Consultation Program.

Action item 4: Conduct incident investigations

Workplace incidents –including injuries, illnesses, close calls/near misses, and reports of other concerns– provide a clear indication of where hazards exist. By thoroughly investigating incidents and reports, you will identify hazards that are likely to cause future

harm. The purpose of an investigation must always be to identify the root causes (and there is often more than one) of the incident or concern, in order to prevent future occurrences.

How to accomplish it

- ✓ Develop a clear plan and procedure for conducting incident investigations, so that an investigation can begin immediately when an incident occurs. The plan should cover items such as:
    - Who will be involved
    - Lines of communication
    - Materials, equipment, and supplies needed
    - Reporting forms and templates
- ✓ Train investigative teams on incident investigation techniques, emphasizing objectivity and open-mindedness throughout the investigation process.
- ✓ Conduct investigations with a trained team that includes representatives of both management and workers.
- ✓ Investigate close calls/near misses.
- ✓ Identify and analyze root causes to address underlying program shortcomings that allowed the incidents to happen.
- ✓ Communicate the results of the investigation to managers, supervisors, and workers to prevent recurrence.

Effective incident investigations do not stop at identifying a single factor that triggered an incident. They ask the questions "Why?" and "What led to the failure?" For example, if a piece of equipment fails, a good investigation asks: "Why did it fail?" "Was it maintained properly?" "Was it beyond its service life?" and "How could this failure have been prevented?" Similarly, a good incident investigation does not stop when it concludes that a worker made an error. It asks such questions as: "Was the worker provided with appropriate tools and time to do the work?" "Was the worker adequately trained?" and "Was the worker properly supervised?"
Note: OSHA has special reporting identifys for work-related incidents that lead to serious injury or a fatality (29 CFR 1904.39). OSHA must be notified within 8 hours of a work-related fatality, and within 24 hours of an amputation, loss of an eye, or inpatient hospitalization.

Action item 5: Identify hazards associated with emergency and nonroutine situations

Emergencies present hazards that need to be recognized and understood. Nonroutine or infrequent tasks, including maintenance and startup/shutdown activities, also present potential hazards. Plans and procedures need to be developed for responding appropriately and safely to hazards associated with foreseeable emergency scenarios and nonroutine situations.

How to accomplish it

- ✓ Identify foreseeable emergency scenarios and nonroutine tasks, taking into account the types of material and equipment in use and the location within the facility. Scenarios such as the following may be foreseeable:
    - Fires and explosions
    - Chemical releases
    - Hazardous material spills
    - Startups after planned or unplanned equipment shutdowns
    - Nonroutine tasks, such as infrequently performed maintenance activities
    - Structural collapse
    - Disease outbreaks
    - Weather emergencies and natural disasters
    - Medical emergencies
    - Workplace violence

Action item 6: Characterize the nature of identified hazards, identify interim control measures, and prioritize the hazards for control

The next step is to assess and understand the hazards identified and the types of incidents that could result from worker exposure to those hazards. This information can be used to develop interim controls and to prioritize hazards for permanent control.

How to accomplish it

- ✓ Evaluate each hazard by considering the severity of potential outcomes, the likelihood that an event or exposure will occur, and the number of workers who might be exposed.
- ✓ Use interim control measures to protect workers until more permanent solutions can be implemented.
- ✓ Prioritize the hazards so that those presenting the greatest risk are addressed first. Note, however, that employers have an ongoing obligation to control all serious recognized hazards and to protect workers.

Note: "Risk" is the product of hazard and exposure. Thus, risk can be reduced by controlling or eliminating the hazard or by reducing workers' exposure to hazards. An assessment of risk helps employers understand hazards in the context of their own workplace and prioritize hazards for permanent control.

PREPARE STORAGE/LOADING FACILITIES

Research storage restrictions

First, be sure to do your homework on what can and can't be stored inside your storage unit. The storage facility should provide you with a list of restricted items, but in case they don't, make sure to ask for all rules and regulations. A few examples of what most likely *can't* be stored inside your storage unit include dangerous items, such as gasoline, fertilizers, paint, chemicals, fireworks, explosives, narcotics and propane tanks. Tip: if it's flammable, it probably can't be placed inside a storage unit. Other no-no items include perishable food, medicine and plants.

Decide which personal items to put in storage

Next, consider whether or not you need to store something before putting it inside your storage unit. Why? Well, for starters, the more you store, the bigger the storage unit you'll need; And, of course, the bigger the storage unit, the more it will cost you. To save money, carefully consider each item before storing it. If it's not sentimental, valuable or useful, try donating or selling it instead.

Create an inventory list of all items

In the midst of a chaotic move, it's easy to forget what you put into storage. So before packing belongings, be sure to create an inventory list of all of the items you plan to store. From paintings and pictures to furniture and smaller knick-knacks, you'll be able to keep up with everything in an organized way. I recommend keeping a copy for yourself and leaving one inside the storage unit. This way when you go to pull things out, you'll have your inventory list right in front of you.

Clean and vacuum belongings

There's nothing worse than retrieving a furnishing or appliance from a storage unit, only to have it stink up your house with its musty, mildewy scent. To avoid this from happening, it's absolutely critical that you thoroughly clean all items before placing them in a storage unit. After all, If they're clean to begin with, they'll be much less likely to smell bad later. I recommend wiping down all surfaces with an all-purpose cleaning spray, vacuuming couch and chair cushions, as well as cleaning appliances with disinfectant wipes.

Use clear plastic bins instead of boxes

Ready to begin the packing process? If possible, I recommend placing items inside airtight, clear plastic bins. This way, you can see what's inside when you visit the storage unit. You won't have to frantically hunt around for a certain book or miscellaneous item. Instead, you'll be able to spot what you're looking for almost immediately.

If using boxes, label them clearly

Have a plethora of leftover moving boxes? If you decide to forego plastic bins and use cardboard boxes instead, be sure that they are sturdy enough to withstand long term storage. Since you can't see what's inside a cardboard box, you'll need to carefully and clearly label each one. Also, be sure to list out specific items inside a box. For instance, instead of labeling a box "kitchen items," label it "pots, pans and utensils."

Safeguard items from outside conditions

If your storage unit isn't climate controlled, you'll need to take matters into your own hands to prevent damage to your belongings. Over time, dust, moisture, mildew and even mold can develop if you fail to take proper precautions. First, I recommend making sure all of your items are dry to begin with. Then apply protective spray on furniture and leather goods. Seal boxes tightly to keep moisture out. For electronics and cords, I suggest storing them in plastic baggies to prevent moisture damage as well. Sweaters and clothing should be packed in wardrobe boxes or zipped inside a hanging garment bag. Mattresses should be placed in a special mattress storage bag. Furniture should also be covered in a cotton sheet to prevent damage from pests and bad weather.

Disassemble large items

Large items, such as beds and dining tables should be disassembled before placed into storage. Not only will you be able to save space by taking these items apart, but you'll also be able to better protect these belongings from potential wear and tear. Tip: Box springs and mattresses should be stored flat inside the storage unit to prevent damage.

Prepare appliances

Putting small kitchen appliances in storage? I recommend wrapping them (and the cords) in bubble wrap or foam to prevent them from breaking. Also, make sure to thoroughly clean the appliances and secure any loose parts with rope or tape. If the appliance is a washer, fridge or dishwasher, leave the appliance doors slightly open to prevent mildew and moisture from building up.

Place items inside a storage unit strategically

Finally, when placing your items in storage, be strategic about how and where you decide to store them in the unit. If you're looking to save space, try storing belongings in a vertical position. Also, all large and heavy items should be placed on the bottom. If laying your mattress flat, avoid putting it at the very bottom of the storage unit, as belongings on top are sure to put pressure on the padding and springs. You'll also want to consider which items you're going to need more often. For instance, if you're planning to store seasonal clothing, I suggest placing these items in an easy-to-reach spot near the door.

Other things to consider when packing for storage

- ✓ The quality of your packing supplies.
- ✓ The size of your storage unit.
- ✓ The overall safety and security of your storage unit. For instance, does it have in-person surveillance or video monitoring? How many locks are on the door? How well lit is the facility?
- ✓ Whether or not your storage unit is climate controlled. If you can do so, I highly recommend renting a unit that provides this feature. These climate controlled units prevent mildew and mold from damaging your items. If you do decide to rent a storage unit that isn't climate controlled, be aware that mold is capable of growing on cardboard and paper products. So pack accordingly.

TRANSFER FLUIDS TO AND FROM TANKS

As we are operating water treatment plants, the process of storing fluids and transferring them from the storage tanks to the other is a major source of contamination. Connections, hoses, pumps, filters and the delivery system all have effects on the fluids being transferred.

Between the storage tank and the fuel tank of a piece of equipment, there will be any number of hoses and piping. Damage to and poor maintenance of these hoses and pipes leave opportunities for foreign material to enter the fluid.

Here are some tips to help you maintain cleanliness of the fluids being transfer and quality while being stored and transferred:

- ✓ Use only hoses and piping that are specifically designed to be used with respective fluid.
- ✓ Check the pumps that enable the movement of the luid for damage, as they are an easy gateway for particles to enter.
- ✓ Routinely ensure that the nozzle that enters the tank of the equipment seals and is properly maintained and cleaned
- ✓ Perform preventative maintenance on all transfer equipment
- ✓ Routinely inspect and replace any and all worn or aged parts including caps, seals, gaskets and filters
- ✓ Handle correct fluid for the environment that it will be stored in and store according to the environment
- ✓ Completely empty and clean the tanks periodically(to reduce contamination)

ISOLATE AND DE-ISOLATE PLANT

The risks associated with any plant or equipment undergoing inspection, maintenance, cleaning, repair or construction should be assessed and appropriate control measures put in place.
Before work commences the plant should be stopped, appropriately isolated/locked and danger tagged, and any stored energy should be dissipated.
Examples of energy sources include electricity, hydraulic pressure, compressed air or gas, gravity, kinetic spring tension and moving parts.
Separate controls away from the plant operator or immediate work area must also be isolated or locked and danger tagged.

Isolation Procedures

An isolation procedure is a set of predetermined steps that should be followed when workers are required to perform tasks such as inspection, maintenance, cleaning, repair and construction.
The aim of an isolation procedure is to:

- ✓ isolate all forms of potentially hazardous energy to ensure that an accidental release of hazardous energy does not occur

- ✓ control all other hazards to those doing the work
- ✓ ensure that entry to a restricted area is tightly controlled.

The following lock-out process is the most effective isolation procedure:

- ✓ shut down the machinery and equipment
- ✓ identify all energy sources and other hazards
- ✓ identify all isolation points
- ✓ isolate all energy sources
- ✓ in the case of electrical equipment 'whole current isolation', such as the main isolator, should be used instead of 'control isolation' by way of the stop button on a control panel
- ✓ control or de-energise all stored energy
- ✓ lock-out all isolation points, using padlocks, multi- padlock hasps and danger tags
- ✓ 'danger tag' machinery controls, energy sources and other hazards.

Test that the isolation is effective by 'trying' to reactivate the plant without exposing the tester or others to risk. Failure to reactivate the plant means that the isolation procedure is effective and that all stored energies have dissipated.
This may require further measures to safely release these energies e.g. hydraulic or pneumatic pressure, suspended weight or compressed springs.

Locks and danger tags

Every person working on isolated equipment should fit their own lock and/or danger tag. Alternatively, another management approved system that achieves an equivalent level of safety may be used.
When using locks or danger tags, consider the following:

- ✓ tags should be dated and signed
- ✓ locks should be accompanied by a corresponding tag to identify who has locked out the plant
- ✓ tags and locks should only be removed by the person who applied them or by the supervisor after consultation with the signatory of the danger tag. In the event
- ✓ that the person who applied the danger tag is unavailable, their tag or lock may only be removed in accordance with a management approved procedure
- ✓ danger Tags and/or locks should be fitted to all isolation points.

Out-of-service tags

Out-of-service tags are used to identify equipment or machinery that has been taken out of service due to a fault, damage or malfunction.

The out-of-service tag is to be securely fixed to the operating control power isolator with the appropriate details completed on the tag (explaining the reason for the machine being 'out of service').

The out-of-service tag should not be removed until the equipment is safe to be returned to service, or the reason for the out-of-service tag no longer exists.

The out-of-service tag may be removed by:

- ✓ the person who attached it
- ✓ the supervisor responsible for the operation or repair of the equipment
- ✓ the maintenance person who carried out the repairs.

UNIT 09

OPERATE AND MAINTAIN PNEUMATIC SYSTEMS AND EQUIPMENT

This unit covers the operation and monitoring of a complex compressor system and associated equipment

PREPARE FOR WORK

Hazard Identification and Assessment

One of the "root causes" of workplace injuries, illnesses, and incidents is the failure to identify or recognize hazards that are present, or that could have been anticipated. A critical element of any effective safety and health program is a proactive, ongoing process to identify and assess such hazards.
To identify and assess hazards, employers and workers:

- ✓ Collect and review information about the hazards present or likely to be present in the workplace.
- ✓ Conduct initial and periodic workplace inspections of the workplace to identify new or recurring hazards.
- ✓ Investigate injuries, illnesses, incidents, and close calls/near misses to determine the underlying hazards, their causes, and safety and health program shortcomings.
- ✓ Group similar incidents and identify trends in injuries, illnesses, and hazards reported.
- ✓ Consider hazards associated with emergency or nonroutine situations.
- ✓ Determine the severity and likelihood of incidents that could result for each hazard identified, and use this information to prioritize corrective actions.

Some hazards, such as housekeeping and tripping hazards, can and should be fixed as they are found. Fixing hazards on the spot emphasizes the importance of safety and health and takes advantage of a safety leadership opportunity. To learn more about fixing other hazards identified using the processes described here, see "Hazard Prevention and Control."

Action item 1: Collect existing information about workplace hazards

Information on workplace hazards may already be available to employers and workers, from both internal and external sources.

How to accomplish it

Collect, organize, and review information with workers to determine what types of hazards may be present and which workers may be exposed or potentially exposed. Information available in the workplace may include:

- ✓ Equipment and machinery operating manuals.
- ✓ Safety Data Sheets (SDS) provided by chemical manufacturers.
- ✓ Self-inspection reports and inspection reports from insurance carriers, government agencies, and consultants.
- ✓ Records of previous injuries and illnesses, such as OSHA 300 and 301 logs and reports of incident investigations.
- ✓ Workers' compensation records and reports.
- ✓ Patterns of frequently-occurring injuries and illnesses.
- ✓ Exposure monitoring results, industrial hygiene assessments, and medical records (appropriately redacted to ensure patient/worker privacy).

- ✓ Existing safety and health programs (lockout/tagout, confined spaces, process safety management, personal protective equipment, etc.).
- ✓ Input from workers, including surveys or minutes from safety and health committee meetings.
- ✓ Results of job hazard analyses, also known as job safety analyses.

Information about hazards may be available from outside sources, such as:

- ✓ OSHA, National Institute for Occupational Safety and Health (NIOSH), and Centers for Disease Control and Prevention (CDC) websites, publications, and alerts.
- ✓ Trade associations.
- ✓ Labor unions, state and local occupational safety and health committees/coalitions ("COSH groups"), and worker advocacy groups.
- ✓ Safety and health consultants.

Action item 2: Inspect the workplace for safety hazards

Hazards can be introduced over time as workstations and processes change, equipment or tools become worn, maintenance is neglected, or housekeeping practices decline. Setting aside time to regularly inspect the workplace for hazards can help identify shortcomings so that they can be addressed before an incident occurs.

How to accomplish it

- ✓ Conduct regular inspections of all operations, equipment, work areas and facilities. Have workers participate on the inspection team and talk to them about hazards that they see or report.
- ✓ Be sure to document inspections so you can later verify that hazardous conditions are corrected. Take photos or video of problem areas to facilitate later discussion and brainstorming about how to control them, and for use as learning aids.
- ✓ Include all areas and activities in these inspections, such as storage and warehousing, facility and equipment maintenance, purchasing and office functions, and the activities of on-site contractors, subcontractors, and temporary employees.
- ✓ Regularly inspect both plant vehicles (e.g., forklifts, powered industrial trucks) and transportation vehicles (e.g., cars, trucks).
- ✓ Use checklists that highlight things to look for. Typical hazards fall into several major categories, such as those listed below; each workplace will have its own list:
    - General housekeeping
    - Slip, trip, and fall hazards
    - Electrical hazards
    - Equipment operation
    - Equipment maintenance
    - Fire protection
    - Work organization and process flow (including staffing and scheduling)
    - Work practices
    - Workplace violence
    - Ergonomic problems
    - Lack of emergency procedures

- ✓ Before changing operations, workstations, or workflow; making major organizational changes; or introducing new equipment, materials, or processes, seek the input of workers and evaluate the planned changes for potential hazards and related risks.

Note: Many hazards can be identified using common knowledge and available tools. For example, you can easily identify and correct hazards associated with broken stair rails and frayed electrical cords. Workers can be a very useful internal resource, especially if they are trained in how to identify and assess risks.

Action item 3: Identify health hazards

Identifying workers' exposure to health hazards is typically more complex than identifying physical safety hazards. For example, gases and vapors may be invisible, often have no odor, and may not have an immediately noticeable harmful health effect. Health hazards include chemical hazards (solvents, adhesives, paints, toxic dusts, etc.), physical hazards (noise, radiation, heat, etc.), biological hazards (infectious diseases), and ergonomic risk factors (heavy lifting, repetitive motions, vibration). Reviewing workers' medical records (appropriately redacted to ensure patient/worker privacy) can be useful in identifying health hazards associated with workplace exposures.

How to accomplish it

- ✓ Identify chemical hazards –review SDS and product labels to identify chemicals in your workplace that have low exposure limits, are highly volatile, or are used in large quantities or in unventilated spaces. Identify activities that may result in skin exposure to chemicals.
- ✓ Identify physical hazards –identify any exposures to excessive noise (areas where you must raise your voice to be heard by others), elevated heat (indoor and outdoor), or sources of radiation (radioactive materials, X-rays, or radiofrequency radiation).
- ✓ Identify biological hazards –determine whether workers may be exposed to sources of infectious diseases, molds, toxic or poisonous plants, or animal materials (fur or scat) capable of causing allergic reactions or occupational asthma.
- ✓ Identify ergonomic risk factors –examine work activities that require heavy lifting, work above shoulder height, repetitive motions, or tasks with significant vibration.
- ✓ Conduct quantitative exposure assessments –when possible, using air sampling or direct reading instruments.
- ✓ Review medical records –to identify cases of musculoskeletal injuries, skin irritation or dermatitis, hearing loss, or lung disease that may be related to workplace exposures.

Note: Identifying and assessing health hazards may require specialized knowledge. Small businesses can obtain free and confidential occupational safety and health advice services, including help identifying and assessing workplace hazards, through OSHA's On-site Consultation Program.

Action item 4: Conduct incident investigations

Workplace incidents –including injuries, illnesses, close calls/near misses, and reports of other concerns– provide a clear indication of where hazards exist. By thoroughly investigating incidents and reports, you will identify hazards that are likely to cause future

harm. The purpose of an investigation must always be to identify the root causes (and there is often more than one) of the incident or concern, in order to prevent future occurrences.

How to accomplish it

- ✓ Develop a clear plan and procedure for conducting incident investigations, so that an investigation can begin immediately when an incident occurs. The plan should cover items such as:
    - o Who will be involved
    - o Lines of communication
    - o Materials, equipment, and supplies needed
    - o Reporting forms and templates
- ✓ Train investigative teams on incident investigation techniques, emphasizing objectivity and open-mindedness throughout the investigation process.
- ✓ Conduct investigations with a trained team that includes representatives of both management and workers.
- ✓ Investigate close calls/near misses.
- ✓ Identify and analyze root causes to address underlying program shortcomings that allowed the incidents to happen.
- ✓ Communicate the results of the investigation to managers, supervisors, and workers to prevent recurrence.

Effective incident investigations do not stop at identifying a single factor that triggered an incident. They ask the questions "Why?" and "What led to the failure?" For example, if a piece of equipment fails, a good investigation asks: "Why did it fail?" "Was it maintained properly?" "Was it beyond its service life?" and "How could this failure have been prevented?" Similarly, a good incident investigation does not stop when it concludes that a worker made an error. It asks such questions as: "Was the worker provided with appropriate tools and time to do the work?" "Was the worker adequately trained?" and "Was the worker properly supervised?"
Note: OSHA has special reporting identifys for work-related incidents that lead to serious injury or a fatality (29 CFR 1904.39). OSHA must be notified within 8 hours of a work-related fatality, and within 24 hours of an amputation, loss of an eye, or inpatient hospitalization.

Action item 5: Identify hazards associated with emergency and nonroutine situations

Emergencies present hazards that need to be recognized and understood. Nonroutine or infrequent tasks, including maintenance and startup/shutdown activities, also present potential hazards. Plans and procedures need to be developed for responding appropriately and safely to hazards associated with foreseeable emergency scenarios and nonroutine situations.

How to accomplish it

- ✓ Identify foreseeable emergency scenarios and nonroutine tasks, taking into account the types of material and equipment in use and the location within the facility. Scenarios such as the following may be foreseeable:

- Fires and explosions
- Chemical releases
- Hazardous material spills
- Startups after planned or unplanned equipment shutdowns
- Nonroutine tasks, such as infrequently performed maintenance activities
- Structural collapse
- Disease outbreaks
- Weather emergencies and natural disasters
- Medical emergencies
- Workplace violence

Action item 6: Characterize the nature of identified hazards, identify interim control measures, and prioritize the hazards for control

The next step is to assess and understand the hazards identified and the types of incidents that could result from worker exposure to those hazards. This information can be used to develop interim controls and to prioritize hazards for permanent control.

How to accomplish it

- ✓ Evaluate each hazard by considering the severity of potential outcomes, the likelihood that an event or exposure will occur, and the number of workers who might be exposed.
- ✓ Use interim control measures to protect workers until more permanent solutions can be implemented.
- ✓ Prioritize the hazards so that those presenting the greatest risk are addressed first. Note, however, that employers have an ongoing obligation to control all serious recognized hazards and to protect workers.

Note: "Risk" is the product of hazard and exposure. Thus, risk can be reduced by controlling or eliminating the hazard or by reducing workers' exposure to hazards. An assessment of risk helps employers understand hazards in the context of their own workplace and prioritize hazards for permanent control.

5 Simple Steps to Maximize Safety at Your Plant

When considering what an organization must have for consistent production, more often than not a facility's safety is not the first thing to come to mind. But dig a little deeper and you'll find that the safety of a facility comes from the very aspects that make for efficient production. What are these key factors? From the technical know-how of operating machines through training to maintaining machines that operate at high levels, every aspect of safety leans toward efficiency. Below are five necessary steps to improve the safety of a standard production facility.

1. **Ongoing Safety-Focused Training**

All new machine operators and maintenance technicians should have a mandatory training process so they can be eased into using and maintaining complex assets. This requires each employee to go through the same safety training exercises using each machine at the facility. Even if one has been working at the plant for a long time, machines are constantly changing as technology evolves. Schedule a few days each year with your employees and conduct the necessary training to ensure everyone stays up to date with the safest way to use the equipment.

In addition, having a safety test administered at the end of the training helps to confirm that personnel understand their own experience level. It might seem like wasted time from normal production, but it's not. Unfortunate accidents cause huge declines in output through long delays. This alone should give you enough reason to dedicate time to safety awareness training.

2. **A High-Performing Asset Is a Safe Asset**

As the saying goes, "You can hurt yourself far worse with a dull knife than a sharp one." This applies to heavy machines, too. New machines work with ease and can get the job done fast. However, after enough wear and tear, every machine comes to a breaking point. If you are running the equipment past its recommended limits and don't pay close attention to its performance and condition, you are asking for trouble. This situation can result in an endless list of problems that create hazards for both the user and those around the machine as well.

Using proper lubricants will help keep machines functioning at their highest level for longer periods of time. On the contrary, one of the quickest ways to run down a machine is to not oil it or grease it regularly. This not only leads to a machine that functions in unpredictable ways but also one that can break down unexpectedly and even put an operator in danger in the process.

Maintenance strategies such as predictive maintenance are very useful in increasing the reliability and availability of critical assets. By better understanding your equipment and identifying when it will begin to wear down, you will know what you can do to prevent a machine breakdown. Ultimately, machines that are operated in the optimum condition by people who know how to interact with them are highly unlikely to cause safety problems.

3. **Keep Your Facility Tidy and Organized**

It is common to race the clock throughout the day. In a plant where many people are operating large machines and each individual is trying to work at the quickest possible speed to make progress on the busy schedule, accidents can occur that otherwise could have been prevented. This might involve empty boxes obstructing a lane, spilled liquid that will be cleaned later, wires and tape that will be put away as soon as the next order is filled, etc. During the pressure of the day, it's understandable that organizing and cleaning tasks may get pushed back to whenever one has time. In the end, though, this can be a big safety concern.

Keep in mind that a facility's safety is increased tenfold the moment an operation makes cleanliness and order the main focus. By acting on spills and accidents as soon as they happen, the hazard is almost removed completely. When each team member does his or her part, everyone can have more peace of mind. Waiting for someone to get seriously injured before introducing necessary changes is simply bad practice.

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STARTUP COMPRESSOR SYSTEMS/EQUIPMENT

Plant & Machinery Pre-Start Checklist

As a responsible operator, running a pre-start check on your plant or machinery before you start the day is the best way to ensure the job gets done safely and without delay.
Undertaking a pre-start check on your machine before you start a days work, happens in three stages.
Step 1 - Visual inspections of important features prior to starting the machine

Step 2 - Visual & function tests while the machine is turned on but stationary
Step 3 - Testing the machine's functions during a short drive
Within each of these steps there are activities that are common to all pre-start checks. We itemised them below and we then go into a few examples of extra items that are unique to those machine classes.
The following items are on all pre-start checklists for plant and machinery and are universal whether they are done on paper or electronically. We then review the slight tweaks you need to make in three pertinent examples - Pre-Start Checks for Excavators, Pre-Start Checks for Forklifts and Pre-Start Checks for Mobile Cranes.

Step 1 - Before turning the machine on:

The following checks need to be made while the engine is off and we recommend that they are done in the following order.

Important Features

- ✓ Inspect Hydraulic Lifts & Tilt Rams (if applicable) - are these lubricated and carry no damage?
- ✓ Battery - are the bracket terminals secure and clean?
- ✓ Are the battery electrolyte levels correct and caps in place?
- ✓ Is the battery charge sufficient for a day's work?

After these steps there are then a bunch of machine specific steps that are unique to each class of machine that you will need to visually inspect prior to turning the machine on. This involves things like the tracks, booms, arms and ground engaging tools.

Safety Fittings and Features

- ✓ Seat and Seatbelt - working and no damage?
- ✓ Data Plate - is it readable?
- ✓ Warning Decals - are they readable?
- ✓ FOPS & ROPS - are they secure and in good condition?

Coolant, Oil & Fuel Levels

- ✓ Engine Oil Level - correct?
- ✓ Fuel - enough for the day?
- ✓ Transmission Oil Level - correct?
- ✓ Hydraulic Oil Level - correct?
- ✓ Coolant Level Correct for temperature?
- ✓ Fluid Leaks - ensure there are no fluid leaks under the machine

Attachment Security

- ✓ Attachments like Buckets, Brooms, Spreader Bars etc - are they secure and the pins secure?
- ✓ Is there any damage to attachments that is visible? Make a note
- ✓ Ground Engaging Tools and surface (such as tracks, buckets etc) - is the cutting edge loose or worn?

At the end of these basic checks, plus the visual inspections you make that are specific to the machine you are checking, then it's time to turn the key. Make note of how smoothly it started and whether it's running well at the point of start.

Step 2 - After turning the machine on:

Now, it's time to get that machine purring and run through the final safety inspections.

General Functions (common to all machines)

Horn - does it work? And is there any issue with its volume?
Hand Controls - do they operate correctly?

- ✓ Foot Pedals - are they clean and do they operate correctly?
- ✓ Control Panel - are there any issues with warning indicators, lights and gauges?
- ✓ Reversing Beeper - does the machine operate in reverse? And do the beepers work?
- ✓ Lights - do they work? Can they operate on spot or drive mode?
- ✓ Rotating Warning Light - is it operational?
- ✓ Park Break - does it hold the machine on an incline?

After these general checks, we are going to run through a bunch of unique features with your machine - like operating the boom, bucket, rippers or GPS if these are fitted to the machine. We'll discuss these below.

Step 3 - While driving the machine now:

To complete the final checks you need to drive the machine a small distance.

- ✓ Is the steering working well with no undue noise/stress?
- ✓ Steering clutches - is there no excessive play?
- ✓ Creep - the machine doesn't creep when controls are neutralised

CONTROL AND MONITOR THE COMPRESSOR

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SHUT DOWN COMPRESSOR

How to Plan for Plant Maintenance Shut-Down

Some factories temporarily shut down each year for scheduled plant maintenance shut-down. Within that period of time, the plant floor is cleaned, equipment is inspected or replaced, processes are improved, and/or production lines are added. The "off-line" time can be detrimental, or advantageous, to your bottom line depending if a plan is properly prepared and executed through these 5 phases.

Phase I: Define and Implement Strategies for Plant Maintenance Shut-Down

- ✓ Provides a foundation for the goals of your plant maintenance shut-down.

- ✓ Analyzes how frequently plant maintenance must be performed to allow the production process to function optimally.
- ✓ Estimates how long plant maintenance shut-down must occur, and assesses the best time for plant maintenance shut-down to occur, in relation to manufacturing forecasts. Plant maintenance shut-down is a long-term business strategy – not a "week of" decision.
- ✓ Key drivers of plant maintenance shut-down:
    - Improve equipment to reduce waste in manufacturing resources, thus reducing operating costs.
    - Improve overall equipment effectiveness (OEE).
    - Maintenance equipment to sustain its equipment life cycle.
    - Maintenance equipment to improve mean time between failure (MTBF).
    - Equipment inspection.
    - Equipment repair.
    - Replacement of worn equipment.
    - Replacement of broken equipment.
    - Replace depreciated equipment (ie: Equipment that has reached the end of its useful life).
    - Ensure compliance with health & safety codes.
- ✓ Be mindful of and create a budgetary buffer for the fact that unexpected issues will be found internal to the system, once maintenance inspections have begun.
- ✓ Appoint a steering committee to lead the plant maintenance shut-down. That committee should host meetings with executive management to assess how the maintenance shut-down will impact the greater good of the company, and to assess what Key Performance Indicators (KPIs) are most important to the company's long-term business goals. Typical KPIs include safety, cost, production scheduling, labor hours, overtime hours, lead times, and more. By assessing KPIs, a business can prioritize its investments in system components, based on level of importance to the business' common, overarching goals. (Example: If the goal is to increase capabilities at bulk bag loading stations, a wise investment would be in a flap diverter to double the loading capacity capabilities. A less appropriate investment would be in a new silo of equal size above the loading station, if that silo was still capable of efficiently holding materials.)
- ✓ Make a list of all equipment parts that should be up for debate. Categorize those list items based on what items are required for maintenance to remain compliant with agency guidelines, and which improvements are "a la carte" to benefit the system's goals, ranking in level of importance. Use data analysis to determine what equipment areas are "bottlenecks" and more degrading to efficiency, in comparison to the rest of the system. Upon analysis of improvement priorities, finalize what improvements will be made during the curing system shut-down by adding them to the CMMS (Computerized Maintenance Management System). Those improvements that were opted against for this shut-down should be noted, so that they can be re-considered for the next system shut-down.

- ✓ Be sure the improvements being made during plant maintenance shut-down can only be done during full shut-down. If a task can be performed while the system remains active, the company is not best utilizing their shut-down resources.
- ✓ Document the estimated costs, down-time schedule, list of jobs, and estimated resources needed to complete the shut-down project. This allows the company to anticipate the full scope of the project. Have this agreement approved by the shut-down steering team and the company executive team before the project is to begin. Once approved, disseminate the information throughout the organization, so that there is project transparency across company sectors.

Phase II: Plant Maintenance Shut-Down Preparation

- ✓ Develop plans for how the maintenance will be performed, prior to project execution. To reinforce the improvements being made, consider adjusting the company's environmental, health and safety plans. Analyze the different manufacturing departments to determine if they can be optimized or otherwise improved in any way. Determine the logistics on what materials are needed for the shut-down project, when they will arrive on-site, how they will arrive on-site, and who will be working on this equipment during the shut-down. Make sure equipment and materials are ordered early, so that the shut-down is not delayed. Consider how the equipment and materials will be stored until they are called upon during shut-down.
- ✓ Develop plans for quality assurance. This provides standard procedures for quality control techs, so that they can inspect new equipment after system shut-down has concluded, to be sure the equipment is running safely and efficiently.
- ✓ Using information from Phase I, develop the work package. A work package details the job scope, the number of laborers assigned to the shut-down project, the estimated number of labor hours needed for project execution, and scheduling of task completion. This includes a detailed, step-by-step instruction plan on how the project will be complete. Include safety steps and precautions to be taken, drawings of the project at-hand, and photos to support how each sub-project will be completed most effectively.
- ✓ Determine what steps of the shut-down will be completed using internal resources, and which project stages will external resources be necessary. For those jobs demanding external resources, begin fielding bids from contractors for such jobs. (Example: Contracting a crane company to remove valves from line.)
- ✓ Create contingency plans, to account for any risks or problems that may occur during plant maintenance shut-down.
- ✓ Determine any necessity work that must be done pre-shut-down. Complete those jobs, so that they are ready to accommodate the shut-down improvements, when called upon. (Example: If adding a production line, prepare new piping to run toward the inlet and outlet of new equipment.)
- ✓ If Phase II is done correctly, a full, detailed schedule of the plant maintenance shut-down will be complete, and cost figures will be estimated within approximately 10 percent of budget allocations.
- ✓ Have plans approved by both the shut-down steering committee and the company executive team. Once approved, communicate Phase II to each of the company's departmental sectors, to create project transparency.

- ✓ It is also important to consider the effects the shut-down may have on your customers and constituents. If the shut-down will have a direct impact on the customer, frequent and effective communication is crucial. Update your customers regularly throughout the process to reduce the risk of dissatisfaction and future loss of business.

Phase III: Execution of the Project

- ✓ As previously discussed, once the project begins, it is the inevitable that undetected and unpredictable findings will arise during inspection. On the fly, it is important to assess these issues to determine the necessity of their repair, the costliness of their repair, and how they will affect the overall scope of completion for the original project. Be sure to stay true to the work package, to avoid working over-budget, and to be sure the important projects are brought to fruition during the allotted project time schedule.
- ✓ Be sure the internal and external resources on the project are well-managed, so that the project is being executed efficiently.
- ✓ Update the work package schedule daily, so that resources who finish their tasks early can be re-delegated to assist on tasks that are understaffed, not begun, incomplete, or otherwise behind schedule. Prioritize which projects are more pertinent to the project's overall success, as well as which projects are more or less time-consuming. This creates a planned sequence for job tasks. Continuously update the package, so that communication across the project team is transparent for what projects have or have not been completed, and which projects are currently in progress.
- ✓ Track data to compare with the pre-determined KPIs – ie: actual vs. estimated labor hours, actual vs. estimated overtime hours, actual costs vs. budgeted costs, etc. This data is critical to project progression, in order to maximize costs and labor utilization. For example, if the project is developing too slowly and the staff is at maximum utilization plus ample overtime, it may be necessary to contract more resources to assist on the project. Oppositely, as the project comes to an end, often times, only a few tasks remain. In many instances, the crew becomes overstaffed for completing these minor tasks. KPI analysis allows the project supervisor to determine when resources are not being fully utilized, so that they can make the decision to cut resources for project cost efficiency.
- ✓ Once improvements and repairs have been complete, the system must be tested to be sure all improvements are running as predicted.

Phase IV: Start Up & Turn Over

Part I: Handoff

- ✓ Once testing has been complete by the shut-down team, the operations team is introduced to the new system. Then, the operations team runs testing on the full asset base to be sure the process was actually improved. The shut-down team stands by as tests are performed, to provide technical support, if necessary.

Part II: Ramp Up

- ✓ Once testing has been complete by the operations team, trials runs are performed by the system, so that the equipment can be observed in-operations and adjustments can be made accordingly. This stage is arguably the most important aspect of plant maintenance shut-down, as it is the time when errors are most likely to occur, and it is the most important aspect of the project because it determines how the system as a whole will operate and stabilize, moving forward.

Part III: the Punch List

- ✓ Once the shut-down team and the operations team are satisfied with the results of the shut-down, the shut-down team does a final walk-through to assess what tasks on the project list were completed, and which ones were not. Because of budgetary issues and un-predictable issues, it's nearly impossible to finish all items on the punch list. However, by determine what items were not complete during this shut-down, it creates a starting point when planning the next system shut-down.

Phase V: Evaluation

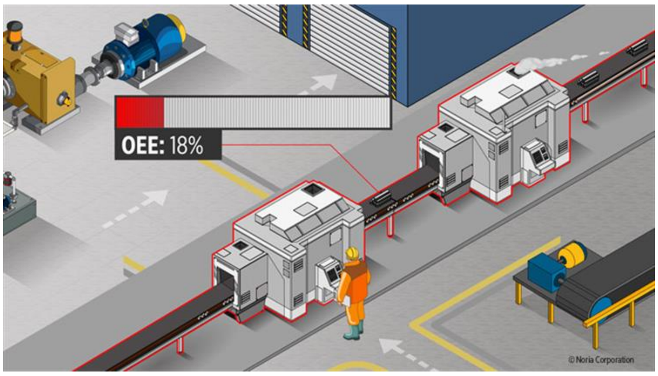
- ✓ Demobilize the work site: Plan the logistics for returning any external resources or equipment. Determine how unused resources will be disposed. Clean the work site to prepare it for operations. Get rid of the equipment removed from the system. Tear down any trailers/offices constructed for the purpose of the maintenance shut-down (ie: Those assembled to house external work teams).
- ✓ Host a post-mortem meeting to summarize the success/failures of the shut-down project. Detail the work that was complete, what remains to be complete, and lessons learned on the project. Assess the KPIs and determine the efficiency of the project's completion, to learn from the data to better shut-down practices for next time. The premise is that if best practices can be determined, fewer problems and unforeseen complications will arise during upcoming projects, making the project streamlined of error or ambiguity.
- ✓ Finally, tie up the loose ends of the project. For bookkeeping purposes, close purchase orders, work orders, external resource contracts, or any other financial paperwork that must be processed for project completion. Keep records of how much material was used versus quantities returned upon project completion, so that more accurate material quantities can be ordered when they are needed for the next shut-down project.
- ✓ Make a cost analysis document to directly compare estimated/budgeted costs versus actual costs. Based upon this analysis, draw conclusions on how the numbers can be more accurately aligned on future projects.
- ✓ Over time, until the next shut-down is to occur, continuously monitor the equipment that was improved during the previous shut-down. This helps to justify the effectiveness of decision making in previous shut-down(s), and gives insight on major equipment categories that are most impactful for improving the asset base.

  Because career changes occur, it is unlikely that the same shut-down team will work on multiple projects – especially consecutively. This is why thorough and formal documentation is necessary throughout each phase of shut-down, as it serves as an "instruction manual" for the team(s) to follow. The key factors to successful plant maintenance shut-down are simple: Outstanding management, repeatability, and consistency. If the best practices are streamlined, understandable and attainable for any team, regardless of ever-changing resources, shut-down projects themselves will also be well-oiled machines.

MAINTAIN PLANT EFFECTIVENESS

What is Overall Equipment Effectiveness (OEE)?

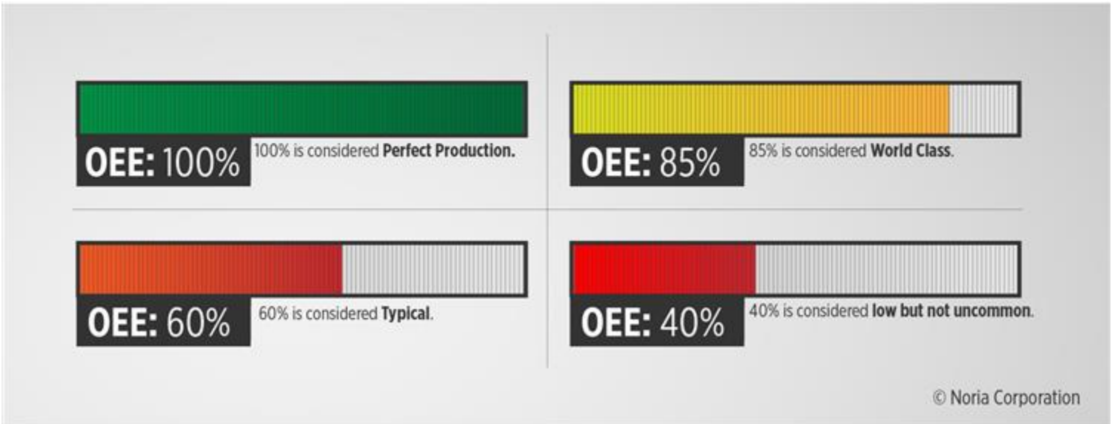
Overall equipment effectiveness (OEE) is a term used to evaluate how efficiently a manufacturer's operation is being used. In other words, overall equipment effectiveness helps you notice a problem in your operations, identify which percentage of manufacturing time is actually productive and fix it while giving you a standardized gauge for tracking progress. The goal for measuring your OEE is continuous improvement.



How to Use Overall Equipment Effectiveness (OEE) to Measure Manufacturing Productivity

Overall equipment effectiveness is a powerful figure. It provides a lot of information in one number, so there are multiple ways OEE is used to measure manufacturing productivity. When calculated and interpreted correctly, it can significantly maximize your production. Overall equipment effectiveness is used as a benchmark to compare any given production to industry standards, in-house equipment or other shifts working on the same piece of equipment. Standard OEE benchmarks are as follows:

- ✓ An OEE score of 100 percent is considered perfect production, meaning you're only manufacturing quality parts as quickly as possible with no downtime.
- ✓ An OEE score of 85 percent is considered world class for discrete manufacturers and is a sought-after long-term goal.
- ✓ An OEE score of 60 percent is typical for discrete manufacturers and shows there is considerable room for improvement.
- ✓ An OEE score of 40 percent is considered low but not uncommon for manufacturers just starting to track and improve performance. In most cases, a low score can easily be improved through easy-to-apply measures.



Overall Equipment Effectiveness is not only a great tool for managers but can have a significant impact on employees working the plant floor. Plant floor metrics can include:

- ✓ **Target** - A real-time production target
- ✓ **Actual** - The actual production count
- ✓ **Efficiency** - The ratio of target to actual; the percentage of how far ahead or behind production is
- ✓ **Downtime** - This includes all unplanned stoppage time for each shift and is updated in real-time.

Overall Equipment Effectiveness: Terms to Know

Before we discuss overall equipment effectiveness further, there are some important terms to be aware of.

- ✓ **Fully Productive Time** - Production time after all losses are subtracted
- ✓ **Planned Production Time** - The total time your equipment or system is expected to produce
- ✓ **Ideal Cycle Time** - The time it takes to manufacture one part
- ✓ **Run Time** - The time your system is scheduled for production and is running
- ✓ **Total Count** - The total of all parts produced including those with defects
- ✓ **Good Count** - Parts produced that meet quality-control standards
- ✓ **Good Parts** - Parts produced that meet standards and don't need to be redone
- ✓ **Quality** - This refers to manufactured parts that don't meet quality-control standards, including ones that need to be reworked. It is calculated as *Quality = Good Count / Total Count.*
- ✓ **Performance** - This takes into account the number of times there are slowdowns or brief stops in production. A perfect performance score in OEE terms means your operation is running as quickly as possible. It is calculated as *Performance = (Ideal Cycle Time x Total Count) / Run Time.*
- ✓ **Availability** - This takes into account planned and unplanned stoppage time. A perfect availability score means your operation is constantly running during planned production times. It is calculated as *Availability = Run Time / Planned Production Time.*

How to Calculate Overall Equipment Effectiveness (OEE)

Before calculating overall equipment effectiveness, it's important to denote the difference between the terms *effectiveness* and *efficiency* when discussing OEE.

Effectiveness is the relationship between what could technically be produced and what is actually produced at the end of a production period. For example, if your machinery is capable of making 100 products an hour and it only makes 80, then it is 80 percent effective.

However, this doesn't tell us how *efficient* the machinery is because we didn't consider things like the number of operators, energy and the materials needed to reach 80 percent effectiveness. For example, if your machinery runs 60 percent effective with one employee and becomes 75 percent effective with two employees, the effectiveness increases by 25 percent, but efficiency decreases to 50 percent based on labor.

There are two main ways to calculate OEE:

- ✓ **Simple Calculation:** The easiest way to calculate OEE is the ratio of fully productive time to planned production time. It looks like this: *OEE = (Good Count x Ideal Cycle Time) / Planned Production Time.*
- ✓ **Preferred Calculation:** This type of OEE calculation is based on the three OEE factors discussed earlier – availability, performance and quality (good count). It looks like this: *Availability x Performance x Quality = OEE*. This is the preferred calculation method because not only do you get your OEE score showing how well you're doing, but you get three numbers (availability, performance and quality) showing what caused your losses.

What Are the Six Big Losses When It Comes to Overall Equipment Effectiveness (OEE)?

Perhaps the biggest goal of implementing an OEE program is to reduce or eliminate the most common causes of machine- or equipment-based productivity loss, known as the six big losses. These six losses are broken down into the three main OEE categories (availability, performance and quality).

Availability Loss	**Equipment Failure**
	Setup and Adjustments
Performance Loss	Idling and Minor Stops
	Reduce Speeds
Quality Loss	Process Defects
	Reduced Yield

Available Losses

- ✓ **Equipment Failure:** This is equipment that is not running when it is scheduled for production, causing unplanned downtime. Machine breakdowns, unplanned maintenance stops and tooling failure are common examples.
- ✓ **Setup and Adjustments:** This is production downtime due to changeovers, machine and tooling adjustments, planned maintenance, inspections and setup/warmup time.

Performance Losses

- ✓ **Idling and Minor Stops:** Sometimes called small stops, idling and minor stops are when equipment stops for a short period of time. This can be caused by jams, flow obstructions, wrong settings or cleaning. These issues are usually resolved by the operator.
- ✓ **Reduced Speed:** Sometimes referred to as slow cycles, reduced speed is when equipment runs at speeds slower than the ideal cycle time (the fastest possible time). Worn out or poorly maintained equipment due to poor lubrication practices, substandard materials and bad environmental conditions are common causes of reduced speed.

Quality Losses

- ✓ **Process Defects:** This refers to any defective part manufactured during stable production, including scrapped parts and parts that can be reworked. Incorrect machine settings and operator or equipment errors are common reasons for process defects.
- ✓ **Reduced Yield:** Reduced yield refers to defective parts made from startup until stable production is achieved. Like process defects, this can mean scrapped parts and parts that can be reworked. Reduced yield most commonly occurs after changeovers, incorrect settings and during machine warmups.

Five Benefits of Using Overall Equipment Effectiveness (OEE) to Improve Production

Implementing an overall equipment effectiveness strategy is a powerful advantage in achieving your production targets. It allows you to take a proactive approach by tweaking manufacturing processes in real time, reducing downtime, increasing capacity, reducing costs, improving quality and increasing efficiency. Let's take a look at 10 benefits of OEE.

- ✓ **Return of Investment (ROI) for Equipment:** Companies invest heavily in machinery, so it's important to maximize the return on this investment. If you can use an OEE strategy to produce 15 percent more product on the same equipment in the same amount of time, it can greatly impact your bottom line.
- ✓ **Increase Competitiveness:** Manufacturers always strive to reduce losses during production to achieve maximum competitiveness. Using data from an OEE report helps you identify bottlenecks or weaknesses in production, allowing you to take immediate action.

  Quality and competitiveness go hand-in-hand, and OEE's quality metric can help you identify problems in production causing scrap or rework parts.
- ✓ **Cutting Machinery Costs:** An OEE strategy helps you understand your equipment's actual performance so you know whether it is working efficiently. It also alerts you to issues that may lead to future breakdowns and repairs. Overall equipment effectiveness lets you anticipate potential machine failure, reducing maintenance costs and downtime.
- ✓ **Maximize Workforce Productivity:** Use OEE to see why you experience operator downtime, reveal productivity data and pinpoint long changeovers or setup times. Information like this helps you appropriately allot resources, identify where excess capacity is occurring and determine where you need new hires.
- ✓ **Easily Visualize Performance:** Overall equipment effectiveness emphasizes visibility, letting you visualize production problems instead of having to rely on your best guess. By highlighting the biggest sources of productivity losses into one single percentage, everyone can see what's working and where improvement is needed.

Overall Equipment Effectiveness (OEE): A Case Study

Based out of Fort Collins, Colorado, New Belgium Brewing company started as a small-batch hobby brewery and quickly became the nation's third biggest craft brewery (eighth overall) by 2012. Making popular beers such as Fat Tire amber ale, New Belgium quickly found itself struggling to keep up with demand, especially when it came to bottling. With their brewing operations quickly reaching capacity, New Belgium was struggling to identify efficiencies and inefficiencies in their bottling lines. Their goals quickly shifted toward improving OEE. The goals were as follows:

- ✓ Increase the brewery's ability take advantage of more manufacturing capabilities.
- ✓ Improve Overall Equipment Effectiveness (OEE) so quality products are being produced, production efficiency is managed and make sure the production line is available during scheduled downtimes, package changes and maintenance procedures.
- ✓ Operate the brewery at full capacity and double case production.

New Belgium faced a few challenges when it came to meeting their OEE goals. It didn't have any way to view real-time information during unscheduled downtimes on various equipment, causing slowdowns; The production team were constantly reacting to unscheduled downtime on certain assets; and the bottling operation didn't have the ability to predict capabilities, which would allow them to effectively place brewery staff in certain areas to help meet specific production goals.

Over a five-year span, the brewery implemented a series of manufacturing automation initiatives, including an upgrade to their manufacturing automation software system to help streamline its bottling production and figure out its maximum potential. After an audit, the brewery quickly realized its existing lines are capable of producing 294,000 cases a week, but were only producing 150,000 cases a week due to scheduled and unscheduled downtime.

This issue, coupled with its still archaic manual data recording process, which involved managing paper production logs and spreadsheets, wasn't cutting it when it came to keeping up with the level of production the brewery was facing. They realized using a software-based system for production greatly helped in managing the various beer mixes and packaging options, as well as accurately managing scheduled and unscheduled downtime.

Upgrading their automation system also allowed for the massive amounts of data that was being collected to be put into context, making it easier to analyze and be turned int actionable information. This greater visibility of the overall production picture led to a real understanding of the actual production capacity, which helped predictable order fulfillment.

Finally, New Belgium needed a way to react more quickly to unscheduled downtime. Thanks to the data from the upgraded software, the brewery realized it need to increase its maintenance team by 60 percent. They added a process improvement and analysis team, educated key staff in Kaizen processes and trained other team members in Six Sigma to react to issues more quickly.

New Belgium needed an effective way to gather, processes and analyze data to better benefit its overall business production. It had a significant impact on the brewery's OEE:

- ✓ OEE increased from 45 to 65 percent in a little over two years.
- ✓ Downtime was decreased by over 50 percent.
- ✓ Scheduled run time efficiency increased by 25 to 30 percent.
- ✓ Production weeks broke records by producing 190,000 to 200,000 cases consistently.
- ✓ Packaging area capacity was extended to around 1.3 million barrels a year.
- ✓ The brewery maintained lower operating costs by delaying capital investments.

UNIT 10

OPERATE PROCESS CONTROL SYSTEMS

This unit covers the operation of a centralized control panel. These controllers use a range of control algorithms and multiple control loops. The panel will control multiple vessels/plant items and or products. It will typically be located off plant in a control room

PREPARE FOR WORK

Hazard Identification and Assessment

One of the "root causes" of workplace injuries, illnesses, and incidents is the failure to identify or recognize hazards that are present, or that could have been anticipated. A critical element of any effective safety and health program is a proactive, ongoing process to identify and assess such hazards.
To identify and assess hazards, employers and workers:

- ✓ Collect and review information about the hazards present or likely to be present in the workplace.
- ✓ Conduct initial and periodic workplace inspections of the workplace to identify new or recurring hazards.
- ✓ Investigate injuries, illnesses, incidents, and close calls/near misses to determine the underlying hazards, their causes, and safety and health program shortcomings.
- ✓ Group similar incidents and identify trends in injuries, illnesses, and hazards reported.
- ✓ Consider hazards associated with emergency or nonroutine situations.
- ✓ Determine the severity and likelihood of incidents that could result for each hazard identified, and use this information to prioritize corrective actions.

Some hazards, such as housekeeping and tripping hazards, can and should be fixed as they are found. Fixing hazards on the spot emphasizes the importance of safety and health and takes advantage of a safety leadership opportunity. To learn more about fixing other hazards identified using the processes described here, see "Hazard Prevention and Control."

Action item 1: Collect existing information about workplace hazards

Information on workplace hazards may already be available to employers and workers, from both internal and external sources.

How to accomplish it

Collect, organize, and review information with workers to determine what types of hazards may be present and which workers may be exposed or potentially exposed. Information available in the workplace may include:

- ✓ Equipment and machinery operating manuals.
- ✓ Safety Data Sheets (SDS) provided by chemical manufacturers.
- ✓ Self-inspection reports and inspection reports from insurance carriers, government agencies, and consultants.
- ✓ Records of previous injuries and illnesses, such as OSHA 300 and 301 logs and reports of incident investigations.
- ✓ Workers' compensation records and reports.
- ✓ Patterns of frequently-occurring injuries and illnesses.
- ✓ Exposure monitoring results, industrial hygiene assessments, and medical records (appropriately redacted to ensure patient/worker privacy).
- ✓ Existing safety and health programs (lockout/tagout, confined spaces, process safety management, personal protective equipment, etc.).

- ✓ Input from workers, including surveys or minutes from safety and health committee meetings.
- ✓ Results of job hazard analyses, also known as job safety analyses.

Information about hazards may be available from outside sources, such as:

- ✓ OSHA, National Institute for Occupational Safety and Health (NIOSH), and Centers for Disease Control and Prevention (CDC) websites, publications, and alerts.
- ✓ Trade associations.
- ✓ Labor unions, state and local occupational safety and health committees/coalitions ("COSH groups"), and worker advocacy groups.
- ✓ Safety and health consultants.

Action item 2: Inspect the workplace for safety hazards

Hazards can be introduced over time as workstations and processes change, equipment or tools become worn, maintenance is neglected, or housekeeping practices decline. Setting aside time to regularly inspect the workplace for hazards can help identify shortcomings so that they can be addressed before an incident occurs.

How to accomplish it

- ✓ Conduct regular inspections of all operations, equipment, work areas and facilities. Have workers participate on the inspection team and talk to them about hazards that they see or report.
- ✓ Be sure to document inspections so you can later verify that hazardous conditions are corrected. Take photos or video of problem areas to facilitate later discussion and brainstorming about how to control them, and for use as learning aids.
- ✓ Include all areas and activities in these inspections, such as storage and warehousing, facility and equipment maintenance, purchasing and office functions, and the activities of on-site contractors, subcontractors, and temporary employees.
- ✓ Regularly inspect both plant vehicles (e.g., forklifts, powered industrial trucks) and transportation vehicles (e.g., cars, trucks).
- ✓ Use checklists that highlight things to look for. Typical hazards fall into several major categories, such as those listed below; each workplace will have its own list:
    - General housekeeping
    - Slip, trip, and fall hazards
    - Electrical hazards
    - Equipment operation
    - Equipment maintenance
    - Fire protection
    - Work organization and process flow (including staffing and scheduling)
    - Work practices
    - Workplace violence
    - Ergonomic problems
    - Lack of emergency procedures

- ✓ Before changing operations, workstations, or workflow; making major organizational changes; or introducing new equipment, materials, or processes, seek the input of workers and evaluate the planned changes for potential hazards and related risks.

Note: Many hazards can be identified using common knowledge and available tools. For example, you can easily identify and correct hazards associated with broken stair rails and frayed electrical cords. Workers can be a very useful internal resource, especially if they are trained in how to identify and assess risks.

Action item 3: Identify health hazards

Identifying workers' exposure to health hazards is typically more complex than identifying physical safety hazards. For example, gases and vapors may be invisible, often have no odor, and may not have an immediately noticeable harmful health effect. Health hazards include chemical hazards (solvents, adhesives, paints, toxic dusts, etc.), physical hazards (noise, radiation, heat, etc.), biological hazards (infectious diseases), and ergonomic risk factors (heavy lifting, repetitive motions, vibration). Reviewing workers' medical records (appropriately redacted to ensure patient/worker privacy) can be useful in identifying health hazards associated with workplace exposures.

How to accomplish it

- ✓ Identify chemical hazards –review SDS and product labels to identify chemicals in your workplace that have low exposure limits, are highly volatile, or are used in large quantities or in unventilated spaces. Identify activities that may result in skin exposure to chemicals.
- ✓ Identify physical hazards –identify any exposures to excessive noise (areas where you must raise your voice to be heard by others), elevated heat (indoor and outdoor), or sources of radiation (radioactive materials, X-rays, or radiofrequency radiation).
- ✓ Identify biological hazards –determine whether workers may be exposed to sources of infectious diseases, molds, toxic or poisonous plants, or animal materials (fur or scat) capable of causing allergic reactions or occupational asthma.
- ✓ Identify ergonomic risk factors –examine work activities that require heavy lifting, work above shoulder height, repetitive motions, or tasks with significant vibration.
- ✓ Conduct quantitative exposure assessments –when possible, using air sampling or direct reading instruments.
- ✓ Review medical records –to identify cases of musculoskeletal injuries, skin irritation or dermatitis, hearing loss, or lung disease that may be related to workplace exposures.

Note: Identifying and assessing health hazards may require specialized knowledge. Small businesses can obtain free and confidential occupational safety and health advice services, including help identifying and assessing workplace hazards, through OSHA's On-site Consultation Program.

Action item 4: Conduct incident investigations

Workplace incidents –including injuries, illnesses, close calls/near misses, and reports of other concerns– provide a clear indication of where hazards exist. By thoroughly investigating incidents and reports, you will identify hazards that are likely to cause future

harm. The purpose of an investigation must always be to identify the root causes (and there is often more than one) of the incident or concern, in order to prevent future occurrences.

How to accomplish it

- ✓ Develop a clear plan and procedure for conducting incident investigations, so that an investigation can begin immediately when an incident occurs. The plan should cover items such as:
    - Who will be involved
    - Lines of communication
    - Materials, equipment, and supplies needed
    - Reporting forms and templates
- ✓ Train investigative teams on incident investigation techniques, emphasizing objectivity and open-mindedness throughout the investigation process.
- ✓ Conduct investigations with a trained team that includes representatives of both management and workers.
- ✓ Investigate close calls/near misses.
- ✓ Identify and analyze root causes to address underlying program shortcomings that allowed the incidents to happen.
- ✓ Communicate the results of the investigation to managers, supervisors, and workers to prevent recurrence.

Effective incident investigations do not stop at identifying a single factor that triggered an incident. They ask the questions "Why?" and "What led to the failure?" For example, if a piece of equipment fails, a good investigation asks: "Why did it fail?" "Was it maintained properly?" "Was it beyond its service life?" and "How could this failure have been prevented?" Similarly, a good incident investigation does not stop when it concludes that a worker made an error. It asks such questions as: "Was the worker provided with appropriate tools and time to do the work?" "Was the worker adequately trained?" and "Was the worker properly supervised?"

Note: OSHA has special reporting identifys for work-related incidents that lead to serious injury or a fatality (29 CFR 1904.39). OSHA must be notified within 8 hours of a work-related fatality, and within 24 hours of an amputation, loss of an eye, or inpatient hospitalization.

Action item 5: Identify hazards associated with emergency and nonroutine situations

Emergencies present hazards that need to be recognized and understood. Nonroutine or infrequent tasks, including maintenance and startup/shutdown activities, also present potential hazards. Plans and procedures need to be developed for responding appropriately and safely to hazards associated with foreseeable emergency scenarios and nonroutine situations.

How to accomplish it

- ✓ Identify foreseeable emergency scenarios and non routine tasks, taking into account the types of material and equipment in use and the location within the facility. Scenarios such as the following may be foreseeable:
    - Fires and explosions
    - Chemical releases
    - Hazardous material spills
    - Startups after planned or unplanned equipment shutdowns
    - Nonroutine tasks, such as infrequently performed maintenance activities
    - Structural collapse
    - Disease outbreaks
    - Weather emergencies and natural disasters
    - Medical emergencies
    - Workplace violence

Action item 6: Characterize the nature of identified hazards, identify interim control measures, and prioritize the hazards for control

The next step is to assess and understand the hazards identified and the types of incidents that could result from worker exposure to those hazards. This information can be used to develop interim controls and to prioritize hazards for permanent control.

How to accomplish it

- ✓ Evaluate each hazard by considering the severity of potential outcomes, the likelihood that an event or exposure will occur, and the number of workers who might be exposed.
- ✓ Use interim control measures to protect workers until more permanent solutions can be implemented.
- ✓ Prioritize the hazards so that those presenting the greatest risk are addressed first. Note, however, that employers have an ongoing obligation to control all serious recognized hazards and to protect workers.

Note: "Risk" is the product of hazard and exposure. Thus, risk can be reduced by controlling or eliminating the hazard or by reducing workers' exposure to hazards. An assessment of risk helps employers understand hazards in the context of their own workplace and prioritize hazards for permanent control.

USE OPERATOR INTERFACE

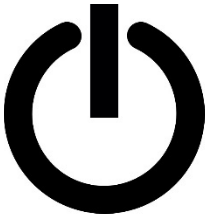
Getting started with your first computer

A computer is more than just another household appliance. The vast amount of information and possibilities can be overwhelming. But you can accomplish a lot with a computer, and using one can be a good experience. Let's walk through getting started with your first computer.

Turning on a computer for the first time can be different from one computer to the next. Your experience could be different from this lesson. It's OK to ask someone for help.

If you're using a desktop computer, you'll need to make sure that the keyboard, mouse, and monitor are plugged into the computer case before you continue. Review our lesson on Setting Up a Computer to learn how.

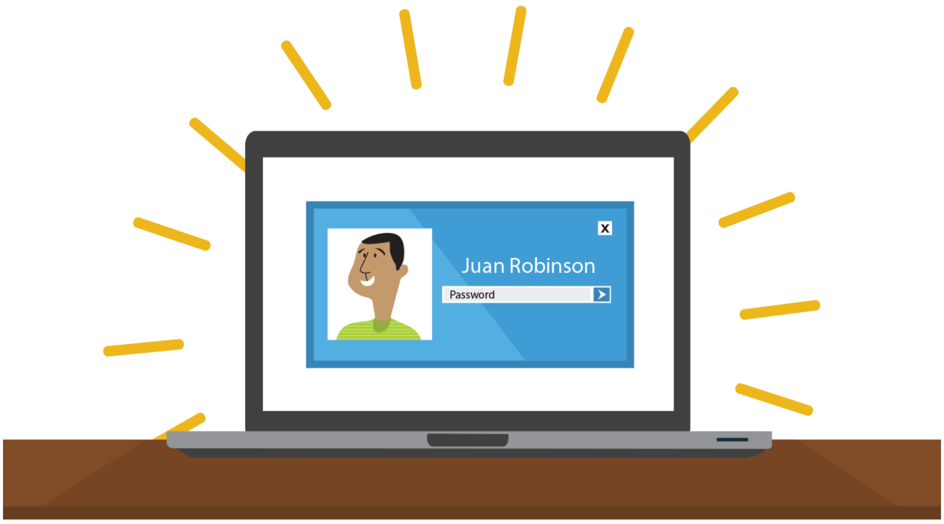
Turning on a computer



The very first step is to turn on the computer. To do this, locate and press the power button. It's in a different place on every computer, but it will have the universal power button symbol (shown below).

Once turned on, your computer takes time before it's ready to use. You may see a few different displays flash on the screen. This process is called booting up, and it can take anywhere from 15 seconds to several minutes.

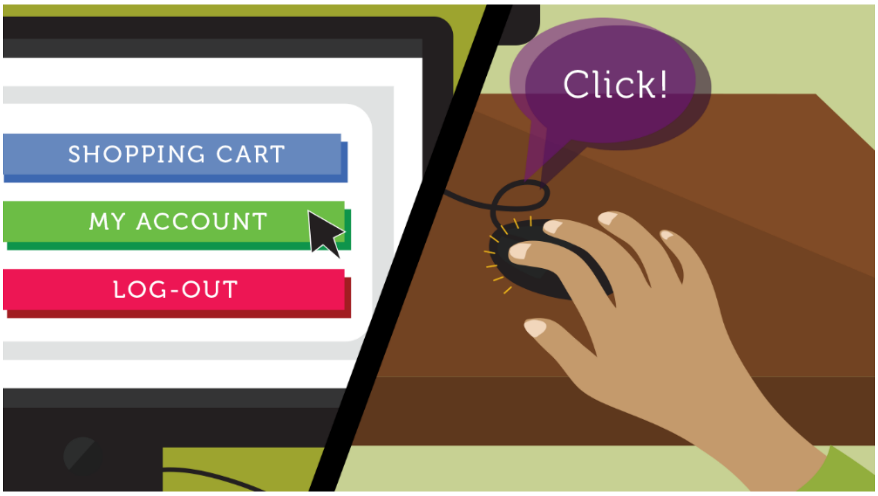
Once the computer has booted up, it may be ready to use, or it may require you to log in. This means identifying yourself by typing your user name or selecting your profile, then typing your password. If you've never logged in to your computer before, you may need to create an account.



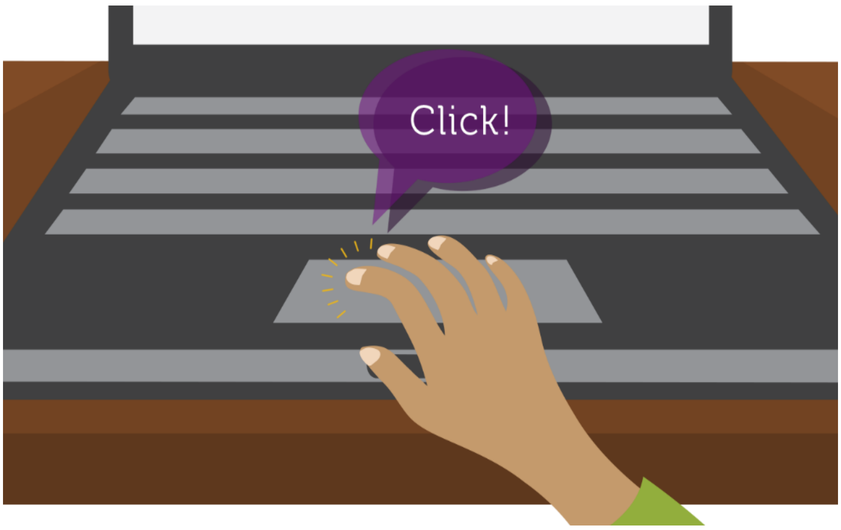
The keyboard and mouse

You interact with a computer mainly by using the keyboard and mouse, or a trackpad on laptops. Learning to use these devices is essential to learning to use a computer. Most people find it comfortable to place the keyboard on the desk directly in front of them and the mouse to one side of the keyboard.

The mouse controls the pointer on the screen. Whenever you move the mouse across the desk, the pointer will move in a similar manner. A mouse usually has two buttons, which are referred to as the left button and the right button. You will often interact with the computer by moving the mouse pointer over something on the computer screen, then clicking one of the buttons.



On laptops, you can use the trackpad, located below the keyboard, instead of a mouse. Simply drag your finger across the trackpad to move the pointer on the screen. Some trackpads do not have buttons, so you'll either press or tap the trackpad to click.



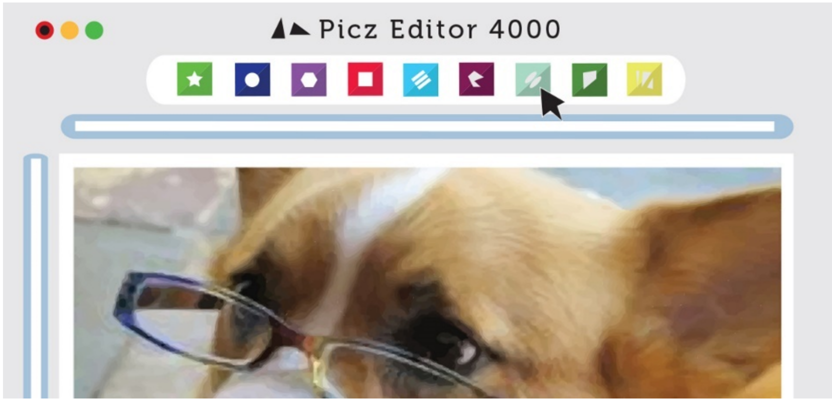
The keyboard allows you to type letters, numbers, and words into the computer. Whenever you see a flashing vertical line—called the cursor—you can start typing.

Note that the mouse

pointer is also called a cursor, but it is shaped differently. The keyboard cursor is also called the insertion point.

Using a computer

The main screen you'll start from is the desktop. This is sort of like a main menu or a table of contents. From here, you can access the programs and features you need to use your computer.
Icons are used to represent the different files, applications, and commands on your computer. An icon is a small image that's intended to give you an idea at a glance of what it represents, like a logo. Double-clicking an icon on the desktop will open that application or file.



A button is a command that performs a specific function within an application. The **most** commonly used commands in a program will be represented by buttons.
Menus are organized collections of commands and shortcuts. Click a **menu** to open it and display the commands and shortcuts within. Then click an item in the **menu** to execute it.

When you open an application or folder, it is displayed in its own window. A window is a contained area—like a picture within a picture—with its own menus and buttons specific to that program. You can rearrange multiple windows on the desktop and switch between them.

ACCESS CONTROL INFORMATION

Inside SCADA Systems

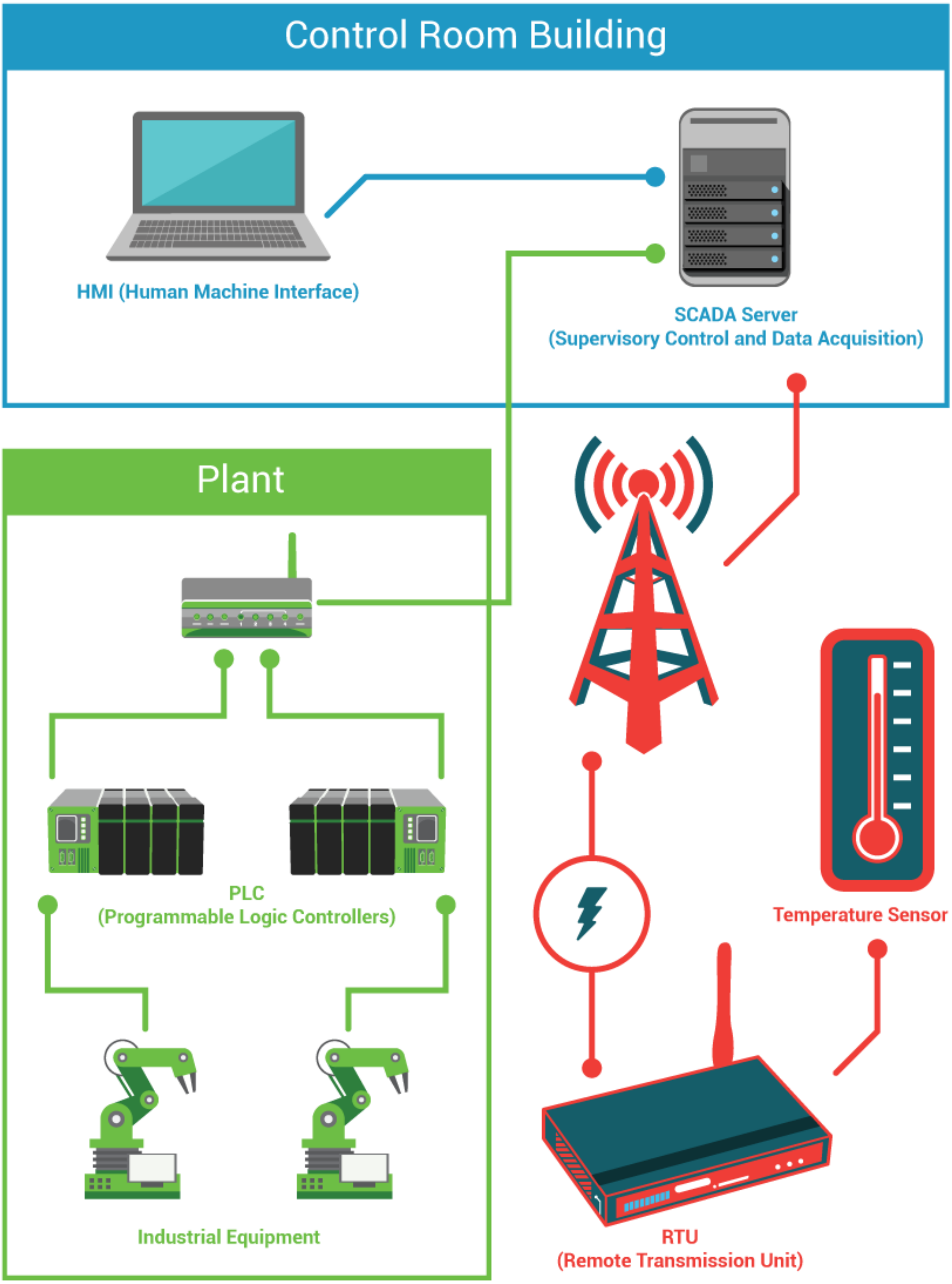
A SCADA (supervisory control and data acquisition) is an automation control system that is used in industries such as energy, oil and gas, water, power, and many more. The system has a centralized system that monitors and controls entire sites, ranging from an industrial plant to a complex of plants across the country. A SCADA system works by operating with signals that communicate via channels to provide the user with remote controls of any equipment in a given system. It also implements a distributed database, or tag database, that contains tags or points throughout the plant. These points represent a single input or output value that is monitored or controlled by the SCADA system in the centralized control room. The points are stored in the distributed database as value-timestamp pairs. It's very common to set up the SCADA systems to also acquire metadata, such as programmable logic controller (PLC) register paths and alarm statistics.

While these systems simplify a given infrastructure, their components are quite complex. There are five essential composing parts of a SCADA system:

- ✓ Human Machine Interface (HMI)
- ✓ supervisory system
- ✓ Remote Terminal Units (RTUs)
- ✓ Programmable Logic Controllers (PLCs)
- ✓ communication infrastructures

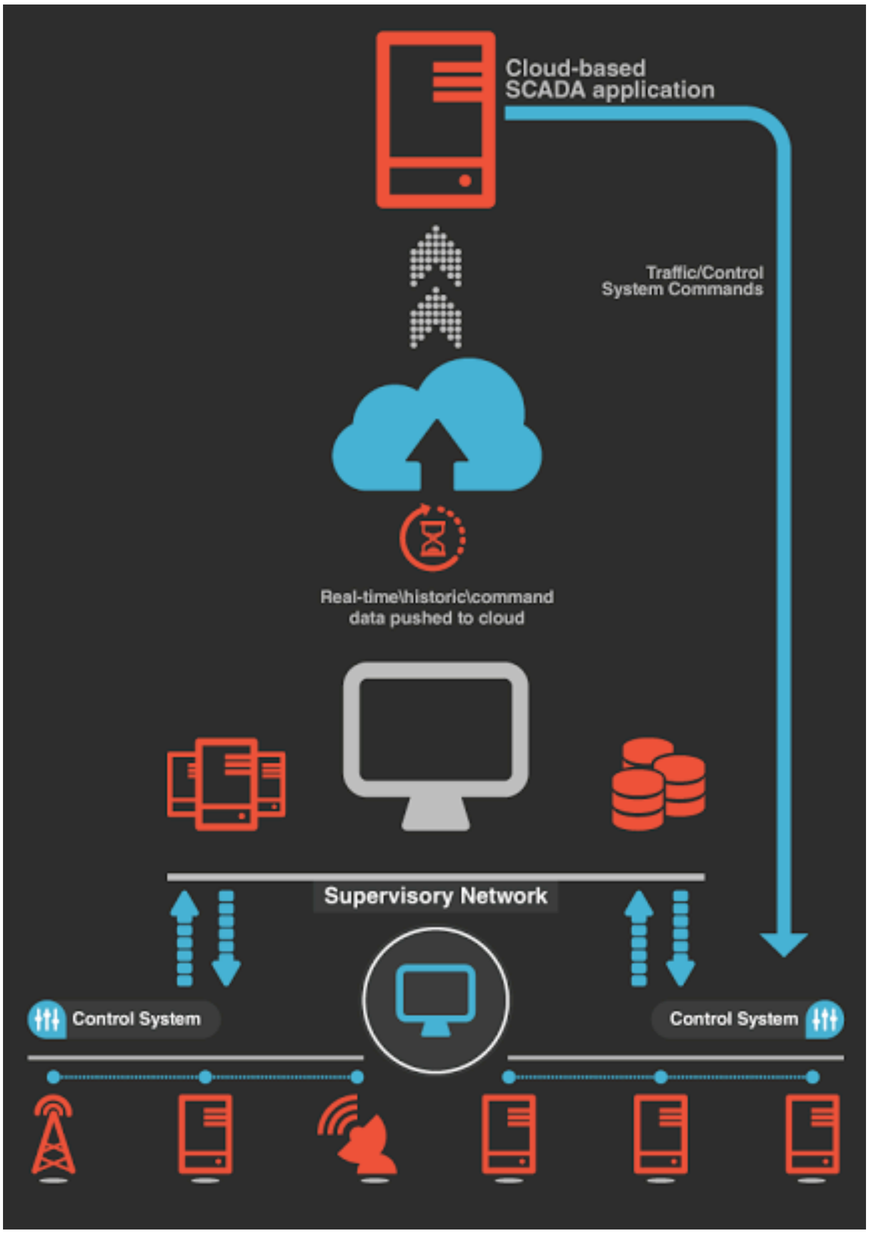
The HMI processes data from each tag and sends it to a human operator, where he or she then can monitor or control the system. The supervisory system gathers the data sent from each tag and sends commands or operations to the process. The RTUs connect sensors and convert their signals to digital data and send it to the supervisory system, where it can be stored in a distributed database. PLCs are used as field devices because they are much more versatile and economical than process-specific RTUs.

Finally, the communication infrastructure delivers connectivity to the supervisory system and then to the RTUs and PLCs for the user to command. The communication infrastructure is necessary to relay data from remote RTU/PLCs, which run along electric grids, water supplies, and pipelines. Communication is the absolute most essential link for a SCADA system to operate properly; however, how well the system manages communication from HMI to RTUs and PLCs fundamentally determines how successful a SCADA system can be. Below is a figure of what a basic SCADA system might look like for a given infrastructure.



Optimizing Performance

While many power, electric, and water companies still use manual labor to perform measurements and adjustments, these tasks can be easily automated with SCADA systems. With utilization from automation in a framework, labor costs can be cut as well as minimize errors with measurements or adjustments. It may seem that SCADA systems just process and store data in a distributed database, but there's much more complexity to the system itself. The system provides numerous benefits over manual labor such as redundancy adjustments, stable backups of time stamped data, and a secure alarm system. Instead of using humans to check for errors throughout the plant, grid, or pipeline, SCADA uses scripts that detect problems in the system, and quickly adjusts the system from creating an outage. If an outage were to occur that slipped past, a SCADA system's distributed database would help workers instantly identify the location of failure. Also, the automation system significantly increases the time of power restoration that comes with an outage; from the control room, at the press of a button, a worker can enable switches and help reroute power to unaffected sections.



SCADA systems now have the available power of cloud computing; these systems can report close to real-time accuracy and use cloud environments to implement more complex algorithms. These algorithms otherwise would not be implementable on traditional PLCs or RTUs. Without even being at the plant, workers can access computing resources such as networks, storage, servers, and equipment controls. Cloud computing can be supported by two ways: The SCADA system is running on-site, connected to the communication infrastructure directly, and delivering information to the cloud or the SCADA system is running completely in the cloud network and remotely connected to the communication infrastructure. As practical as accessing controls to an on-site location might be, cloud computing through SCADA applications is still very vulnerable to cyber-attacks. If the system were hit with an attack, hackers could have access to organizational data and resources that could expose the company and inadvertently push customers to another service provider. Below is a figure of what a common SCADA platform looks like utilizing cloud computing methods.

SCADA Security

While they were once isolated entities that were at the hands of engineers, operators, and system technicians, SCADA systems didn't always prioritize secure connections to public networks, leaving many SCADA platforms open to attack. Today there are numerous standards that are required for a secure SCADA platform to run and be operated by its users. If any of these procedures and standards are not practiced correctly, the SCADA platform can be left open for attacks or viruses. However, even with all of these procedures and practices, there is a huge lack of authentication in the design and operation of some existing SCADA networks. While these systems control electricity grids, gas and oil pipelines, and water distribution, the security of these systems needs to be developed extremely well because it can cause massive problems to many areas of society.

While SCADA platforms provide a vast number of benefits and reductions of cost and downtime of the system, there are still many security threats that need to be worked out. The drive of SCADA platforms is to provide users with quick access to PLCs/RTUs and provide simplistic integration of equipment controls to user interfaces. These systems can be a great tool, but need to be heavily monitored through HMIs. For example, the system can switch a motor or power on or off and can operate the equipment locally.

CONTROL PROCESS VARIATIONS

In today's highly globalized economy, technology allows businesses to transact with consumers outside their geographical boundaries. Companies set up offices offshore to cater to their global clientele and top regional talent. The world is more connected than ever before that even small businesses can hit it big in the global scene. While these advancements due to eCommerce and globalization are great, they come with challenges.

Operating on a global scale also opens businesses to a bunch of process variations. Companies can be subjected to regional or local government regulations. They may need to tweak their processes to accommodate upstream suppliers.

There can be local market-specific needs that require a change in how a certain product or service is done. While process standardization should be every company's goal, the path towards it is not linear.

The Illusion of a Standard Process

Process variations are process management's dirty little secret and there's no surprise why. I remember a project I worked on for the HR department of a broadcasting network. Our goal was to design the payroll management software for their off-camera staff.

As I interviewed each of the process owners for the different staff groups, they all told me, "We have a standard way of doing things." At the back of my mind, I thought, "Yes! This is going to be easy since they have one way of doing things." So I let them detail this "standard process" while I take notes.

As I went back to my desk to map out all the information I got, I realized how "standard" means differently from each of the process owners. They all had a general idea of what their standard process looked like, but when it's time to execute, they each had their way of doing things. Since they were handling different employee groups that had specific payroll needs and terms, they needed to tweak the process to work for them.

What I thought was "easy" turned out to be more complicated than it seems. There were a lot of process variations experienced by this group.

Process variations are experienced by any business at any level. It's hard to make everything fit into a mold. A multinational company may think their procurement processes are uniform across their offices. But there can be nuances that are specific to a regional office. What's worse, one office is doing things very differently than the rest. While these variations are a reality for businesses, it doesn't mean we shouldn't strive for process standardization.

Process variations come with costs and if we are unable to manage them, we can't optimize the capability of our people and systems. What we should do is become aware of the variations that exist and find a way to manage them.

7 Steps to Effectively Manage Process Variations

While we can expect process variations, we are not powerless in controlling them. The key is becoming aware of them and deciding which are necessary and which ones should be eliminated. Here are 7 steps to manage process variations in your business:

1. **Agree on the standard process –** The standard process becomes the foundation to which any process variation can be reviewed and measured against. All process owners involved should agree to what the standard process looks like and use it to govern the implementation and evolution of the process as variations are factored in. Creating your value stream map will help you visualize what your standard process looks like.
2. **Establish local variations based on the standard process –** Local process variant experts should highlight any change that needs to be done from the standard process. It's strongly advised that a business process mapping tool is used by the company to properly visualize and review how local process variants differ from the standard process.
3. **Compare and review all process variations –** Compare all process variations for each standard process and assess which are legitimately needed. We need to ensure that all process variations are visible so that all process owners know what activities have been changed, added, or removed. This also facilitates streamlining activities to further rationalize the process. Comparing and reviewing processes

should be an ongoing thing as we can expect both standard processes and local process variants to evolve.

4. **Ensure easy access to process variations** – Business teams should easily access any process variation according to their specific needs, whether it be for their business unit, location, or team. A platform or tool that automatically routes them to their process variation of choice can be used for this purpose. This capability is particularly important when implementing new processes and onboarding new teams.
5. **Notifications on process changes** – There should be the capability to notify and track any change to the standard process or any of its process variations. This will help process owners to review the changes and determine whether they will be implemented or not.
6. **Enable global reporting** – Standard process champions should have the capability to review and assess all process variations. This allows them to ensure that nuances are controlled and only legitimate process variations are implemented.
7. **Analyze cost and time data** – By tracking costs and time incurred in both standard process and its variations, process champions can make informed decisions on how to further streamline their processes. There can be process variation steps that get implemented as a standard.

There can be process variations that need to be removed because they're incurring significant costs and time delay. These analyses can only be done when data is present.

The Path to Process Standardization

The journey to process standardization starts by having a clear path of what variations lie in your way. By having a clear picture of your process, you have better control of what variations you are going to let in. This helps you become more flexible to the needs of your business but still maintains the level of quality you expect.

Process standardization is not a one-time project. You must develop a continuous process improvement mindset and challenge every process variation that comes your way. Only then will you have a robust process and a solid foundation to which process maturity can be attained.

FACILITATE PLANNED AND UNPLANNED PROCESS START-UPS AND SHUT-DOWNS

Start-up and Shutdown Procedures

Conditions requiring Implementation of Start-up and Shutdown Procedures

Routine Procedures

Most plants keep all filters into service except unit under backwash operation and maintenance. Filter units are routinely taken off line for backwashing when the media becomes clogged with particulates, turbidity break through occurs or demands for water are reduced.

Implementation of Start-up and Shut-down Procedures

1. **Filter check-out procedures**

- ✓ Check operational status of filter
- ✓ Be sure that the filter media and wash water troughs are clean of all debris such as leaves, twigs, and tools.
- ✓ Check and be sure that all access covers and walk-way gratings are in place.
- ✓ Make sure that the process monitoring equipment such as head-loss and turbidity systems are operational.
- ✓ Check the source of back-wash to ensure that it is ready to go

2. **Backwash procedure**

Filters should be washed before placing them into service.

- ✓ The surface wash system should be activated just before the backwash cycle starts to aid in removing and breaking up solids on the filter media and to prevent the development of mud balls. The surface wash system should be stopped before completion of the back-wash cycle to permit proper settling of the filter media.
- ✓ A filter wash should begin slowly for about one minute to permit removing of an entrapped air from the filter media, and also to provide uniform expansion of the filter bed. After this period, the full backwash rate can be applied. Sufficient time should be allowed for cleaning of the filter media. Usually when the backwash water coming up through the filter becomes clear, the media is washed. This generally takes from 3 to 8 minutes. If flooding of wash water troughs or carryover of filter media is a problem, the backwash rate must be reduced

Procedure for back-washing a filter is as follows:

- ✓ Close filter influent valve (V-1).
- ✓ Open drain valve (V-4).
- ✓ Close filter effluent valve (V-5).
- ✓ Start surface wash system (Open V-2).
- ✓ Slowly start back- wash system (Open V3). Observe filter during washing process.
- ✓ When wash water from filter becomes clear (filter media is clean), close surface wash system valve (V-2).
- ✓ Slowly turn off back-wash system (closeV-3). Close drain valve (V-4). Log length of wash and the quantity of water used to clean filter
- ✓ Filter Startup Procedures
- ✓ Start filter slowly open influent valve.
- ✓ When proper elevation of water is reached on top of filter, filter effluent valve should be gradually opened. This effluent control valve should be adjusted itself to maintain a constant level of water over the filter media.
- ✓ Waste some of the initial filtered water if such a provision exists.
- ✓ Perform turbidity analysis of filtered water and make process adjustments as necessary.

3. **Filter Shutdown Procedures**

- ✓ Remove filter from service by closing influent valve and closing effluent valve Backwash filter. If filters to be out of service for a prolonged period,
- ✓ Drain water from filter to avoid algal growth
- ✓ Note of filter in operations log.

Support Equipment

The operator must be familiar/ trained with the operation and maintenance instructions for each specific equipment item or control system.

Types of equipment

1. Filter Control Valves.
2. Backwash and surface wash pumps.
3. Flow meter and level/ pressure gauges.
4. Water quality monitors such as turbidity-meters.
5. Process monitors (head-loss and water level).
6. Mechanical and electrical filter control systems

Equipment operation

Before starting mechanical equipment, such as a back-wash pump, the operator should be sure that the unit has been serviced as per schedule and is fit for operation. After startup, the operator should always check for excessive noise and vibrations, over-heating, and leakage (water, lubricants) otherwise, in doubt about the performance of equipment, check/refer to manufacturer's instructions. Periodical lubrication and maintenance of the equipment's are necessary.

RESPOND TO ALARMS OR OUT OF SPECIFICATION CONDITIONS

Do You Have the Tools to Analyze Abnormal Operating Conditions (AOCs)?

As we approach 2020, you may be viewing the new year as a fresh opportunity to address your Alarm Management program in the pipeline control room. Specifically, how to address Abnormal Operating Conditions (AOCs).
We have heard from control room managers on several issues related to AOCs, including:

- ✓ Lack of a clear definition of AOCs
- ✓ Same AOCs occurring repeatedly
- ✓ Controllers unable to respond to AOCs in a timely manner
- ✓ AOCs not recorded properly in the SCADA system
- ✓ Lack of tools to review and analyze AOCs

Set a Goal to Address Specific AOC Issues

Each pipeline control room is different. Take time to identify the most prevalent AOC-related issue that you need to address in 2020. Then, prioritize the next most important issues you need to address to support your Alarm Management program.
Consider these common situations and what steps you can take to elevate your control room response to AOCs to support safety, compliance, and operational objectives.

1. Lack of Clear Definitions

A root issue for how your control room handles AOCs could be a lack of understanding of the actual definition of an AOC.
Create clarity in the control room by relaying the definition that an Abnormal Operating Conditions is an operating condition of the pipeline outside the normal operating parameters, but not yet an emergency.
Additionally, an abnormal operating condition may indicate a malfunction of a component or deviation from normal operations that may (a) indicate a condition exceeding design limits or (b) result in a hazard(s) to persons, property, or the environment.

2. Repeated AOCs

For many control rooms, the same AOCs occur repeatedly on a regular basis. Controllers become desensitized to this example of alarm flood and cannot separate actual alarms from the bad actors.
Your goal should be to remove unnecessary triggers that generate a high number of alarms in the SCADA system. By removing these bad actors from the system, controllers can maintain focus on actual alarms associated with an AOC.

3. Lack of Timely Response

A byproduct of alarm flood in the control room is slow response time to important AOCs.
Your controllers may be slowed down in either identifying AOCs or responding to AOCs because of the bad actors. Ensure that controllers can achieve situational awareness in a timely manner by evaluating response time to actual alarms.

4. Inconsistent Recording of AOCs

Proper recording of AOCs in the SCADA system is critical to support analysis, compliance, and safety.
However, if control room personnel do not have a clear definition of AOCs, they may be challenged to understand how to record the alarms they are seeing.
Or, if you lack clear policies and procedures for identifying and responding to AOCs, there may be inconsistencies in how AOCs are recorded in the SCADA system.
Ensure that your team has a clear understanding of the importance of accurate recording to support your objectives for analysis, compliance, and safety.

5. Lack of Tools to Analyze AOCs

The quality of your recordkeeping feeds into your ability to analyze the AOCs. Control room managers need to be able to review and analyze AOCs to identify issues surrounding alarm flood, bad actors, controller response time, and recordkeeping.

This ties into the importance of alarm rationalization, which is the process of documenting the alarm-specific process to verify, diagnose, determine causes, and take the appropriate course of action to respond to an alarm. Ideally, the alarm rationalization defines the AOCs that can be associated with the alarm.

Take a step forward by assessing the quality of the alarm rationalization within your Alarm Management program. Look at the alarm response for each controller to see whether the controller is following a specified course of action when presented an alarm through the SCADA system on their HMI display. Ideally, the controller will follow the rationalized procedure each time.

If you lack tools to perform this analysis, talk to our company about implementing or updating software to support your control room. Our POEMS Control Room Management Suite (CRM Suite) includes a module to manage the pipeline alarm rationalization process so that you can perform informed analysis of the AOCs.

UNIT 11

MONITOR AND OPERATE WATER DISTRIBUTION SYSTEMS

In this scenario operations technicians maintain a watching brief over the network from the control Centre. The centre will be the hub for network activities in order to achieve minimum risk to continued safe and efficient operation of the network

GATHER INFORMATION ABOUT NETWORK OPERATIONS NEEDS

Operational Data Gathering

Access to accurate, timely data regarding safety, quality, maintenance and performance metrics has never been more important. Manufacturers need up-to-the-minute information from the factory floor to operate with the agility today's volatile environment requires. Foreknowledge of surfacing trends, critical issues, and operational efficiency can make or break a manufacturing organization.

However, many organizations struggle to get their data collection balance right. Often the challenge is not a lack of access to data but rather the ability to collect the right data and to put it to work in the right way. Below, we've gathered steps to help you identify vulnerable areas in your inspection processes and increase the structure and efficiency of your data collection operations.

1. **Consider the kind of data you need to collect**

Most manufacturers already gather massive quantities of data on a regular basis. Prioritizing information is the first step in better data collection. Begin by classifying what kind of data you're collecting. This will help you define the most significant data. For example, if you're collecting safety inspections, your key data will involve the number of violations per quarter, the number of accidents in a year, and so on.

2. **Set goals for your data**

Establish goals for your data. In the above example, the goal of collecting safety data would be to prevent accidents. The purpose of collecting customer surveys would be to improve satisfaction and enhance sales. Likewise, gathering performance metrics would strive to improve your manufacturing processes. Once you've defined your goals, determine how you will measure your success.

A great way to do this is to outline your top-level organizational goal, such as "improve overall workplace safety," and allow each division or team to set their own OKRs (Objectives and Key Results). Each team can then prepare a numerical stretch goal and compare their outcomes against it, like reducing the number of safety incidents or accident-related downtime by a set amount. Setting clear objectives ensures that you're collecting the right data and sets you up to get the most out of analyzing it.

3. **Standardize your process**

In manufacturing, consistent processes are at the core of most operations, and data collection should be no different. Define a consistent, reliable process for collecting data. Your data collectors should all do the job in the same way. Variance in practice can lead to erroneous numbers, and volatility makes data unreliable or unactionable. It's critical to ensure that everyone collecting data on your behalf knows the procedure and is familiar with the organization's standards.

4. **Optimize your tools**

Better manufacturing data collection begins with using the right tools and tuning them for peak performance. Highly customizable, mobile-first electronic forms are key for collecting timely and actionable data. And, as with any tools, optimizing your forms will drive better results. Here are a few tips for designing forms that will help your data collectors make better, smarter choices:

- ✓ Simpler is better. Whenever possible, keep forms short and to the point. Save reference information for other sections. Don't cram dozens of questions on a single page. Single-column layouts are best because they show a clear, unmistakable trajectory to the finish line.
- ✓ Make forms self-explanatory. For an experienced worker in the field, the content of your forms should provide all the information they need to get the job done. Try to refrain from referencing external sources. When in doubt, include examples of the standard within the form. If you're using a mobile forms app, be sure to clearly label where help sections can be accessed.
- ✓ Break up complex questions. If you have conditional questions, or questions that should only be answered based on a previous question's response, keep them separate and clear. If you're working with digital forms, this is a great place to exercise conditional logic.

The cleaner and easier-to-understand your forms are, the higher quality your data will be. If your employees are finding forms hard to understand or feel that they're inefficient, talk to them about potential changes. Better yet, perform user testing to determine how long it takes to fill out a form and which sections prove to be problem areas. Often, it's the people closest to your data collection processes who know where the weak points lie.

5. **Make data actionable**

One of the most significant parts of data collection is also one of the most overlooked—where data goes once it's gathered. Workflows help you ensure that data is actionable right away. When you route data directly into the next logical step, you can dramatically improve productivity.

If a regular inspection uncovers a maintenance issue, that should trigger an automated chain of events. Built-in workflows can initiate a repair order, send an email to the relevant supervisor, and assign a task to the right person, all without any added human-to-computer interaction.

Instead of sending countless emails to get everyone on the same page, a workflow will automatically engage stakeholders. Automated workflows get straight to the point and forgo any unnecessary clarifications. Approvals, escalations, and follow-up tasks automatically trigger based on predefined conditions.

Bringing it all together

In the post-COVID-19 world, you can't afford to miss critical inspection data, especially with so many new guidelines in effect. Data collection in manufacturing is vital to your success and crucial for your employees' health and safety. Getting accurate data from the front lines will allow you to quickly pivot when necessary and make adjustments based on the circumstances. The best way to stay ahead is to shape your data collection processes based on what works for your organization. Make sure to use the right tools, define your processes, and put your data to work.

Alarm system

In industrial plants and installations, control systems are used to monitor and control processes. Control Systems, whether a conventional Control Desk or a Computer/PLCs System with SCADA or a Distributed Control System (DCS), provides a human-machine-interface to monitor and control the plant equipment and processes.
This is why every industrial plant MUST have an alarm system (on photo: Warning lights and alarms sound when any one of three gases is detected by sensitive equipment; credit: transformingedmonton.ca)
Alarm Systems are an integral part of human-machine interface (HMI).
An alarm system consists of both hardware and software including: field signal sensors, transmitters, alarm generators and handlers, alarm processors, alarm displays, annunciator window panels, alarm recorders and printers. Alarm systems indicate the abnormal conditions and problems of the plant and equipment to the operators, enabling them to take corrective action and bring the plant/equipment back to normal conditions.
Alarm systems **give signals to the operators** in the form of audible sound, visual indications in different colors and/or continuous blinking, text messages, etc.
An alarm system brings the following to the notice of the operator //

- ✓ Problems that need operator attention
- ✓ Process changes that require corrective action
- ✓ Unsafe operating conditions before Emergency Shut-down of the plant
- ✓ Hazardous conditions
- ✓ Deviations from desired/normal conditions

Functions of the plant or process operator

An alarm system helps/assists the operators in monitoring and controlling the plant, equipment and processes within safe and normal operating conditions. In order to design a suitable alarm system, it is important to understand the functions of the operator who monitors and controls the equipment and processes in the plant.
Generally, the functions of a plant operator are inclusive of the following activities but are not limited to:

- ✓ Safe and normal operation of plant/equipment
- ✓ Production at optimum levels
- ✓ Identification of abnormal, hazardous and unsafe plant/equipment conditions and taking corrective action
- ✓ Fault identification and communication of faults to maintenance

The above mentioned function and task priorities of a plant operator change with the changing conditions of the plant. For instance:

- ✓ During start-up
- ✓ When the plant is being stabilized
- ✓ When the plant is running under normal conditions
- ✓ When the plant is running in abnormal conditions
- ✓ When the plant is in emergency shut-down
- ✓ When the plant is in planned shut-down,
- ✓ When the plant, or sub-section of plant, is in manual mode of operation
- ✓ During automatic mode of operation

Functions of an alarm system

The main function of an alarm system is to direct the attention of an operator towards the plant abnormal conditions that need timely assessment and/or timely corrective action(s).
An Alarm system alerts, informs and guides an operator regarding an abnormal situation and helps him to take timely corrective action to bring back the plant to normal conditions.
When an abnormal condition arises, the alarm system gives an alarm in the form of an audible warning, flashing or blinking alarm indication and an alarm message. The Alarm gives information about the problem or abnormal condition and its details.
In a good alarm system, guidance or help messages on how to respond and take corrections are also provided.
An ideal Alarm system also provides feedback on the corrective actions taken by the operator in response to the alarm. Such feedback is generally provided on supplementary display screens that can be accessed by selecting an alarm in the Alarm list.

An effective alarm system

For designing an effective Alarm system, it is important to consider the following key points

- ✓ Present only relevant and useful alarms to the operator
- ✓ Each alarm should have a defined response from the operator
- ✓ Configure and present only a good alarm
- ✓ Allow adequate time for an operator to respond to an alarm

Alarm system design

Designing an alarm system is a process. While designing each alarm it is important to consider how important the alarm is and what its reliability should be.
To determine the importance and reliability of an alarm, it is necessary to carry out a qualitative and quantitative risk assessment to consider ***whether the alarm is safety related*** and whether it is to be implemented on an independent stand-alone system as opposed to the process control system.
Safety related alarms should be given special considerations while designing the human-machine interface.

Protection provided by the alarm system

Protection provided by an alarm system can take place in two ways. The operator is warned by the alarm and he/she takes corrective action before the protection operates, or the operator is warned that the protection has failed to operate and he/she takes corrective action.

Safety related alarms

As per the international standard IEC 61508, an alarm system, whether electrical or electronic or programmable, should be considered as safety related only if:

- ✓ It is a claimed part of the facilities for reducing the risk(s) from hazards to people to an acceptable or tolerable level, and
- ✓ The claimed reduction by the alarm system in the risk(s) is significant. Here the significant reduction means a claimed Average Probability of Failure on Demand **(PFDAvg) < 0.1**,
- ✓ It is designed, operated and maintained as per the requirements defined in the standard,
- ✓ It is independent and separate from the process control system, unless the process control system itself has been identified as a safety related system and implemented accordingly.

What is the purpose of an alarm?

1. It is important to know **what the purpose is of the proposed alarm** and for what hazards or risks it will provide a warning or an alert to the operator. The consequences of alarm failure or the alarm being missed need to be identified. If the proposed alarm provides only information of an event/incident, then it should not be configured as an alarm.
2. **Assessment of the severity of the risk** in terms of potential loss of life or an injury, economic losses, environmental impact and plant damages must be done. Any hazard to people should be in the form of formal risk assessment for the plant. Economic risks, potential plant damages or losses should be expressed in terms of financial losses.
3. Expected frequency of the risk occurrence should be estimated. Though it is difficult to know the accurate chances/frequency of occurrence, it may be appropriate to have some approximate estimate that is more realistic. Appropriate frequency of occurrence may be specified as once a week or once in month, etc.
4. **Are there any other protection systems** in the plant to provide protection against the risk? If not, then it needs to be decided whether or not an automatic protective system can be used with or without configuring the alarm.
5. Are any reliability claims made in the plant, in terms of safety and protection, provided by the alarm? Do these reliability claims require the alarm to be classified as a safety related alarm? If an alarm is not safety related, then what are the economic and/or environmental risks involved in implementing the alarm within the process control system?

6. It is important to **know** the implications of alarm failure due to alarm sensor/instrument failure. How then can these failures be detected and can the alarm signal be validated. Should the alarm sensor/instrument be made redundant?
7. How effective will the operator response to the alarm be? If the operator cannot take any corrective or preventive action to prevent the risk, then the alarm hardly provides any benefit and should not be configured as an alarm.

COMMUNICATE NETWORK INFORMATION

Operational technology (OT) – definitions and differences with IT

It's impossible to talk about the evolutions in manufacturing, industrial transformation and Industry 4.0, innovations in areas such as Industrial IoT without mentioning the convergence of IT and OT.

While everyone has a good grasp of what IT is, for people who don't have an OT background might wonder what OT or operational technology really means. Operational technology or OT is a category of computing and communication systems to manage, monitor and control industrial operations with a focus on the physical devices and processes they use.

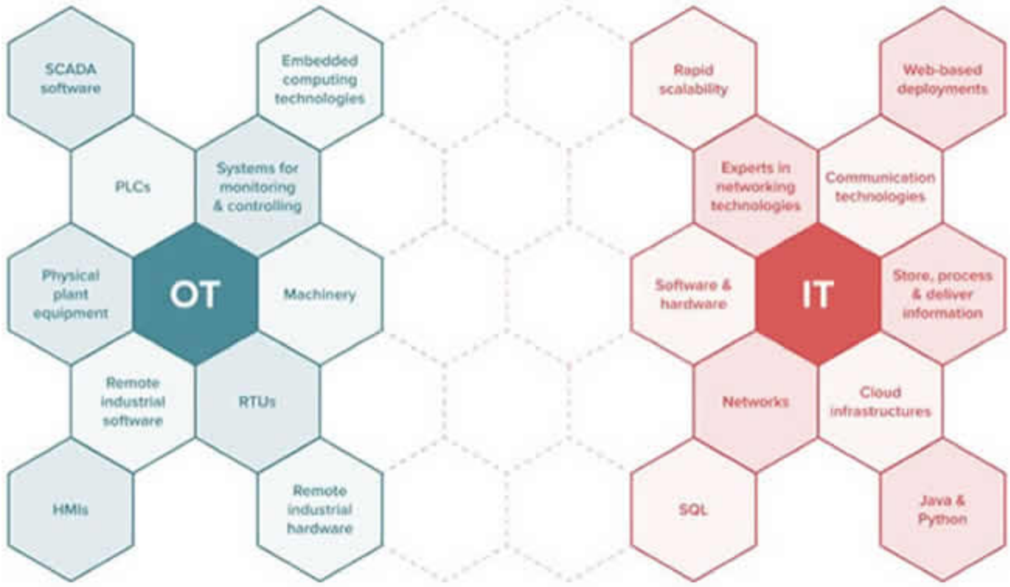
Operational technology, monitors and manages industrial process assets and manufacturing/industrial equipment. OT exists much longer than IT or information technology, more specifically since we started to use machinery and equipment powered by electricity in factories, buildings, transportation systems, the utility industry, etc. The term, however, is more recent. Essentially, OT is the hardware and software that keeps things, for instance factories, power plants, facility equipment etc. running.

Operational technology – definition, origins and evolution

While operational technology is about control and safety systems and industrial process assets, IT or information technology is about business and enterprise systems that store, process and deliver information.

The most often used definition of operational technology comes from Gartner: "Hardware and software that detects or causes a change through the direct monitoring and/or control of physical devices, processes and events in the enterprise".

The definition from Gartner is more for IT people and that's probably why it's so popular. There are several other definitions of OT whereby some limit themselves to the lowest levels of the traditional automation pyramid (field level, control level, production level,…) while others go higher.



OT has also been defined as technology that interfaces with the physical world and includes Industrial Control Systems (ICS), which in turn includes Supervisory Control and Data Acquisition (SCADA) and Distributed Control Systems (DCS).

Operational technology is everywhere around us: you find it in industrial operations in the smart factory, transportation, oil & gas, mining, in the utility industry (electricity, water….) and in facilities such as office buildings and healthcare facilities to give some examples. OT might be invisible for most; without it the economy and modern way of life wouldn't be possible.

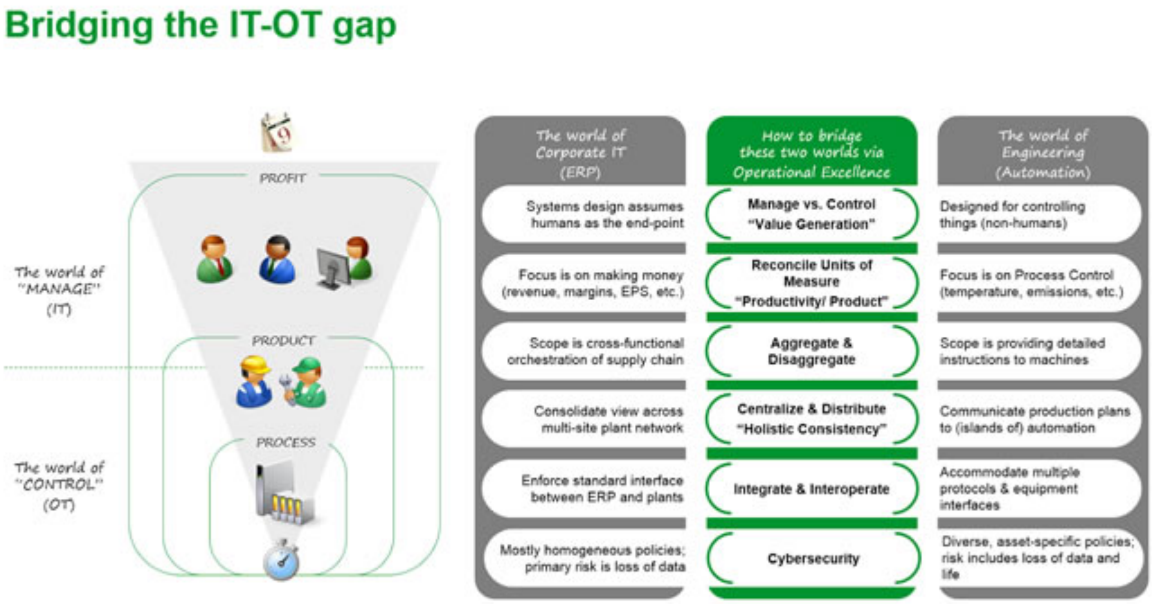
Originally, OT was mainly a mechanical given. Yet, just like IT, OT evolved through time. In many fields where OT plays an important role, proprietary protocols started to be used and today often still are used. In applications such as building management, communication protocols next started to be used over IP.

An important evolution in OT was the ability to monitor and control physical devices remotely. The injection of IT-based technologies such as big data and machine learning in OT, along with the evolutions in machine-to-machine (M2M) communication and the Internet of Things (sensors), enabled ample innovations with regards to the management of physical devices in industrial processes, among others in diagnostics and maintenance (remote diagnostics, predictive maintenance) and other use cases we know from Industrial IoT. Whereas operational technology elements once were not connected, today you must look hard to find some that aren't. Connections and digital technologies are in ever more assets and control devices and systems.

It's an ongoing trend that will make that in the end we'll stop talking about operational technology, let alone the differences between IT and OT. The people in operational technology will know about IT in the same way IT people will now about operational technology. Everything digital and connected, with the benefits and the risks.

Operational technology challenges as the borders with IT blur

IT and OT networks typically were and often still are separated from each other. IT was always the domain of the CIO with a rather strict difference between IT and OT networks but also between the people working in these respective areas. They have different profiles, different types of systems to work with and different tasks/priorities.



Several years ago, the lines between IT and OT gradually started to blur and the convergence of operational technology and IT is still ongoing. This convergence is not just about technologies but also about the teams and ways of working. With the mentioned IT-based technologies becoming integrated with OT networks and the whole Industry 4.0 and industrial transformation phenomenon, the responsibility over OT is also evolving.

Operational technology is increasingly mentioned from a cybersecurity perspective in these times of industrial transformation. With industrial infrastructures becoming more complex and the ongoing digitization, additional attention is required for OT security. There are also important differences between IT and OT security (without the cyber part). The latter traditionally was more about protecting physical processes, safety, uptime/production/efficiency and protection of people while IT security is more oriented on protecting all aspects of data and how information is stored, transmitted, processed and used in business processes.

With the mentioned convergence, these different priorities and resulting approaches regarding security, often prove to be a challenge now that all these aspects become key. It's not unusual that there are conflicts between IT and OT when there are computing priorities.

Examples of operational technology, depending on the definition, include the previously mentioned Industrial Control Systems (ICS), key from a security perspective since they are mission-critical. This OT segment is really an umbrella term for various systems to monitor and control industrial processes across a broad range of applications where availability and uptime are key.

Control systems include SCADA systems (Supervisory Control and Data Acquisition), DCS (Distributed Control System) and Programmable Logic Controllers (PLCs). RTUs (Remote Terminal Units), Human-Machine Interfaces (HMI), embedded systems and computing technologies, machinery, physical equipment in plants and Variable Frequency Drives (VFDs) also are operational technologies, as are most connected assets in industrial markets.

PLM Systems, MES applications, Safety Automation Systems, Building Management Systems etc. are often categorized as operational technology too. Operational technology field devices include valves, transmitters, switches and actuators.

More technologies and various types of devices and systems used in operational technology, as well as the usage of operational technology as such, depend on the industry and types of industrial processes.

COORDINATE NETWORK SYSTEMS OPERATIONS

Temperature, Pressure, and Flow Measurement for Monitoring Performance

Flow measurement, along with measuring temperature and pressure, are critical for optimal operation in gas and steam turbines. If these parameters do not stay within appropriate ranges, a power plant will suffer from issues with safety, performance, and efficiency. WIKA USA has the ability to provide instrumentation to monitor barometric pressure, temperature and flow of exhaust gas, and much more. In power plants, safe operations and efficiency are directly linked to business sustainability, financial performance, and long-term feasibility. That's why flow measurement, temperature measurement, and pressure measurement are so important. Turbines work best when these three parameters are maintained within certain ranges – some of which are quite narrow.

Monitoring for Safety and Efficiency

Temperature is a determining factor in turbine safety and efficiency. Increases in the turbine inlet improve the engine's efficiency: the turbine can produce the same amount of power with less fuel, or produce more power with the same amount of fuel. Components, however, face very demanding temperature conditions, in particular at the high pressure compressor exit and at the high pressure turbine inlet. If temperatures get too hot, chances of compressor blade failure and serious component damage increase dramatically.

Another important element is flow nozzle measurement. Measurements at the flow nozzle are critical because readings are plugged directly into efficiency calculations in the turbine's control system. During plant commissioning and routine operations, operators rely on flow nozzle measurements to validate performance and verify the efficiency of the turbine.

The key to plant safety and performance is the ability to accurately measure and track temperature, pressure, and flow. Information collected at specific measuring points can be used to:

Avoid Metallurgical Failures — Temperatures need to be maintained below the vessel's melting point in order to avoid metallurgical failure. Too-high temperatures can also lead to creep deformation in the rotating blades.

Determine Efficiency and Performance — Performance engineers can calculate the efficiency of a compressor or turbine if they know the inlet and exit temperatures, as well as the flow rate at the nozzle. When a gas turbine exhaust is used as heat input to a steam cycle,

engineers can also estimate the performance of the heat recovery steam generator (HRSG) by using the temperature and flow measurement of the gas turbine exhaust.
Detect Inefficiencies — High exhaust temperatures and flow changes can be symptoms of a compressor or turbine that is not operating as it should. If a flow measurement device picks up irregularities, the plant operator can perform a diagnostic to identify the underlying causes.
Calculate Residual Life — By tracking temperatures over time, engineers can see the temperature history of a component, such as a furnace tube. This history allows them to calculate how much life the component has left and to plan maintenance and replacements.

What and Where to Monitor

In distribution system, the following parameters are critical and are continuously monitored:

- ✓ Pressure of the network
- ✓ Flow of water
- ✓ Conductivity and other chemical properties of water
- ✓ Temperature of the pumps and motors
- ✓ Energy consumption of the pumps

RECORD AND REPORT

This is primarily addressed as the communication of KPIs to the stakeholders and regulators.

Benefits (why it matters)

- ✓ Forms basis for measurable business value
- ✓ Provides mutual agreement of value delivered
- ✓ Allows tracking and implementation of Best Standard Operation procedures
- ✓ Fulfilling regulatory requirements
- ✓ Identifies opportunities for improvement and expansion

Reporting may include:

- ✓ KPI Communication;
- ✓ Operational Activities;
- ✓ Maintenance Activities;
- ✓ Safety Compliance;
- ✓ Non-Conformance Actions;
- ✓ Profit and Loss "P&L"; and
- ✓ Improvement of projects capital output.

UNIT 12

CONDUCT CHLORINE DOSING OF WATER AT THE POINT OF SUPPLY

This unit covers the competency required to conduct chlorine dosing of water at the point of supply and appropriately monitor the collected samples and manage to keep a record of the dosing data

PREPARE FOR CHORINE DOSING

Preparation

- ✓ Work in a well ventilated room or, better still, outside in the shade but protected from the wind.
- ✓ Wear personal protective equipment
- ✓ Prepare solutions with clean, cold (or room temperature) water, in plastic containers only (corrosion of metal, inactivation of chlorine).
- ✓ Respect the recommended dilutions (an over-diluted product is less active; an over-concentrated product can cause irritation and corrosion).
- ✓ Use a clean, dry, plastic or glass receptacle to measure the dose of product or the measurer (e.g. measuring spoon) provided by the manufacturer.
- ✓ Pour the amount of water required into a container then add the product (and not the other way round) without splashing. Mix well using a clean stirrer used only for this purpose.
- ✓ Do not add any other product (e.g. a detergent) to chlorine solutions.
- ✓ For calcium hypochlorite, leave the solution to rest for a few minutes and only use the supernatant. Transfer the supernatant into another receptacle and discard the calcium residue into a waste pit after each preparation.
- ✓ Label the containers, specifying the chlorine concentration.

Use

- ✓ Chlorine solutions are inactivated by the presence of organic matter (such as blood and other biological liquids, secretions or excreta, or dirt).
- ✓ The WHO and CDC recommend cleaning objects, floors, surfaces, laundry with detergent and water before applying chlorine solution. This helps prevent the inactivation of chlorine.
- ✓ Chlorine is also a bleaching agent. Use 0.05% chlorine solution to disinfect laundry and not a 0.2% solution which discolours it.
- ✓ The disinfection of objects, floors and surfaces requires 15 minutes of contact time. Laundry must also be soaked for 15 minutes, but not longer.
- ✓ Do not rinse afterwards objects, floors and surfaces disinfected with chlorine solutions, except stainless steel surfaces that must be imperatively rinsed (risk of corrosion).

Storage

Solid products

- ✓ Store in air-tight non-metallic containers, away from heat, light and humidity in a ventilated area.
- ✓ Carefully close containers after use.
- ✓ Never place them in contact with water, acid, fuel, detergents, organic or inflammable materials (e.g. food, paper or cigarettes).
- ✓ Never mix NaDCC with calcium hypochlorite (risk of toxic gas or explosion).
- ✓ NaDCC is more stable than calcium hypochlorite.

Prepared solutions

Change solutions every day. Do not prepare too much solution at a time (to avoid wasting unused solution).

	Products	0.05% solution	0.2% solution	2% solution	1% solution
Use		**Hand washing Disinfection of laundry (after cleaning)**	**Floors, surfaces, materials, aprons, boots, dishes (after cleaning)**	**Preparation of corpses Excreta and vomit buckets**	**Mother solution for chlorinating water**
Preparation	**Sodium dichloroisocyanurate** (NaDCC) granules, 55% active chlorine	18 g/20 litres 1 level 20 ml measuring spoon per 20 litres of water (110 g in 120 litres of water)	72 g/20 litres 4 level 20 ml measuring spoons per 20 litres of water (430 g in 120 litres of water)	720 g/20 litres 40 level 20 ml measuring spoons per 20 litres of water	18 g/litre 1 level 20 ml measuring spoon per 1 litre of water
	Sodium dichloroisocyanurate (NaDCC) tablet, 1 g of active chlorine/tablet	10 tablets per 20 litres of water	40 tablets per 20 litres of water (2 tablets per litre)	400 tablets per 20 litres of water (20 tablets per litre)	10 tablets per 1 litre of water
	Calcium hypochlorite (HTH®) granules, 65-70% active chlorine	15 g/20 litres 1 level 20 ml measuring spoon per 20 litres of water (90 g in 120 litres of water)	60 g/20 litres 4 level 20 ml measuring spoons per 20 litres of water (360 g in 120 litres of water)	600 g/20 litres 40 level 20 ml measuring spoons per 20 litres of water	15 g/litre 1 level 20 ml measuring spoon per 1 litre of water

If preparing large quantities (e.g. 120 litre containers), preferably use a receptacle marked with a graduation corresponding to the necessary quantity of product (e.g. a cup with a mark corresponding to 110 g of NaDCC to prepare a 120 litre container of 0.05% chlorine solution).

Note:

Liquid bleach (sodium hypochlorite solution) should be reserved for domestic use only (e.g. homes, collective facilities likes schools or orphanages where a case has been declared), when the population is familiar with the product. There are various commercial forms of bleach under different names, different concentrations and different packaging.

To prepare a 0.2% chlorine solution the concentration of the bleach to be used, expressed in "active chlorine" on the commercial product, must be taken into account. The following *formula is used to calculate the amount of water per quantity of bleach: % of chlorine in liquid bleach ÷ % chlorine desired – 1.*

% chlorine in liquid bleach	**0.2% chlorine solution to disinfect (after cleaning) floors, surfaces, materials contaminated by a patient**
2.6%	1 volume of bleach in 12 volumes of water
3.5%	1 volume of bleach in 16 volumes of water
4%	1 volume of bleach in 19 volumes of water

The volume can be a litre, a gallon, a glass or any other recipient used to measure a dose. These solutions must be prepared just before use.

PERFORM CHLORINE DOSING

Chlorine treatment

Chlorine readily combines with chemicals dissolved in water, microorganisms, small animals, plant material, tastes, odors, and colors. These components "use up" chlorine and comprise the chlorine demand of the treatment system. It is important to add sufficient chlorine to the water to meet the chlorine demand and provide residual disinfection.

The chlorine that does not combine with other components in the water is free (residual) chlorine, and the breakpoint is the point at which free chlorine is available for continuous disinfection. An ideal system supplies free chlorine at a concentration of 0.3-0.5 mg/l. Simple test kits, most commonly the DPD colorimetric test kit (so called because diethyl phenylene diamine produces the color reaction), are available for testing breakpoint and chlorine residual in private systems. The kit must test free chlorine, not total chlorine. We also recommend monitoring the ORP (Oxidation Reduction Potential) of the water. Paper - Use of ORP Monitoring for Disinfection University of California and YSI.

Contact time with microorganisms

The **contact (retention) time** (Table 1) in chlorination is that period between the introduction of the disinfectant and when the water is used. A long interaction between chlorine and the microorganisms results in an effective disinfection process. The contact time varies with chlorine concentration, the type of pathogens present, pH, and temperature of the water. The calculation procedure is given below.

Contact time must increase under conditions of low water temperature or high pH (alkalinity). Complete mixing of chlorine and water is necessary, and often a holding tank is needed to achieve appropriate contact time. In a private well system, the minimum-size holding tank is determined by multiplying the capacity of the pump by 10. For example, a 5-gallons-per-minute (GPM) pump requires a 50-gallon holding tank. Pressure tanks are not recommended for this purpose since they usually have a combined inlet/outlet and all the water does not pass through the tank.

An alternative to the holding tank is a long length of coiled pipe to increase contact between water and chlorine. Scaling and sediment build-up inside the pipe make this method inferior to the holding tank.

Table 1. Calculating Contact Time

minutes required = K / chlorine residual (mg/l)

K values to determine chlorine contact time			
Highest	Lowest Water Temperature (degrees F)		
pH	> 50	45	< 40
6.5	4	5	6
7.0	8	10	12
7.5	12	15	18
8.0	16	20	24
8.5	20	25	30
9.0	24	30	36

To calculate contact time, one should use the highest pH and lowest water temperature expected. For example, if the highest pH anticipated is 7.5 and the lowest water temperature is 42 °F, the "K" value (from the table below) to use in the formula is 15. Therefore, a chlorine residual of 0.5 mg/l necessitates 30 minutes contact time. A residual of 0.3 mg/l requires 50 minutes contact time for adequate disinfection.

Chlorination levels

If a system does not allow adequate contact time with normal dosages of chlorine, super chlorination followed by dichlorination (chlorine removal) may be necessary.

Super chlorination provides a chlorine residual of 3.0-5.0 mg/l, 10 times the recommended minimum breakpoint chlorine concentration. Retention time for super chlorination is approximately 5 minutes. Activated carbon filtration removes the high chlorine residual.

Shock chlorination is recommended whenever a well is new, repaired, or found to be contaminated. This treatment introduces high levels of chlorine to the water. Unlike super chlorination, shock chlorination is a "one time only" occurrence, and chlorine is depleted as water flows through the system; activated carbon treatment is not required. If bacteriological problems persist following shock chlorination, the system should be evaluated. More information regarding shock disinfection can be found at Shock Well Disinfection Website.

Chlorination Guidelines

- ✓ Chlorine solutions lose strength while standing or when exposed to air or sunlight. Make fresh solutions frequently to maintain the necessary residual.
- ✓ Maintain a free chlorine residual of 0.3-0.5 mg/l after a 10-minute contact time. Measure the residual frequently.
- ✓ Once the chlorine dosage is increased to meet greater demand, do not decrease it.
- ✓ Locate and eliminate the source of contamination to avoid continuous chlorination. If a water source is available that does not require disinfection, use it.
- ✓ Keep records of pertinent information concerning the chlorination system and we recommend that you monitor the ORP of the water.
- ✓

Types of chlorine used in disinfection

Public water systems use chlorine in the gaseous form, which is considered too dangerous and expensive for home use. Private systems use liquid chlorine (sodium hypochlorite) or dry chlorine (calcium hypochlorite). To avoid hardness deposits on equipment, manufacturers recommend using soft, distilled, or demineralized water when making up chlorine solutions.

Liquid Chlorine

- household bleach most common form
- available chlorine range:
- 5.25% (domestic laundry bleach)
- 18% (commercial laundry bleach)
- slightly more stable than solutions from dry chlorine
- protect from sun, air, and heat

Dry Chlorine

- powder dissolved in water
- available chlorine: 4%
- produces heavy sediment that clogs equipment; filtration required
- dry powder stable when stored properly
- dry powder fire hazard near flammable materials
- solution maintains strength for 1 week
- protect from sun and heat

Equipment for continuous chlorination

Continuous chlorination of a private water supply can be done by various methods. The injection device should operate only when water is being pumped, and the water pump should shut off if the chlorinator fails or if the chlorine supply is depleted. A brief description of common chlorination devices follows.

MONITOR CHLORINE DOSING PERFORMANCE

Microorganisms can be found in raw water from rivers, lakes and groundwater. While not all microorganisms are harmful to human health, there are some that may cause diseases in humans. These are called pathogens. Pathogens present in water can be transmitted through a drinking water distribution system, causing waterborne disease in those who consume it.

In order to combat waterborne diseases, different disinfection methods are used to inactivate pathogens. Along with other water treatment processes such as coagulation, sedimentation, and filtration, chlorination creates water that is safe for public consumption.

Chlorination is one of many methods that can be used to disinfect water. This method was first used over a century ago, and is still used today. It is a chemical disinfection method that uses various types of chlorine or chlorine-containing substances for the oxidation and disinfection of what will be the potable water source.

The History of Chlorination

Chlorine was first discovered in Sweden in 1744. At that time, people believed that odours from the water were responsible for transmitting diseases. In 1835, chlorine was used to remove odours from the water, but it wasn't until 1890 that chlorine was found to be an effective tool for disinfecting; a way to reduce the amount of disease transmitted through water. With this new find, chlorination began in Great Britain and then expanded to the United States in 1908 and Canada by 1917. Today, chlorination is the most popular method of disinfection and is used for water treatment all over the world.

Why do we chlorinate our water?

A large amount of research and many studies have been conducted to ensure success in new treatment plants using chlorine as a disinfectant. A leading advantage of chlorination is that it has proven effective against bacteria and viruses; however, it cannot inactivate all microbes. Some protozoan cysts are resistant to the effects of chlorine.

In cases where protozoan cysts are not a major concern, chlorination is a good disinfection method to use because it is inexpensive yet effective in disinfecting many other possibly present contaminants. The chlorination process is also fairly easy to implement, when compared to other water treatment methods. It is an effective method in water emergency situations as it can eliminate an overload of pathogens relatively quickly. An emergency water situation can be anything from a filter breakdown to a mixing of treated and raw water.

How does chlorine inactivate microorganisms?

Chlorine inactivates a microorganism by damaging its cell membrane. Once the cell membrane is weakened, the chlorine can enter the cell and disrupt cell respiration and DNA activity (two processes that are necessary for cell survival).

When/how do we chlorinate our waters?

Chlorination can be done at any time/point throughout the water treatment process - there is not one specific time when chlorine must be added. Each point of chlorine application will subsequently control a different water contaminant concern, thus offering a complete spectrum of treatment from the time the water enters the treatment facility to the time it leaves.

Pre-chlorination is when chlorine is applied to the water almost immediately after it enters the treatment facility. In the pre-chlorination step, the chlorine is usually added directly to the raw water (the untreated water entering the treatment facility), or added in the flash mixer (a mixing machine that ensures quick, uniform dispersion of the chlorine). Chlorine is added to raw water to eliminate algae and other forms of aquatic life from the water so they won't cause problems in the later stages of water treatment. Pre-chlorination in the flash mixer is found to remove tastes and odours, and control biological growth throughout the water treatment system, thus preventing growth in the sedimentation tanks (where solids are removed from the water by gravity settling) and the filtration media (the filters through which the water passes after sitting in the sedimentation tanks). The addition of chlorine will also oxidize any iron, manganese and/or hydrogen sulphide that are present, so that they too can be removed in the sedimentation and filtration steps.

Disinfection can also be done just prior to filtration and after sedimentation. This would control the biological growth, remove iron and manganese, remove taste and odours, control algae growth, and remove the colour from the water. This will not decrease the amount of biological growth in the sedimentation cells.

Chlorination may also be done as the final step in the treatment process, which is when it is usually done in most treatment plants. The main objective of this chlorine addition is to disinfect the water and maintain chlorine residuals that will remain in the water as it travels through the distribution system. Chlorinating filtered water is more economical because a lower CT value is required. This is a combination of the concentration (C) and contact time (T). The CT concept is discussed later on in this fact sheet. By the time the water has been through sedimentation and filtration, a lot of the unwanted organisms have been removed, and as a result, less chlorine and a shorter contact time is required to achieve the same effectiveness. To support and maintain the chlorine residual, a process called re-chlorination is sometimes done within the distribution system. This is done to ensure proper chlorine residual levels are maintained throughout the distribution system.

Residual Chlorine, Breakpoint

Any type of chlorine that is added to water during the treatment process will result in the formation of hypochlorous acid (HOCl) and hypochlorite ions (OCl-), which are the main disinfecting compounds in chlorinated water. More detail is provided later on in this fact sheet.

A Form of Chlorine + H_2O -> HOCl + OCl^-

Of the two, hypochlorous acid is the most effective. The amount of each compound present in the water is dependent on the pH level of the water prior to addition of chlorine. At lower pH levels, the hypochlorous acid will dominate. The combination of hypochlorous acid and hypochlorite ions makes up what is called 'free chorine.' Free chlorine has a high oxidation potential and is a more effective disinfectant than other forms of chlorine, such as chloramines. Oxidation potential is a measure of how readily a compound will react with another. A high oxidation potential means many different compounds are able to react with the compound. It also means that the compound will be readily available to react with others.

Combined chlorine is the combination of organic nitrogen compounds and chloramines, which are produced as a result of the reaction between chlorine and ammonia. Chloramines are not as effective at disinfecting water as free chlorine due to a lower oxidation potential. Due to the creation of chloramines instead of free chlorine, ammonia is not desired product in the water treatment process in the beginning, but may be added at the end of treatment to create chloramines as a secondary disinfectant, which remains in the system longer than chlorine, ensuring clean drinking water throughout the distribution system.

The amount of chlorine that is required to disinfect water is dependent on the impurities in the water that needs to be treated. Many impurities in the water require a large amount of chlorine to react with all the impurities present. The chlorine added must first react with all the impurities in the water before a chlorine residual is present. The amount of chlorine that is required to satisfy all the impurities is termed the 'chlorine demand.' This can also be thought of as the amount of chlorine needed before free chlorine can be produced. Once the chlorine demand has been met, breakpoint chlorination (the addition of chlorine to water until the chlorine demand has been satisfied) has occurred. After the breakpoint, any additional chlorine added will result in a free chlorine residual proportional to the amount of chlorine added. Residual chlorine is the difference between the amount of chlorine added and the chlorine demand. Most water treatment plants will add chlorine beyond the breakpoint.

If ammonium is present in the water at the time of chlorine addition breakpoint chlorination will not occur until all the ammonium has reacted with the chlorine. Between 10 and 15 times more chlorine than ammonia is required before free chlorine and breakpoint chlorination can be achieved. Small water treatment plants frequently only add a fraction of the required chlorine (in relation to ammonium ions) and end up not properly disinfecting their water supplies.

The type of chloramines that are formed is dependent on the pH of the water prior to the addition of chlorine. Between the pH levels 4.5 and 8.5, both monochloramine and dichloramine are created in the water. At a pH of 4.5, dichloramine is the dominant form, and below that trichloramine dominates. At a pH above 8.5 monochloramine is the dominant form. Hypochlorous acid reacts with ammonia at its most rapid rate at a pH level around 8.3.

The chlorine to ammonia nitrogen ratio characterizes what kind of residual is produced.

Are there other uses for chlorine?

The main purpose of chlorination is to disinfect water, but it also has many other benefits. Unlike some of the other disinfection methods like ozonation and ultraviolet radiation, chlorination is able to provide a residual to reduce the chance of pathogen regrowth in water storage tanks or within the water distribution system. At times, distribution systems can be a fair distance from the storage tanks and in dead end sections or where water is not used pathogens may re-grow if a proper (chlorine) residual is cannot be maintained in the treated water sent out for consumption. This results in poor water quality as well as slime and biofilms in the distribution systems that will end up contaminating the clean, treated water being distributed. Many government environmental bodies have set guidelines or standards for the amount of chlorine residual that must be present at all points in the system. The guidelines for each province are shown in the table below.

In addition to providing a residual, adding chlorine to water will also: oxidize iron, manganese, taste and odour compounds, remove colour in the water, destroy hydrogen sulphide, and aid other water treatment processes, such as sedimentation and filtration. Oxidizing soluble reduced iron and manganese will result in particle formation as oxidized iron and manganese are not soluble in water.

Is chlorine all the same?

The chlorination process involves adding chlorine to water, but the chlorinating product does not necessarily have to be pure chlorine. Chlorination can also be carried out using chlorine-containing substances. Depending on the pH conditions required and the available storage options, different chlorine-containing substances can be used. The three most common types of chlorine used in water treatment are: chlorine gas, sodium hypochlorite, and calcium hypochlorite.

Chlorine Gas

Chlorine gas is greenish yellow in colour and very toxic. It is heavier than air and will therefore sink to the ground if released from its container. It is the toxic effect of chlorine gas that makes it a good disinfectant, but it is toxic to more than just waterborne pathogens; it is also toxic to humans. It is a respiratory irritant and it can also irritate skin and mucus membranes. Exposure to high volumes of chlorine gas fumes can cause serious health problems, including death. However, it is important to realize that chlorine gas, once entering the water, changes into hypochlorous acid and hypochlorite ions, and therefore its human toxic properties are not found in the drinking water we consume.

Chlorine gas is sold as a compressed liquid, which is amber in color. Chlorine, as a liquid, is heavier (more dense) than water. If the chlorine liquid is released from its container it will quickly return back to its gas state. Chlorine gas is the least expensive form of chlorine to use. The typical amount of chlorine gas required for water treatment is 1-16 mg/L of water. Different amounts of chlorine gas are used depending on the quality of water that needs to be treated. If the water quality is poor, a higher concentration of chlorine gas will be required to disinfect the water if the contact time cannot be increased.

When chlorine gas (Cl_2) is added to the water (H_2O), it hydrolyzes rapidly to produce hypochlorous acid (HOCl) and the hypochlorous acid will then dissociate into hypochlorite ions (OCl^-) and hydrogen ions (H^+).

$Cl_2 + H_2O \rightarrow HOCl + H^+ + OCl^-$

Because hydrogen ions are produced, the water will become more acidic (the pH of the water will decrease). The amount of dissociation depends on the original pH of the water. If the pH of the water is below a 6.5, nearly no dissociation will occur and the hypochlorous acid will dominate. A pH above 8.5 will see a complete dissociation of chlorine, and hypochlorite ions will dominate. A pH between 6.5 and 8.5 will see both hypochlorous acid and hypochlorite ions present in the water. Together, the hypochlorous acid and the hypochlorite ions are referred to as free chlorine. Hypchlorous acid is the more effective disinfectant, and therefore, a lower pH is preferred for disinfection.

Calcium Hypochlorite

Calcium hypochlorite (CaOCl) is made up of the calcium salts of hypochlorous acid. It is produced by dissolving chlorine gas (Cl_2) into a solution of calcium oxide (CaO) and sodium hydroxide (NaOH). Calcium hypochlorite is a white, corrosive solid that comes either in tablet form or as a granular powder. Calcium hypochlorite is very stable, and when packaged properly, large amounts can be purchased and stored until needed. The chemical is very corrosive however, and thus requires proper handling when being used to treat water. Calcium hypochlorite needs to be stored in a dry area and kept away from organic materials. It cannot be stored near wood, cloth or petrol because the combination of calcium hypochlorite and organic material can create enough heat for an explosion. It must also be kept away from moisture because the tablets/granular powder readily adsorb moisture and will form (toxic) chlorine gas as a result. Calcium hypochlorite has a very strong chlorine odour – something that should be kept in mind when placing them in storage.

When treating water, a lesser amount of calcium hypochlorite is needed than if using chlorine gas. Compared to the 1-16 mg/L required with chlorine gas, only 0.5-5 mg/L of calcium hypochlorite is required. When calcium hypochlorite is added to water, hypochlorite and calcium ions are produced.

$Ca(OCl)_2 \rightarrow Ca^{+2} + 2OCl^-$

Instead of decreasing the pH like chlorine gas does, calcium hypochlorite increases the pH of the water (making the water less acidic). However, hypochlorous acid and hypochlorite concentrations are still dependent on the pH of the water; therefore by decreasing the pH of the water, hypochlorous acid will still be present in the water. As a result, calcium hypochlorite and chlorine gas both produce the same type of residuals.

Sodium Hypochlorite

Sodium hypochlorite (NaOCl) is made up of the sodium salts of hypochlorous acid and is a chlorine-containing compound that can be used as a disinfectant. It is produced when chlorine gas is dissolved into a sodium hydroxide solution. It is in liquid form, clear with a light yellow color, and has a strong chlorine smell. Sodium hypochlorite is extremely corrosive and must be stored in a cool, dark, and dry place. Sodium hypochlorite will naturally decompose; therefore it cannot be stored for more than one month at a time. Of all the different types of chlorine available for use, this is the easiest to handle.

The amount of sodium hypochlorite required for water treatment is much less than the other two forms of chlorine, with 0.2-2 mg of NaOCl/L of water being recommended. Like calcium hypochlorite, sodium hypochlorite will also produce a hypochlorite ion, but instead of calcium ions, sodium ions are produced. NaOCl will also increase the pH of the water through the formation of hypochlorite ions. To obtain hypochlorous acid, which is a more effective disinfectant, the pH of the water should be decreased.

$NaOCl \rightarrow Na^+ + OCl^-$

Is chlorine a sure way of eliminating pathogens?

Chlorination has been proven to be very effective against bacteria and viruses. However, it cannot disinfect all waterborne pathogens. Certain pathogens, namely protozoan cysts, are resistant to the effects of chlorine. Cryptosporidium and Giardia, two examples of protozoan cysts, have caused great concern due to the serious illnesses they can cause. Cryptosporidium was the cause of the outbreak in North Battleford in 2001, and Milwaukee in April 1993. In raw water with high Giardia and Cryptosporidium levels, another method of disinfection should be considered. For more information on these protozoa, please read their self-titled fact sheets in the public information section.

Is chlorinating water 'fool-proof'?

There are a number of factors that affect the disinfection process. Of these, the concentration or dosage of chlorine and the chlorine contact time (the time that chlorine is allowed to react with any impurities in the water) are the most important factors.
Chlorine needs time to inactivate any microorganisms that may be present in the water being treated for human consumption. The more time chlorine is in contact with the microorganisms, the more effective the process will be. The contact time is the time from when the chlorine is first added until the time that the water is used or consumed.
The same positive relationship is seen when considering the chlorine concentration. The higher the concentration of chlorine, the more effective the water disinfection process will be. This relationship holds true because as the concentration increases, the amount of chlorine for disinfection is increased. Unlike the relationship between chlorine concentration and disinfection effectiveness, the chlorine concentration and the contact time of chlorine with water show an inverse relationship. As the chlorine concentration increases, the required water-chlorine contact time ultimately decreases. To determine the level of disinfection (D), a CT value can be calculated. This value is the product of the chlorine concentration (C) and contact time (T). The formula is as follows: $C*T=D$. This concept shows that an increase in chlorine concentration (C) would require less contact time to achieve the same desired level of disinfection. Another possibility would be an increase in contact time that would in turn require a lower chlorine concentration in order for the level of disinfection to stay the same.
The required CT value depends on several factors, including: the type of pathogens in the water, the turbidity of the water, the pH of the water and the temperature of the water. Turbidity is the suspended matter in the water and the types of pathogens can range from bacteria like E.coli and Campylobacter to viruses including Hepatitis A. At lower temperatures, higher turbidity, or higher pH levels, the CT value (i.e. the disinfection level) will have to be increased, but at lower turbidity, there is less suspended material in the water that will prevent contact of the disinfectant with the microorganisms, thus requiring a lower CT value. A higher water temperature and a lower pH level will also allow for a lower CT value.

Impurity Reactions

Chlorine can react with a number of different substances. In raw water, there may be a number of different impurities to react with the added chlorine, resulting in an increase of the chlorine demand. As a result, more chlorine will need to be added for the same level of inactivation. Some major impurities that may exist in water include: dissolved iron, hydrogen sulphide, bromine, ammonia, nitrogen dioxide, and organic material. In some cases, the result of chlorine reacting with impurities will increase the quality of the water (by eliminating the undesired elements), while in other cases, the chlorine-impurity reactions will create undesired side products that are harmful to human health. Chlorine will first react with inorganic impurities (dissolved iron, bromine, ammonia, etc.) before reacting with the organic compounds (dissolved organic material, bacteria, viruses, etc.).

Iron, which will give water an undesirable metallic taste if present, is one of the inorganic compounds that will react with hypochlorous acid (the stronger form of free chlorine that is produced after pure chlorine is added to water). By reacting with hypochlorous acid, the dissolved iron will go from a soluble state to an insoluble state, as a precipitate is formed as a result of the reaction. The iron precipitate, in its insoluble state, can be removed by filtration process within the water treatment centre.

$2\ Fe^{2+}$ (liquid) + $HOCl + 5H_2O$ -> $2\ Fe(OH)_3$ (solid) + $5H^+ + Cl^-$

Hypochlorous acid can also react with hydrogen sulphide (H2S), if it is present in the water being treated. Hydrogen sulfide is an undesirable impurity in water because it gives water an undesired smell. At levels below 1 mg/L hydrogen sulphide generates a musty smell to the water, while at levels above 1 mg/L a rotten egg smell will prevail. Hydrogen sulphide is also toxic. The hypochlorous acid and H2S reaction gives hydrochloric acid and sulphur ions as its products.

$H_2S + HOCl \rightarrow H^+ + Cl^- + S + H_2O$

Bromine in the water can result in the production of undesired compounds. Bromine ions can react with hypochlorous acid to create hypobromous acid. Hypobromous acid also has disinfectant properties and is more reactive than hypochlorous acid. Hypochlorous acid or hypobromous acid will react with organic material in the water and create halogenated by-products, such as trihalomethanes.

$Br^- + HOCl \rightarrow HOBr + Cl^-$

Ammonia is a compound that may exist in the water. It is a nutrient to aquatic life, but one that will become toxic in high concentrations. Ammonia is produced as a result of decaying matter and therefore naturally exists in the water; however, human activity also releases a large amount of ammonia into the water, which contributes to an increasing level of ammonia that may cause concern. Some 'human activity sources' include: municipal wastewater treatment plants, agricultural releases, and industrial releases, such as pulp and paper mills, mines, food processing, and fertilizer production. Reactions between ammonia and chlorine will produce monochloramines, dichloramines, and trichloramines, which are collectively known as chloramines. These compounds are beneficial to the water treatment process as they have disinfection capacity, but they are not as effective as chlorine although chloramines will last longer in the water.

Chlorine also reacts with phenols to produce monochlorophenols, dichlorophenols, or trichlorophenols, which cause taste and odour problem at low levels. At higher levels, chlorophenols are toxic and affect the respiration and energy storage process. Chlorophenols are mainly man-made compounds, but can be found naturally in animal wastes and decomposing organic material.

Are There Health Concerns With Chlorinating Water?

Chlorine can be toxic not only for microorganisms, but for humans as well. To humans, chlorine is an irritant to the eyes, nasal passages and respiratory system. Chlorine gas must be carefully handled because it may cause acute health effects and can be fatal at concentrations as low as 1000 ppm. However, chlorine gas is also the least expensive form of chlorine for water treatment, which makes it an attractive choice regardless of the health threat.

In drinking water, the concentration of chlorine is usually very low and is thus not a concern in acute exposure. More of a concern is the long term risk of cancer due to chronic exposure to chlorinated water. This is mainly due to the trihalomethanes and other disinfection by-products, which are by-products of chlorination. Trihalomethanes are carcinogens, and have been the topic of concern in chlorinated drinking water. Chlorinated water has been associated with increased risk of bladder, colon and rectal cancer. In the case of bladder cancer, the risk may be doubled. Although there are concerns about carcinogens in drinking water, Health Canada's Laboratory Centre for Disease Control says that the benefits of chlorinated water in controlling infectious diseases outweigh the risks associated with chlorination and would not be enough to justify its discontinuation. In Europe, however, chorination has been discontinued in many communities.

Chlorination By-Products

A number of different by-products can be produced from the reactions in the disinfection process. By-products created from the reactions between inorganic compounds and chlorine are harmless and can be easily removed from the water by filtration. Other by-products, such as chloramines, are beneficial to the disinfection process because they also have disinfecting properties. However, there are undesired compounds that may be produced from chlorine reacting with organic matter. The compounds of most concern right now are trihalomethanes (THMs) and haloacetic acids (HAAs). THMs and HAAs are formed by reactions between chlorine and organic material such as humic acids and fulvic acids (both generated from the decay of organic matter) to create halogenated organics. A greater level of THM formation has been found in surface water or groundwater influenced by surface water.

Trihalomethanes are associated with several types of cancer and are considered carcinogenic. The trihalomethane of most concern is chloroform, also called trichloromethane. It was once used as an anaesthetic during surgery, but is now used in the process of making other chemicals. About 900 ppm of chloroform can cause dizziness, fatigue, and headaches. Chronic exposure may cause damage to the liver and kidneys. Other harmful disinfection by-products are: trichloracetic acid, dichloroacetic acid, some haloacetonitriles, and chlorophenols.

Trichloracetic acid is produced commercially for use as a herbicide and is also produced in drinking water. This chemical is not classified as a carcinogen for humans, and there is limited information for animals. Dichloroacetic acid is an irritant, corrosive, and destructive against mucous membranes. This is also not currently classified as a human carcinogen. Haloacetonitriles were used as pesticides in the past, but are no longer manufactured. They are produced as a result of a reaction between chlorine, natural organic matter, and bromide. Chlorophenols cause taste and odour problems. They are toxic, and when present in higher concentrations, affect the respiration and energy storage process in the body.

Conclusion

Chlorination is a very popular method of water disinfection that has been used for many years. It has shown to be effective for killing bacteria and viruses, but not for some protozoan cysts. With the concern about trihalomethanes, a carcinogenic disinfection by-product, many communities have become hesitant in the continuation of this process.
Although chlorination does have some drawbacks, it continues to be the most popular, dependable, and cost-effective method of water disinfection.

Find this useful? Please chip in $5 to help us send Operation Water Drop kits to schools so students can measure the amount of total chlorine in the water they drink every day! Or donate $20 or more and receive an Official Donation Receipt for Income Tax Purposes.

UNIT 13

PERFORM SAMPLING AND TESTING OF WATER

This unit covers the competency required to prepare and perform sampling along with understanding of the testing requirements and conducting according to a specific standard while maintaining a safer environment

CONFIRM SAMPLING AND TESTING REQUIREMENTS

Periodic drinking water analysis is necessary to ensure safe quality water supply. Water samples should be analyzed for various microbiological and physic chemical contaminants. However, the authenticity of water analysis greatly depends on the sampling procedure.
The objective of sampling is to collect a small portion of water which can be easily transported to laboratory, without contamination or deterioration and which should accurately represent the water being supplied. It should cover locations which are most venerable in the supply system. For recommended sampling procedures and guideline values regarding physical and chemical parameters.

Location of sampling points

One objective of surveillance is to assess the quality of the water supplied by the supply agency and of that at the point of use, so that samples of both should be taken. Any significant difference between the two has important implications for remedial strategies. Samples must be taken from locations that are representative of the water source, treatment plant, storage facilities, distribution network, points at which water is delivered to the consumer, and points of use. In selecting sampling points, each locality should be considered individually; however, the following general criteria are usually applicable:

- ✓ Sampling points should be selected such that the samples taken are representative of the different sources from which water is obtained by the public or enters the system.
- ✓ These points should include those that yield samples representative of the conditions at the most unfavourable sources or places in the supply system, particularly points of possible contamination such as unprotected sources, loops, reservoirs, low-pressure zones, ends of the system, etc.
- ✓ Sampling points should be uniformly distributed throughout a piped distribution system, taking population distribution into account; the number of sampling points should be proportional to the number of links or branches.
- ✓ The points chosen should generally yield samples that are representative of the system as a whole and of its main components.
- ✓ Sampling points should be located in such a way that water can be sampled from reserve tanks and reservoirs, etc.
- ✓ In systems with more than one water source, the locations of the sampling points should take account of the number of inhabitants served by each source.
- ✓ There should be at least one sampling point directly after the clean-water outlet from each treatment plant.
- ✓ Sampling sites in a piped distribution network may be classified as:
    - o fixed and agreed with the supply agency;
    - o fixed, but not agreed with the supply agency; or
    - o Random or variable.

Each type of sampling site has certain advantages and disadvantages. Fixed sites agreed with the supplier are essential when legal action is to be used as a means of ensuring improvement; otherwise, the supply agency may object to a sample result on the grounds that water quality may have deteriorated in the household, beyond the area of responsibility of the supplier. Nevertheless, fixed sample points are rare or unknown in some countries. Fixed sites that are not necessarily recognized by the supply agency are used frequently in investigations, including surveillance. They are especially useful when results have to be compared over time, but they limit the possibility of identifying local problems such as cross-connections and contamination from leaking distribution networks. Sampling regimes using variable or random sites have the advantage of being more likely to detect local problems but are less useful for analysing changes over time.

Sampling frequency

The most important tests used in water-quality surveillance or quality control in small communities are those for microbiological quality (by the measurement of indicator bacteria) and turbidity, and for free chlorine residual and pH where chlorination is used. These tests should be carried out whenever a sample is taken, regardless of how many other physical or chemical variables are to be measured.
The recommended minimum frequencies for these critical measurements in unpiped water supplies

PREPARE FOR WATER SAMPLING

Field personnel Responsibilities

Before sample collection begins, field personnel must take steps to ensure that the samples collected will be representative of the aqueous system being investigated. A representative water sample is a sample that typifies ("represents") in time and space that part of the aqueous system to be studied and is delineated by the objectives and scope of the study.

- ✓ Be alert to sample representativeness. The data are no better than the confidence that can be placed in how well the sample represents the aqueous system
- ✓ Plan to collect quality-control samples. Quality-control checks applied during laboratory analyses of the samples cannot compensate for data that are biased because samples were not representative of the aqueous system or because samples were improperly collected and processed.

Before selecting sites or making other preparations:

- ✓ Understand the purpose for which the various types of data will be collected and the aqueous system that each sample should represent.
- ✓ Review the study work plan, especially types of measurements and samples needed.
- ✓ Make field reconnaissance trips before selecting sampling sites, if possible.
    - o Note conditions that could affect sampling operations (such as the seasonal high or low streamflow, flowing wells, or site access peculiarities)
    - o Evaluate potential sources of contamination at the site, based on target analytes1 to be collected.
- ✓ Review site files and field folders. (Note site location, description and access, and review any previously collected physical, chemical, and biological data.)

- ✓ Obtain and keep current with training and the laboratory requirements associated with your data-collection activities

Before selecting equipment:

Understand the physical and chemical limitations of each piece of equipment, in order to meet data-collection objectives and dataquality requirements2 (refer to NFM 2). Verify and test, if possible, the operational range of the sampling equipment to be used

Before starting field work:

- ✓ Review site files and update and review the field folder for each site from which samples and ancillary data will be collected
- ✓ Review the safety plan. Be sure that you have the training needed if you will be working at sites designated as hazardous

Selection of equipment

The selection of equipment for collecting or processing water-quality samples depends on the physical constraints and safe operation of the equipment and on its suitability with respect to achievement of study objectives.

Criteria for selecting equipment for water sampling depend on (1) the mechanical constraints of the equipment to perform adequately under given environmental conditions, (2) the adequacy of equipment operation to obtain water-quality samples that represent the environmental conditions of the sample source, and (3) the adequacy of the equipment materials and construction to maintain sample integrity and not to be a source of leaching and sorption of target analytes.

- ✓ Always operate equipment safely.
- ✓ Be thoroughly familiar with requirements for equipment operation and maintenance.
- ✓ Be aware of the limitations as well as applications of the equipment with respect to your field site.
- ✓ Maintain and test equipment on a regular schedule

Chemical Compatibility with the Water Sample

The materials used to construct equipment and the materials that contact equipment can alter sample chemistry. Equipment designed for water-quality sampling commonly is constructed of a combination of materials, the most inert being used for components that will contact the sample. Nonsample-wetted components and manual contact with sampling equipment can be a source of sample contamination. Field personnel must wear gloves and use other techniques to minimize potential contamination, implement quality-assurance procedures, and quantify potential effects by analyzing quality-control samples collected using laboratory-certified deionized and blank water. When selecting equipment to be used, consider keeping several sets of precleaned equipment available. Using a clean set of equipment for each sampling site can lessen the chance of cross contamination between sites and eliminate the need for time-consuming equipment cleaning in the field. An extra set of precleaned equipment could also serve as a backup should equipment break or become contaminated.

Equipment Materials

Materials used in the construction of water-sampling equipment can include glass, plastics, ceramics, and metals. Chemical reactivity varies widely within the same group of materials, depending on the chemical composition, the physical configuration, and the manufacturing process. Thus, regarding reactivity with water and most other chemical substances, fluorocarbon polymers are less reactive than plastics such as polyethylene, and 316-type stainless steel (SS 316) is less reactive than brass, iron, or galvanized steel. For plastics and metals in general:

- ✓ The softer or more flexible forms of any plastic or metal are more reactive than the rigid forms.
- ✓ The more polished the surface, the less reactive the material tends to be.

Disposable Gloves

Wearing disposable, powderless gloves is required when handling equipment used to collect and process water-quality samples. Gloves protect field personnel from contact with pathogens and chemical contaminants and preservatives. Wearing gloves also helps to avoid sample contamination that could result from improper sample handling. Neither gloved nor ungloved hands should come in contact with the sample or with an equipment surface that the sample could contact.

- ✓ Wear powderless nitrile gloves when handling equipment and chemical solutions. Do not allow the water that enters the sample bottle to contact gloved (or bare) hands.
- ✓ When working in a sampling chamber, wearing elbow-length gloves is recommended if sampling for pharmaceutical or personal-care analytes—this will minimize exposure of the sample to chemicals (such as DEET (n,n-Diethyl-meta-toluamide)) that have been applied to skin.
- ✓ Check the manufacturer's chemical resistance chart for any compound, such as acid, base, or organic solvent, to which the glove might be exposed.

Physical properties to consider when selecting disposable gloves are glove length, slip protection, puncture resistance, heat and flame resistance, cold protection, and comfort. These factors can vary among manufacturers. Visually inspect gloves for defects.

Sample Collection Equipment

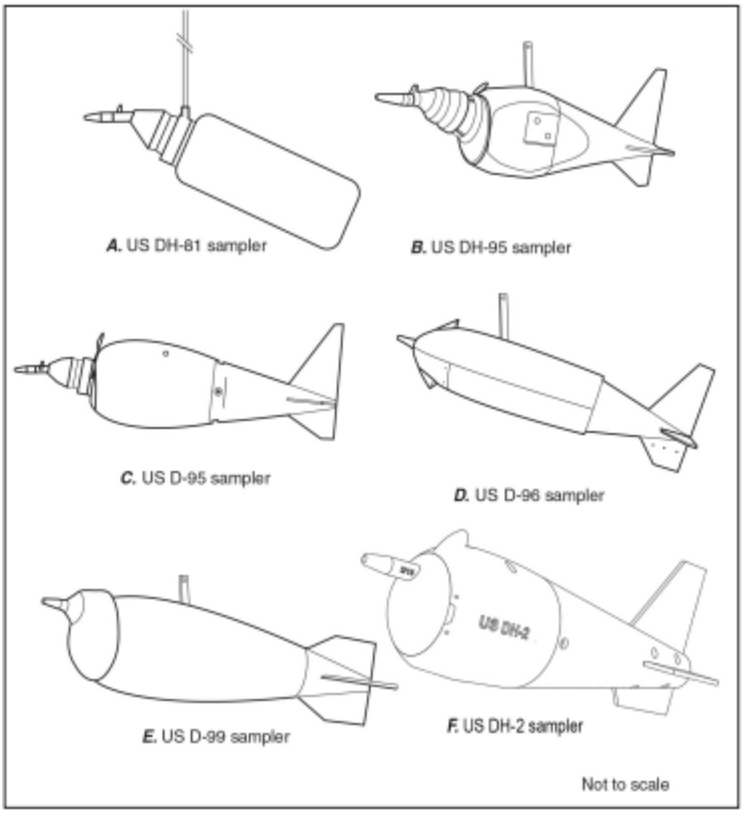
Guidelines for selecting sample-collection equipment and related supplies differ, depending on the chemical nature of the target analyte and on whether samples are collected for surface water or groundwater.

Surface-Water Equipment

Study objectives, flow conditions, and structures (such as a bridge, cableway, or boat) from which sample collection equipment (a sampler) is deployed must be considered when determining which equipment to use. Isokinetic depth-integrating samplers and nonisokinetic samplers are the primary types of surfacewater samplers in common use for surface-water studies

1. Isokinetic Depth-Integrating Samplers

An isokinetic depth-integrating sampler is designed to accumulate a representative water sample continuously and isokinetically (that is, streamwater approaching and entering the sampler intake does not change in velocity) from a vertical section of a stream while transiting the vertical at a uniform rate



2. Nonisokinetic Samplers

Nonisokinetic samplers are sampling devices in which the sample enters the device at a velocity that differs from ambient stream velocity. All of the isokinetic samplers can be used to collect depth-integrated, although nonisokinetic, samples, when used beyond the minimum and maximum ranges of velocity and depth When collecting a nonisokinetic sample, the sampler intake should not enter the unsampled zone. As with all samplers, the materials that contact the sample must not bias concentrations of target analytes by sorbing or leaching target analytes

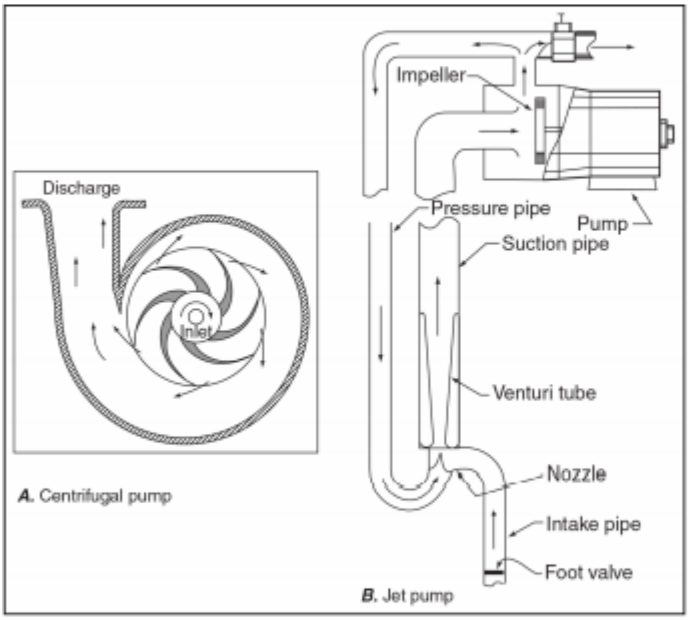
Ground Water Equipment

The type of sampler or sampling system selected for collecting groundwater samples depends on the type and location of a well, the depth to water from land surface, physical characteristics of the well, groundwater chemistry, and the analytes targeted for study. Selecting the appropriate equipment for collecting groundwater samples is important in order to obtain data that will meet study objectives and data-quality requirements. Groundwater sampling equipment is available from a variety of commercial sources.

Groundwater most commonly is collected using either pumps designed specifically for water sampling from monitoring wells, pumps installed in supply wells, or a bailer or other point or thief-type sampler.

Pumps

Pumps transport water from depth to land surface either by suction lift or positive pressure. The pumping mechanism for most suction-lift pumps (peristaltic, jet, and some nonsubmersible centrifugal pumps) is at land surface. Positive-pressure pumps (helical rotor, gear, bladder, piston, inertial submersible, and centrifugal) are grouped together as submersible pumps because they are placed below the static water level.



Bailers, Thief Samplers, and Passive Diffusion Bag Samplers

Bailers and other thief samplers disturb the water column, especially when raised and lowered repeatedly; for this reason, use of these devices is not recommended. The disturbance can stir up or mobilize particulate matter, including colloidal or mineral precipitates that are artifacts of well construction and are not part of the ambient groundwater flow. This, in turn, can result in the analysis of substantially greater than ambient concentrations of trace elements and hydrophobic organic compound(s). Passive diffusion bag (PDB) samplers do not disturb the water column.

1. Bailers and thief samplers

Although bailers are not, in general, recommended for groundwater sampling because of the potential aeration of the sample, bailers can have some necessary and useful applications and may be the only sampling option, especially when sampling at great depth. Use of a bailer may be preferred, for example, for sampling sites at which contaminant concentrations are extremely large, because bailers are easier to clean or are disposable and less expensive to replace than pumps.

2. Passive diffusion bag samplers

Water-filled passive diffusion bag samplers (PDBs) are suitable for obtaining samples to be analyzed for selected VOCs.16 A typical PDB sampler consists of a low-density polyethylene (LDPE) lay-flat tube closed at both ends and containing deionized water. The sampler is positioned at the target horizon of the well by attachment to a weighted line or fixed pipe.

Sample Processing

Water samples must be processed as quickly as possible after collection. The equipment most commonly used for sample processing includes sample splitters, disposable capsule and disk filters, filtration assemblies, solid-phase extraction systems, and chambers in which samples are processed and treated with chemical preservatives. Having several sets of cleaned processing equipment on hand is recommended.

Filtration Systems

Filtration systems separate particulate substances (solid phase and biological materials) from the solute or aqueous phase of a water sample. Water samples are filtered for analysis of inorganic constituents, organic compounds, and biological materials to help determine the environmental fate and quantify the transport of these target analytes..

Organic Compounds

Filtering whole-water samples isolates suspended solid-phase substances from the aqueous phase, thus allowing for separate determinations of organic compounds in the solid and aqueous phases. Filtering also helps to preserve samples for organic determinations by removing microorganisms that could degrade compounds in the sample.

Pump Tubing and Tube Connectors

Pump tubing refers to the sample lines that are used with various pumps to collect and process groundwater and surface-water samples. Tubing connectors join the tubing to pumps, filters, or other sections of tubing that may be of the same or different diameter or material. The tubing and connectors for surface-water samples usually are consistent in material and diameter. The tubing and connectors for groundwater samples can vary according to the type of well to be sampled and the data quality objectives. Tubing and connections for groundwater may be used to pump water from the well or to connect to groundwater wells having preinstalled pumps. Field personnel are cautioned to evaluate possible artifacts in a sample associated with pump tubing and tubing connectors and connections.

Field Vehicles

Water samples should be processed within vehicles that are designed, designated, prepared, and dedicated for that purpose. If multiple-use vehicles are used for water-quality work, then use of portable processing and preservation chambers is mandatory, and additional quality-control samples should be collected to document that the quality of the data has not been compromised. Contamination of the sample for target analytes is much more likely when multiple-use vehicles are used for the collection of water-quality data. Whether using a field vehicle dedicated for water-quality work or a multi-use vehicle, every effort should be made to keep the work area clean and to eliminate sources of sample contamination, as is emphasized in the examples listed below.

- ✓ Containers of blank water, solvents, buffers, standards, and other chemical substances should be properly labeled, dated, secured, and stored in a manner that prevents accidental spills. Some solutions may need to be stored separately to protect them from contamination.
- ✓ Keep metallic objects, such as surface-water and groundwater sampling support equipment, out of the inorganic sample-processing and -preservation area.
- ✓ Install a dustproof barrier between the vehicle's cab and the sample-processing and -preservation area.
- ✓ Cover metallic surfaces (cabinets or shelving that cannot be replaced) with plastic sheeting in areas where samples will be processed for the analysis of inorganic constituents and cover all work surfaces with heavy-duty aluminum foil in areas where samples will be processed for the analysis of organic constituents.
- ✓ Store chemical substances so that chemical fumes will not enter the sample-processing and -preservation area. Containers of solvents, blank waters, and liquid waste should be stored in separate areas or compartments.
- ✓ If transporting a nitrogen tank, ensure that the tank is fastened securely to the vehicle with a bracket. Brackets specially designed for gas tanks/cylinders can be obtained from companies that sell gas supply equipment.

CONDUCT SAMPLING OF WATER

Processing of Water Samples

Sample processing forms a continuum with sample collection and involves the compositing, subsampling (splitting), filtration, solid-phase extraction, preservation, and shipment of samples. Samples are most vulnerable to sampling artifacts, contamination, incorrect chemical treatment, and mislabeling during sample processing. Samples must be processed as soon as possible after collection.

Preparatory procedures

This is to

- ✓ To minimize delays in sample processing, calibrate field instruments, and set up processing equipment and supplies in the work area before collecting the sample
- ✓ Clean-sampling procedures are recommended as a general practice when processing raw samples, particularly those for analysis of trace levels of inorganic and organic analytes
- ✓ Check sample-designation codes and processing requirements for each sample
- ✓ Clean equipment and supplies
- ✓ Set up a clean work area
- ✓ Prevent direct contact with potential source(s) of contamination

- ✓ Keep sample-processing equipment covered with a clean, noncontaminating material when not in use; keep sample bottles capped and covered or bagged.

Sequence for Processing Samples

The order of sample collection, processing, and preservation for specific analytes should be determined before beginning field work and adhered to consistently. The recommended sequence for sample collection and processing is based on logistics for maintaining sample integrity and differs for ground-water and surface-water sampling. The recommended sequence can be modified, depending on the types of samples to be collected and on data objectives.

Raw Samples

Raw samples, commonly referred to as wholewater or unfiltered samples, are collected directly into the appropriate type of sample bottle from the sampling device (such as a submersible pump, sample-compositing device, peristaltic pump, or cone splitter). It is recommended that this sample collection take place within a processing chamber, especially if analyte concentrations are expected to be near the detection limit, to prevent contamination from airborne sources.

- ✓ Equipment must be clean before samples are collected and processed
- ✓ Disposable, powderless gloves must be worn throughout sample collection and processing. In order to withstand the solvents or chemicals that could be contacted, vinyl gloves are adequate for inorganic work, but use of organic solvents for organic work requires latex or nitrile gloves.

Composites and Subsamples

Surface-water samples normally are composited and processed through sample splitting (subsampling) devices. Ground-water samples are not composited but are pumped either directly through a splitter or through a filtration assembly (filter assembly) into sample bottles, unless a bailer or other thief-type sampler is used to collect the sample. Inorganic-constituent samples usually are composited in the plastic or fluoropolymer churn splitter; organic-compound samples commonly are composited in a fluoropolymer churn splitter or metal container, or are processed through a fluorocarbon polymer polymer cone splitter.

Ground Water: Pumped and Bailed Samples

Steps for filling bottles with raw sample pumped from water-supply wells and monitoring wells are described in this. The recommended method for withdrawing ground-water samples from conventional supply or monitoring wells is to use a submersible or peristaltic pump and to pump the sample directly to a processing chamber (or to a glove box filled with inert gas).

- ✓ Replicates of environmental samples—Fill bottles one after the other
- ✓ Field blanks—Process according to the study quality-assurance plan or as needed

Processing of samples

The steps listed below for processing raw ground-water samples are based on the assumption that both organic-compound and inorganic-constituent samples will be collected. Before proceeding.

- ✓ Prelabel bottles with site identification, sample designation, date, and time
- ✓ Process samples in the order recommended for sample collection. This helps to limit overpurging of volatile compounds, reduce airborne contamination and cross contamination among samples and sites, and minimize discrepancies in the ionic mass balance.
- ✓ When pumping the sample, do not stop the pump or interrupt flow to the processing chamber during sampling. The rate of flow during sampling should remain constant throughout processing and be the same as the rate of flow while making final field measurements at the end of purging

CONDUCT FIELD TESTING OF WATER

Analyses for many important physical, chemical and microbiological variables can be carried out in the field using apparatus made specifically for field use. A significant advantage of field analysis is that tests are carried out on fresh samples whose characteristics have not been contaminated or otherwise changed as a result of storage in a container. This is of special importance for samples that are to undergo microbiological analysis but cannot be transported to a laboratory within the time limits or under the conditions described in Chapter 5. Some variables must be measured in the field, either in situ or very soon after the sample has been collected. Field analysis is necessary for temperature, transparency and pH. Dissolved oxygen may be determined in the field or the sample may be treated (fixed) in the field and the remainder of the analysis completed in a laboratory. If samples are to be chemically preserved before being transported to the laboratory, conductivity (if required) must be measured before preservative chemicals are added.

Another advantage of field analysis is that samples are highly unlikely to lose the labels that identify the time and place of sampling. Loss of such identification would be disastrous if, for example, many samples had been collected to determine the water quality profile of a river.

Where there are no laboratories within a reasonable distance of the sampling stations, field analysis may be the only feasible way to obtain water quality information. Mobile laboratories are expensive to set up and maintain, while a temporary laboratory is justified only if a large sampling and analysis programme is to be carried out within a relatively compact sampling area.

Temperature

Measurements of air and water temperature at a field site are essential for water-quality data collection. Determination of dissolved-oxygen concentrations, conductivity, pH, rate and equilibria of chemical reactions, biological activity, and fluid properties relies on accurate temperature measurements.

Accurate air- and water-temperature data are essential to document thermal alterations to the environment caused by natural phenomena and by human activities. Water temperature can be subject to environmental regulation and monitoring by State and local agencies.

Equipment and Supplies

Thermometers and other temperature-measurement equipment and supplies must be tested before each field trip and cleaned soon after use. Each temperature instrument must have a log book in which all calibrations and repairs are recorded, along with the manufacturer make and model and serial or property number.

Measurement

Air temperature, in addition to water temperature, should be measured and recorded whenever water-quality samples are collected. Water temperature must always be measured in situ and in a manner that ensures that the measurement accurately represents the intended sample conditions. Before measuring air or water temperature:

- ✓ Inspect the liquid-in-glass thermometer to be certain that the liquid column has not separated.
- ✓ Check that batteries are fully charged for thermister thermometers or temperature sensors incorporated into other field meters

Surface Water

The reported surface-water temperature must be measured in situ—do not measure temperature on subsamples from a sample compositing device. Measure temperature in such a manner that the mean or median temperature at the time of observation is represented Record any deviation from this convention in the data base and report it with the published data.

To measure the temperature of surface water:

- ✓ Making a cross-sectional temperature profile first, to determine the temperature variability of the stream section, is recommended—a hand-held digital thermometer works best for this purpose

- ✓ To determine which sampling method to use, examine the cross-sectional profile and consider study objectives
- ✓ Measure temperature in those sections of the stream that represent most of the water flowing in a reach. Do not make temperature measurements in or directly below stream sections with turbulent flow or from the stream bank (unless this specifically represents the intended condition to be monitored).

MAINTAIN A SAFE WORK ENVIRONMENT

Personal Protective Equipment

The purpose of personal protective equipment is to reduce employee exposure to hazards when engineering and administrative controls are not feasible or effective to reduce these risks to acceptable levels. Personal protective equipment has the serious limitation that it does not eliminate the hazard at the source and may result in employees being exposed to the hazard if the equipment fails. Protective gloves. Personal protective equipment, or PPE, is designed to protect employees from serious workplace injuries or illnesses resulting from contact with chemical, radiological, physical, electrical, mechanical, or other workplace hazards. Besides face shields, safety glasses, hard hats, and safety shoes, protective equipment includes a variety of devices and garments such as goggles, coveralls, gloves, vests, earplugs, and respirators.

Protective gloves.

Head Protection

Hard hats can protect employees from head impact, penetration injuries, and electrical injuries such as those caused by falling or flying objects, fixed objects, or contact with electrical conductors. Employees must cover and protect long hair to prevent it from getting caught in machine parts such as belts and chains.

Foot and Leg Protection

In addition to foot guards and safety shoes, leggings (for example, leather, aluminized rayon, or other appropriate material) can help prevent injuries by protecting employees from hazards such as falling or rolling objects, sharp objects, wet and slippery surfaces, molten metals, hot surfaces, and electrical hazards. Examples of situations in which an employee should wear foot and/or leg protection include:

- ✓ When heavy objects such as barrels or tools might roll onto or fall on the employee's feet.
- ✓ Working with sharp objects such as nails or spikes that could pierce the soles or uppers of ordinary shoes.
- ✓ Exposure to molten metal that might splash on feet or legs.
- ✓ Working on or around hot, wet, or slippery surfaces.

- ✓ Working when electrical hazards are present.

Eye and Face Protection

It is important to choose the appropriate eye and face protection for the particular hazard. Besides spectacles and goggles, personal protective equipment such as special helmets or shields, spectacles with side shields, and face shields can protect employees from the hazards of flying fragments, large chips, hot sparks, optical radiation, splashes from molten metals, as well as objects, particles, sand, dirt, mists, dusts, and glare.

Hearing Protection

Employees who are exposed to noise that is loud enough that they must shout to be heard at arm's length from another person must have a noise exposure assessment performed. The noise measurements will help select the appropriate level of hearing protection. Wearing earplugs or earmuffs can help prevent damage to hearing. Exposure to high noise levels can cause irreversible hearing loss or impairment as well as physical and psychological stress.

Hand Protection

Employees exposed to harmful substances through skin absorption, severe cuts or lacerations, severe abrasions, chemical burns, thermal burns, and harmful temperature extremes will benefit from hand protection. Assess the job for chemical and physical exposures. Base selection of gloves on the evaluation of performance characteristics relative to task(s) to be performed, conditions present, duration of use, hazards and potential hazards identified.

Body Protection

In some cases employees must shield most or all of their bodies against hazards in the workplace, such as exposure to heat and radiation as well as hot metals, scalding liquids, body fluids, hazardous materials or waste, and other hazards. In addition to fire-retardant wool and fire-retardant cotton, materials used in whole-body personal protective equipment include rubber, leather, synthetics, and plastic.

Respiratory Protection

When engineering controls are not feasible to control airborne exposures below applicable limits, employees must use appropriate respirators. Adverse health effects can be caused by breathing air contaminated with harmful dusts, fogs, fumes, mists, gases, smokes, sprays, or vapors. Respirators generally cover the nose and mouth or the entire face or head and help prevent illness and injury. A proper fit is essential for respirators to be effective. Required respirators must be approved by the National Institute for Occupational Safety and Health (NIOSH) and medical evaluation and training must be provided before use.

UNIT 14

OPERATE AND MAINTAIN WATER PRODUCTION SYSTEMS

This unit describes the outcomes required to operate, monitor and maintain water production systems across the water plants installed. Proper operational techniques including all the relevant knowledge will be developed among the participants while completing this unit

CONDUCT LOCAL INSPECTIONS AND PRE-OPERATIONAL SAFETY CHECKS

Inspections are a key part of good health and safety management. They allow you to check that your workplace and work activities are healthy and safe. Workplace inspections together with the Water plant will help prevent incidents, injuries and illnesses.

An inspection helps you identify hazards or processes that are not working efficiently and decide what measures to take before they lead to an accident or incident.

How to carry out inspection of the Water Plant and the installed site
There are various ways to carry out inspections. Inspection parameters need to be consulted with the team prior to the inspection

You should agree in advance what needs to be inspected (e.g. specific areas, equipment) and to what standard (locally or legally set).

Reading past inspection reports can be useful to check for any issues identified before and whether these have been fixed.

Inspections can be carried out by simply walking around water plant and the premises where the plant is installed and operated to monitor any issues there and then. You may record your findings in a notebook or use a checklist to remind you what to look for.

The inspection might include looking for unsafe conditions and unsafe acts.

Unsafe conditions might include slip, trip and fall hazards like uneven floors or trailing cables. They could also include faulty or damaged work equipment and electrical appliances and systems.

Unsafe acts could include not wearing PPE or not following safe working procedures.

Inspections can be formal, informal, recorded or unrecorded. It is important that they are carried out to an agreed standard and at a suitable frequency.

More formal ways of carrying out inspections include

- ✓ Walk around the power plant
- ✓ inspecting the site where power plant is installed
- ✓ safety sampling – thoroughly examining specific dangerous activities, processes or areas
- ✓ safety surveys – generally inspecting specific dangerous activities, processes or areas
- ✓ Incident inspections – looking at the cause of accidents, incidents and events that could have resulted in an injury or ill health.
- ✓ The findings of formal inspections should be recorded, and it is important these records are kept.

- ✓ While performing the inspection, make sure the Water Plant Manufacturer manuals are reviewed to ensure the findings reported as compared and substantiated.

STARTUP WATER SYSTEMS

Plant & Machinery Pre-Start Checklist

As a responsible operator, running a pre-start check on your plant or machinery before you start the day is the best way to ensure the job gets done safely and without delay.

Undertaking a pre-start check on your machine before you start a days work, happens in three stages.
Step 1 - Visual inspections of important features prior to starting the machine
Step 2 - Visual & function tests while the machine is turned on but stationary
Step 3 - Testing the machine's functions during a short drive
Within each of these steps there are activities that are common to all pre-start checks. We itemised them below and we then go into a few examples of extra items that are unique to those machine classes.
The following items are on all pre-start checklists for plant and machinery and are universal whether they are done on paper or electronically. We then review the slight tweaks you need to make in three pertinent examples - Pre-Start Checks for Excavators, Pre-Start Checks for Forklifts and Pre-Start Checks for Mobile Cranes.

Step 1 - Before turning the machine on:

The following checks need to be made while the engine is off and we recommend that they are done in the following order.

Important Features

- ✓ Inspect Hydraulic Lifts & Tilt Rams (if applicable) - are these lubricated and carry no damage?
- ✓ Battery - are the bracket terminals secure and clean?
- ✓ Are the battery electrolyte levels correct and caps in place?
- ✓ Is the battery charge sufficient for a day's work?

After these steps there are then a bunch of machine specific steps that are unique to each class of machine that you will need to visually inspect prior to turning the machine on. This involves things like the tracks, booms, arms and ground engaging tools.

Safety Fittings and Features

- ✓ Seat and Seatbelt - working and no damage?
- ✓ Data Plate - is it readable?
- ✓ Warning Decals - are they readable?
- ✓ FOPS & ROPS - are they secure and in good condition?

Coolant, Oil & Fuel Levels

- ✓ Engine Oil Level - correct?
- ✓ Fuel - enough for the day?
- ✓ Transmission Oil Level - correct?
- ✓ Hydraulic Oil Level - correct?
- ✓ Coolant Level Correct for temperature?
- ✓ Fluid Leaks - ensure there are no fluid leaks under the machine

Attachment Security

- ✓ Attachments like Buckets, Brooms, Spreader Bars etc - are they secure and the pins secure?
- ✓ Is there any damage to attachments that is visible? Make a note
- ✓ Ground Engaging Tools and surface (such as tracks, buckets etc) - is the cutting edge loose or worn?

At the end of these basic checks, plus the visual inspections you make that are specific to the machine you are checking, then it's time to turn the key. Make note of how smoothly it started and whether it's running well at the point of start.

Step 2 - After turning the machine on:

Now, it's time to get that machine purring and run through the final safety inspections.

General Functions (common to all machines)

Horn - does it work? And is there any issue with its volume?
Hand Controls - do they operate correctly?

- ✓ Foot Pedals - are they clean and do they operate correctly?
- ✓ Control Panel - are there any issues with warning indicators, lights and gauges?
- ✓ Reversing Beeper - does the machine operate in reverse? And do the beepers work?
- ✓ Lights - do they work? Can they operate on spot or drive mode?
- ✓ Rotating Warning Light - is it operational?
- ✓ Park Break - does it hold the machine on an incline?

After these general checks, we are going to run through a bunch of unique features with your machine - like operating the boom, bucket, rippers or GPS if these are fitted to the machine. We'll discuss these below.

Step 3 - While driving the machine now:

To complete the final checks you need to drive the machine a small distance.

- ✓ Is the steering working well with no undue noise/stress?
- ✓ Steering clutches - is there no excessive play?
- ✓ Creep - the machine doesn't creep when controls are neutralized

OPERATE AND CONTROL WATER TREATMENT PROCESSES

Desalination by reverse osmosis

Desalination is a separation process used to reduce the dissolved salt content of saline water to a usable level. All desalination processes involve three liquid streams: the saline feedwater (brackish water or seawater), low-salinity product water, and very saline concentrate (brine or reject water).

The saline feedwater is drawn from oceanic or underground sources. It is separated by the desalination process into the two output streams: the low-salinity product water and very saline concentrate streams. The use of desalination overcomes the paradox faced by many coastal communities, that of having access to a practically inexhaustible supply of saline water but having no way to use it. Although some substances dissolved in water, such as calcium carbonate, can be removed by chemical treatment, other common constituents, like sodium chloride, require more technically sophisticated methods, collectively known as desalination. In the past, the difficulty and expense of removing various dissolved salts from water made saline waters an impractical source of potable water. However, starting in the 1950s, desalination began to appear to be economically practical for ordinary use, under certain circumstances.

The product water of the desalination process is generally water with less than 500 mg/1 dissolved solids, which is suitable for most domestic, industrial, and agricultural uses.

A by-product of desalination is brine. Brine is a concentrated salt solution (with more than 35 000 mg/1 dissolved solids) that must be disposed of, generally by discharge into deep saline aquifers or surface waters with a higher salt content. Brine can also be diluted with treated effluent and disposed of by spraying on golf courses and/or other open space areas.

Technical Description

There are two types of membrane process used for desalination: reverse osmosis (RO) and electrodialysis (ED). The latter is not generally used in Latin America and the Caribbean. In the RO process, water from a pressurized saline solution is separated from the dissolved salts by flowing through a water-permeable membrane. The permeate (the liquid flowing through the membrane) is encouraged to flow through the membrane by the pressure differential created between the pressurized feedwater and the product water, which is at near-atmospheric pressure. The remaining feedwater continues through the pressurized side of the reactor as brine. No heating or phase change takes place. The major energy requirement is for the initial pressurization of the feedwater. For brackish water desalination the operating pressures range from 250 to 400 psi, and for seawater desalination from 800 to 1 000 psi.

In practice, the feedwater is pumped into a closed container, against the membrane, to pressurize it. As the product water passes through the membrane, the remaining feedwater and brine solution becomes more and more concentrated. To reduce the concentration of dissolved salts remaining, a portion of this concentrated feedwater-brine solution is withdrawn from the container. Without this discharge, the concentration of dissolved salts in the feedwater would continue to increase, requiring ever-increasing energy inputs to overcome the naturally increased osmotic pressure.

A reverse osmosis system consists of four major components/processes: (1) pretreatment, (2) pressurization, (3) membrane separation, and (4) post-treatment stabilization. Figure 16 illustrates the basic components of a reverse osmosis system.

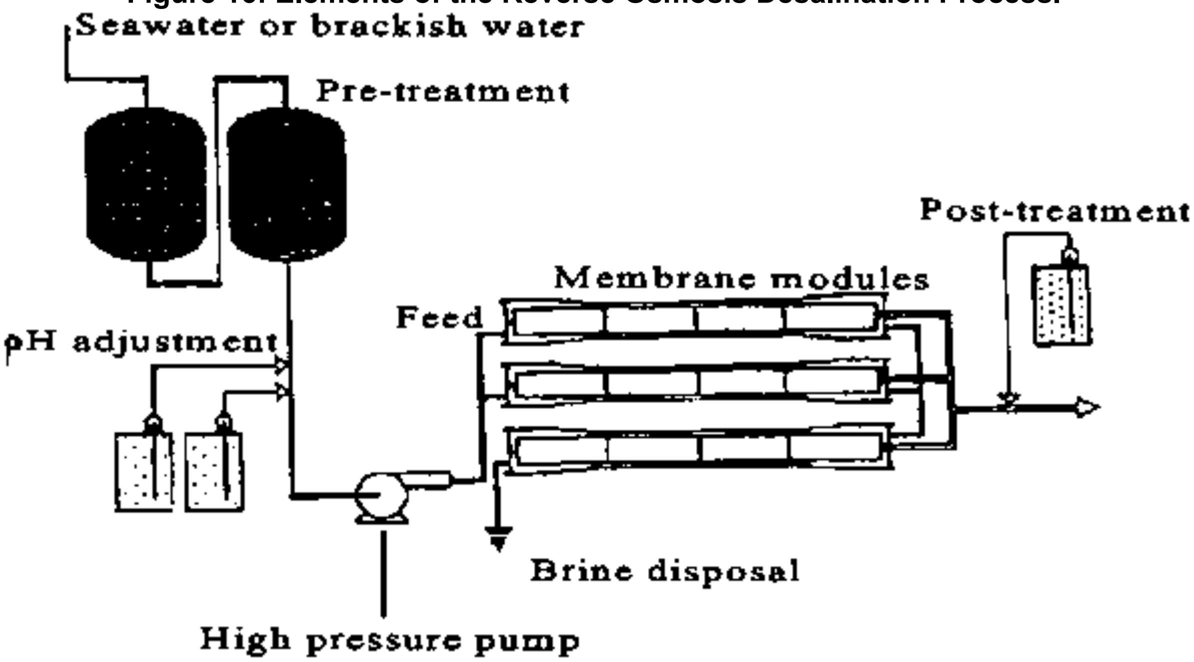
Pretreatment: The incoming feedwater is pretreated to be compatible with the membranes by removing suspended solids, adjusting the pH, and adding a threshold inhibitor to control scaling caused by constituents such as calcium sulphate.

Pressurization: The pump raises the pressure of the pretreated feedwater to an operating pressure appropriate for the membrane and the salinity of the feedwater.

Separation: The permeable membranes inhibit the passage of dissolved salts while permitting the desalinated product water to pass through. Applying feedwater to the membrane assembly results in a freshwater product stream and a concentrated brine reject stream. Because no membrane is perfect in its rejection of dissolved salts, a small percentage of salt passes through the membrane and remains in the product water. Reverse osmosis membranes come in a variety of configurations. Two of the most popular are spiral wound and hollow fine fiber membranes (see Figure 17). They are generally made of cellulose acetate, aromatic polyamides, or, nowadays, thin film polymer composites. Both types are used for brackish water and seawater desalination, although the specific membrane and the construction of the pressure vessel vary according to the different operating pressures used for the two types of feedwater.

Stabilization: The product water from the membrane assembly usually requires pH adjustment and degasification before being transferred to the distribution system for use as drinking water. The product passes through an aeration column in which the pH is elevated from a value of approximately 5 to a value close to 7. In many cases, this water is discharged to a storage cistern for later use.

Figure 16: Elements of the Reverse Osmosis Desalination Process.



Extent of Use

The capacity of reverse osmosis desalination plants sold or installed during the 20-year period between 1960 and 1980 was 1 050 600 m^3/day. During the last 15 years, this capacity has continued to increase as a result of cost reductions and technological advances. RO-desalinated water has been used as potable water and for industrial and agricultural purposes.

Potable Water Use: RO technology is currently being used in Argentina and the northeast region of Brazil to desalinate groundwater. New membranes are being designed to operate at higher pressures (7 to 8.5 atm) and with greater efficiencies (removing 60% to 75% of the salt plus nearly all organics, viruses, bacteria, and other chemical pollutants).

Industrial Use: Industrial applications that require pure water, such as the manufacture of electronic parts, speciality foods, and pharmaceuticals, use reverse osmosis as an element of the production process, where the concentration and/or fractionating of a wet process stream is needed.

Agricultural Use: Greenhouse and hydroponic farmers are beginning to use reverse osmosis to desalinate and purify irrigation water for greenhouse use (the RO product water tends to be lower in bacteria and nematodes, which also helps to control plant diseases). Reverse osmosis technology has been used for this type of application by a farmer in the State of Florida, U.S.A., whose production of European cucumbers in a 22 ac. greenhouse increased from about 4 000 dozen cucumbers/day to 7 000 dozen when the farmer changed the irrigation water supply from a contaminated surface water canal source to an RO-desalinated brackish groundwater source. A 300 l/d reverse osmosis system, producing water with less than 15 mg/1 of sodium, was used.

In some Caribbean islands like Antigua, the Bahamas, and the British Virgin Islands (see case study in Part C, Chapter 5), reverse osmosis technology has been used to provide public water supplies with moderate success.

In Antigua, there are five reverse osmosis units which provide water to the Antigua Public Utilities Authority, Water Division. Each RO unit has a capacity of 750 000 l/d. During the eighteen-month period between January 1994 and June 1995, the Antigua plant produced between 6.1 million l/d and 9.7 million l/d. In addition, the major resort hotels and a bottling company have desalination plants.

In the British Virgin Islands, all water used on the island of Tortola, and approximately 90% of the water used on the island of Virgin Gorda, is supplied by desalination. On Tortola, there are about 4 000 water connections serving a population of 13 500 year-round residents and approximately 256 000 visitors annually. In 1994, the government water utility bought 950 million liters of desalinated water for distribution on Tortola. On Virgin Gorda, there are two seawater desalination plants. Both have open seawater intakes extending about 450 m offshore. These plants serve a population of 2 500 year-round residents and a visitor population of 49 000, annually. There are 675 connections to the public water system on

Virgin Gorda. In 1994, the government water utility purchased 80 million liters of water for distribution on Virgin Gorda.
In South America, particularly in the rural areas of Argentina, Brazil, and northern Chile, reverse osmosis desalination has been used on a smaller scale.

Operation and Maintenance

Operating experience with reverse osmosis technology has improved over the past 15 years. Fewer plants have had long-term operational problems. Assuming that a properly designed and constructed unit is installed, the major operational elements associated with the use of RO technology will be the day-to-day monitoring of the system and a systematic program of preventive maintenance. Preventive maintenance includes instrument calibration, pump adjustment, chemical feed inspection and adjustment, leak detection and repair, and structural repair of the system on a planned schedule.

The main operational concern related to the use of reverse osmosis units is fouling. Fouling is caused when membrane pores are clogged by salts or obstructed by suspended particulates. It limits the amount of water that can be treated before cleaning is required. Membrane fouling can be corrected by backwashing or cleaning (about every 4 months), and by replacement of the cartridge filter elements (about every 8 weeks). The lifetime of a membrane in Argentina has been reported to be 2 to 3 years, although, in the literature, higher lifespans have been reported.

Operation, maintenance, and monitoring of RO plants require trained engineering staff. Staffing levels are approximately one person for a 200 m^3/day plant, increasing to three persons for a 4 000 m^3/day plant.

Level of Involvement

The cost and scale of RO plants are so large that only public water supply companies with a large number of consumers, and industries or resort hotels, have considered this technology as an option. Small RO plants have been built in rural areas where there is no other water supply option. In some cases, such as the British Virgin Islands, the government provides the land and tax and customs exemptions, pays for the bulk water received, and monitors the product quality. The government also distributes the water and in some cases provides assistance for the operation of the plants.

Costs

The most significant costs associated with reverse osmosis plants, aside from the capital cost, are the costs of electricity, membrane replacement, and labor. All desalination techniques are energy-intensive relative to conventional technologies. Table 5 presents generalized capital and operation and maintenance costs for a 5 mgd reverse osmosis desalination in the United States. Reported cost estimates for RO installations in Latin American and the Caribbean are shown in Table 6. The variation in these costs reflects site-specific factors such as plant capacity and the salt content of the feedwater.

The International Desalination Association (IDA) has designed a Seawater Desalting Costs Software Program to provide the mathematical tools necessary to estimate comparative capital and total costs for each of the seawater desalination processes.

Table U.S. Army Corps of Engineers Cost Estimates for RO Desalination Plants in Florida

Feedwater Type	Capital Cost per Unit of Daily Capacity ($/m^3/day)	Operation & Maintenance per Unit of Production ($/m^3)
Brackish water	380 - 562	0.28 - 0.41
Seawater	1341 - 2379	1.02 - 1.54

Table Comparative Costs of RO Desalination for Several Latin American and Caribbean Developing Countries

Country	Capital Cost ($/m^3/day)	Operation and Maintenance ($/m^3)	Production Cost* ($/m^3)[a]
Antigua	264 - 528	0.79 - 1.59	
Argentina		3.25	
Bahamas			4.60 - 5.10
Brazil	1454 - 4483		0.12 - 0.37
British Virgin Islands	1190 - 2642		[b]3.40 - 4.30
Chile	1300		1.00

[a] *Includes amortization of capital, operation and maintenance, and membrane replacement.*
[b] *Values of $2.30 - $3.60 were reported in February 1994.*

Effectiveness of the Technology

Twenty-five years ago, researchers were struggling to separate product waters from 90% of the salt in feedwater at total dissolved solids (TDS) levels of 1 500 mg/1, using pressures of 600 psi and a flux through the membrane of 18 l/m^2/day. Today, typical brackish installations can separate 98% of the salt from feedwater at TDS levels of 2 500 to 3 000 mg/1, using pressures of 13.6 to 17 atm and a flux of 24 l/m^2/day - and guaranteeing to do it for 5 years without having to replace the membrane. Today's state-of-the-art technology uses thin film composite membranes in place of the older cellulose acetate and polyamide membranes. The composite membranes work over a wider range of pH, at higher temperatures, and within broader chemical limits, enabling them to withstand more operational abuse and conditions more commonly found in most industrial applications. In general, the recovery efficiency of RO desalination plants increases with time as long as there is no fouling of the membrane.

Suitability

This technology is suitable for use in regions where seawater or brackish groundwater is readily available.

Advantages

- ✓ The processing system is simple; the only complicating factor is finding or producing a clean supply of feedwater to minimize the need for frequent cleaning of the membrane.
- ✓ Systems may be assembled from prepackaged modules to produce a supply of product water ranging from a few liters per day to 750 000 l/day for brackish water, and to 400 000 l/day for seawater; the modular system allows for high mobility, making RO plants ideal for emergency water supply use.
- ✓ Installation costs are low.
- ✓ RO plants have a very high space/production capacity ratio, ranging from 25 000 to 60 000 $l/day/m^2$.
- ✓ Low maintenance, nonmetallic materials are used in construction.
- ✓ Energy use to process brackish water ranges from 1 to 3 kWh per 1 0001 of product water.
- ✓ RO technologies can make use of use an almost unlimited and reliable water source, the sea.
- ✓ RO technologies can be used to remove organic and inorganic contaminants.
- ✓ Aside from the need to dispose of the brine, RO has a negligible environmental impact.
- ✓ The technology makes minimal use of chemicals.

Disadvantages

- ✓ The membranes are sensitive to abuse.
- ✓ The feedwater usually needs to be pretreated to remove particulates (in order to prolong membrane life).
- ✓ There may be interruptions of service during stormy weather (which may increase particulate resuspension and the amount of suspended solids in the feedwater) for plants that use seawater.
- ✓ Operation of a RO plant requires a high quality standard for materials and equipment.
- ✓ There is often a need for foreign assistance to design, construct, and operate plants.
- ✓ An extensive spare parts inventory must be maintained, especially if the plants are of foreign manufacture.
- ✓ Brine must be carefully disposed of to avoid deleterious environmental impacts.
- ✓ There is a risk of bacterial contamination of the membranes; while bacteria are retained in the brine stream, bacterial growth on the membrane itself can introduce tastes and odors into the product water.
- ✓ RO technologies require a reliable energy source.
- ✓ Desalination technologies have a high cost when compared to other methods, such as groundwater extraction or rainwater harvesting.

Cultural Acceptability

RO technologies are perceived to be expensive and complex, a perception that restricts them to high-value coastal areas and limited use in areas with saline groundwater that lack access to more conventional technologies. At this time, use of RO technologies is not widespread.

Further Development of the Technology

The seawater and brackish water reverse osmosis process would be further improved with the following advances:

- ✓ Development of membranes that are less prone to fouling, operate at lower pressures, and require less pretreatment of the feedwater.
- ✓ Development of more energy-efficient technologies that are simpler to operate than the existing technology; alternatively, development of energy recovery methodologies that will make better use of the energy inputs to the systems.
- ✓ Commercialization of the prototype centrifugal reverse osmosis desalination plant developed by the Canadian Department of National Defense; this process appears to be more reliable and efficient than existing technologies and to be economically attractive.

MONITOR AND CONTROL WATER SYSTEMS

Most industries have now realized that product quality is not an option. There was historical thinking that quality is the equivalent of “gold-plating” your product, but that has mostly fallen away. Product quality is not always a cost-benefit trade-off: it is beneficial to you in the long-term to improve your product quality, and for your customers as well.

As we spoke about in the univariate review section, good quality products (low variability) actually boost your profits by lowering costs in the long term. You have lower costs when you do not have to scrap off-specification product, or have to rework bad product. You have increased long-term sales with more loyal customers and improved brand reputation as a reliable and consistent supplier.

An example that most people in North America can relate to is the rise in Asian car manufacturers’ market share, at the expense American manufacturers’ market share. The market has the perception that Asian cars are more reliable than American cars and resale rates certainly reflect that. The perception has started to change since 2010, as North American manufacturers have become more quality conscious. That is an illustration of how lack of variability in your product can benefit you.

In order to achieve this high level of final product quality, our systems should be producing low variability product at every step of the manufacturing process. Rather than wait till the end of the process to discover poor quality product, we should be monitoring, in real-time, the purchased raw materials and also the intermediate steps in our process. When we discover unusual variability the lofty aim is to make (permanent) process adjustments to avoid that variability from ever occurring again.

Notice here that process monitoring is not intended to be automatic feedback control. It has the same principles of quantifying unusual operation (errors) and reacting to them in some way, but the intention with process monitoring is:

- ✓ that any process adjustments are **infrequent** [not frequently on a set cycle, as feedback control does],
- ✓ these adjustments are made **manually** [not automatically with actuators],
- ✓ and take place due to **special causes** [not due to regularly occurring process disturbances].

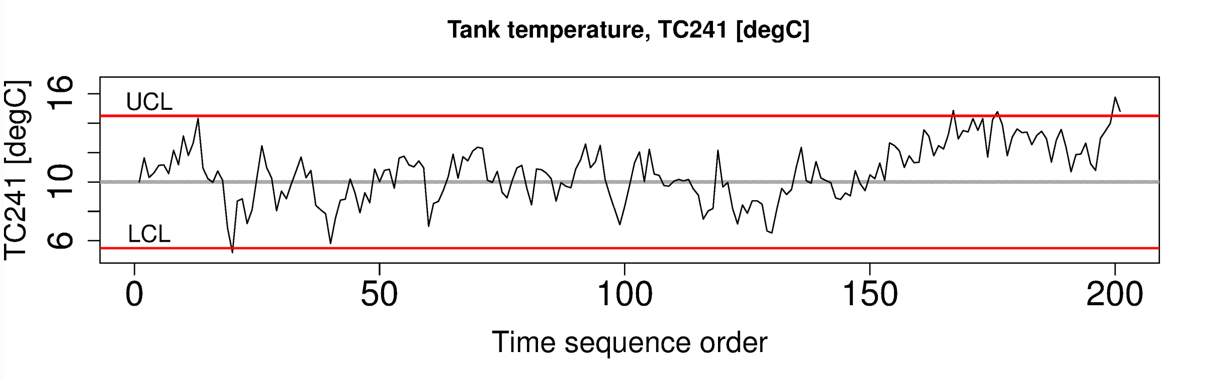
As seen by the items in square brackets above, automatic feedback control is applied continuously by computer systems and makes short-term, temporary changes to the system to keep it at the desired target (called the setpoint) in the face of process disturbances. Process monitoring is very different therefore to feedback control.
Note that process monitoring is often called statistical process control (SPC). This can lead to unnecessary confusion with process control, i.e. the design and implementation of feedback control, feed-forward control and other automated control systems. We will not use the term SPC, rather we will use the term *process monitoring*.

Monitoring charts

We use monitoring charts, also called control charts, to display and detect this unusual variability. A monitoring chart is a display of one value (variable), against time, or in sequence order. These time-based plots also show some additional information: usually a target value, and one or more limits lines are superimposed on the plot. The plots are most useful when displayed in real-time, or close to real-time. There are various technical ways to express what a monitoring chart does exactly, but a general definition is that a monitoring chart helps you detect outliers and other unusual time-based behaviour.
The key points are that a monitoring chart:

- ✓ is most often a time-series plot, or some sort of sequence plot,
- ✓ a target value (center line) may be shown,
- ✓ one or more limit lines are shown, such as the UCL (upper control limit) or LCL (lower control limit),
- ✓ they are displayed and updated in real-time, or as close to real-time as possible, so that the chart appears to move from right to left.

Here is an example that shows these properties.



General approach

Monitoring charts are developed in 2 phases. You will see the terminology of:

- ✓ **Phase 1**: building and testing the chart from historical data that you have collected. This phase is performed off-line, it is very iterative, and you will spend most of your time here. The primary purpose of this phase is to
  - o find portions of the data that are from stable operation
  - o use these stable portions to calculate suitable control chart limits
  - o ensure that your chart works as expected based on historical data

- ✓ **Phase 2**: We use the monitoring chart on new, fresh data from the process. This phase is implemented with computer hardware and software for real-time display of the charts. This phase is skipped if the phase 1 testing is not successful (e.g. too many false alarms). We discuss reasons for failure in the section on judging the chart's performance.

What should we monitor?

Any variable can be monitored. However, the purpose of process monitoring is so that you can **react early** to bad, or unusual operation. This implies we should monitor variables as soon as they become available, preferably in real-time. They are more suitable than variables that take a long time to acquire (e.g. laboratory measurements). We should not have to wait to the end of the production line to find our process was out of statistical control.

Data/measurements available at the start of your process, suc as raw material data from your supplier should also be monitored as soon as it is available, e.g. when received by your company, or even earlier - before the supplier ships it to you.

Intermediate variables measured from sensors at all points along the production process are (a) available much more frequently and without delay, (b) are more precise, (c) are usually more meaningful to the operating staff than final quality variables from the lab, and (d) contain the "fingerprint" of the fault, helping the engineers with diagnosis of what the problem is and point to which part(s) of the process need adjustment (see *MacGregor, 1997*).

Note that we do not have to monitor variables that are measured only from on-line sensors. The variable could be a calculation made from the on-line measurements.

For example, an energy balance could be calculated from various thermocouples on the process and the degree of mismatch in the energy balance could be critical to quality. For example, the mismatch could indicate an unexpected source of heat into or out of the process - so monitor that mismatch, rather than the raw temperature data. Similarly, a mass balance can be monitored in real-time, such as a total mass balance, or a carbon (or other elemental) balance. This is common in the mining industry and bio-processing industries.

Discuss one of these unit operations with your colleague. Which variables would you monitor?

- ✓ Waste water treatment process
- ✓ Tablet/pharmaceutical manufacturing
- ✓ Oil and gas (e.g. a distillation column)
- ✓ Food-processing or bio-engineering (e.g. fermentation) unit
- ✓ Mineral processing plant (e.g. a flotation cell)
- ✓ Plastics processing (e.g. a twin-screw extruder)

In-control vs out-of-control

Every book on quality control gives a slightly different viewpoint, or uses different terminology for these terms.

In this book we will take "in-control" to mean that the behaviour of the process is stable over time. Note though, that in-control *does not* mean the variable of interest meets the specifications required by the customer, or set by the plant personnel. All that "in control" means is that there are no **special causes** in the data, i.e. the process is stable. A special cause, or an assignable cause is an event that occurs to move the process, or destabilize it. Process monitoring charts aim to detect such events. The opposite of "special cause" operation is common cause operation, or stable process operation.

CONDUCT A WATER SYSTEM SHUTDOWN

How to plan for plant maintenance shut-down

Some factories temporarily shut down each year for scheduled plant maintenance shut-down. Within that period of time, the plant floor is cleaned, equipment is inspected or replaced, processes are improved, and/or production lines are added. The "off-line" time can be detrimental, or advantageous, to your bottom line depending if a plan is properly prepared and executed through these 5 phases.

Phase I: Define and Implement Strategies for Plant Maintenance Shut-Down

- ✓ Provides a foundation for the goals of your plant maintenance shut-down.
- ✓ Analyzes how frequently plant maintenance must be performed to allow the production process to function optimally.
- ✓ Estimates how long plant maintenance shut-down must occur, and assesses the best time for plant maintenance shut-down to occur, in relation to manufacturing forecasts. Plant maintenance shut-down is a long-term business strategy – not a "week of" decision.
- ✓ Key drivers of plant maintenance shut-down:
    - Improve equipment to reduce waste in manufacturing resources, thus reducing operating costs.
    - Improve overall equipment effectiveness (OEE).
    - Maintenance equipment to sustain its equipment life cycle.
    - Maintenance equipment to improve mean time between failure (MTBF).
    - Equipment inspection.
    - Equipment repair.
    - Replacement of worn equipment.
    - Replacement of broken equipment.
    - Replace depreciated equipment (ie: Equipment that has reached the end of its useful life).
    - Ensure compliance with health & safety codes.
- ✓ Be mindful of and create a budgetary buffer for the fact that unexpected issues will be found internal to the system, once maintenance inspections have begun.
- ✓ Appoint a steering committee to lead the plant maintenance shut-down. That committee should host meetings with executive management to assess how the maintenance shut-down will impact the greater good of the company, and to assess what Key Performance Indicators (KPIs) are most important to the company's long-term business goals. Typical KPIs include safety, cost, production scheduling, labor hours, overtime hours, lead times, and more. By assessing KPIs, a business can prioritize its investments in system components, based on level of importance to the

business' common, overarching goals. (Example: If the goal is to increase capabilities at bulk bag loading stations, a wise investment would be in a flap diverter to double the loading capacity capabilities. A less appropriate investment would be in a new silo of equal size above the loading station, if that silo was still capable of efficiently holding materials.)

- ✓ Make a list of all equipment parts that should be up for debate. Categorize those list items based on what items are required for maintenance to remain compliant with agency guidelines, and which improvements are "a la carte" to benefit the system's goals, ranking in level of importance. Use data analysis to determine what equipment areas are "bottlenecks" and more degrading to efficiency, in comparison to the rest of the system. Upon analysis of improvement priorities, finalize what improvements will be made during the curing system shut-down by adding them to the CMMS (Computerized Maintenance Management System). Those improvements that were opted against for this shut-down should be noted, so that they can be re-considered for the next system shut-down.
- ✓ Be sure the improvements being made during plant maintenance shut-down can only be done during full shut-down. If a task can be performed while the system remains active, the company is not best utilizing their shut-down resources.
- ✓ Document the estimated costs, down-time schedule, list of jobs, and estimated resources needed to complete the shut-down project. This allows the company to anticipate the full scope of the project. Have this agreement approved by the shut-down steering team and the company executive team before the project is to begin. Once approved, disseminate the information throughout the organization, so that there is project transparency across company sectors.

Phase II: Plant Maintenance Shut-Down Preparation

- ✓ Develop plans for how the maintenance will be performed, prior to project execution. To reinforce the improvements being made, consider adjusting the company's environmental, health and safety plans. Analyze the different manufacturing departments to determine if they can be optimized or otherwise improved in any way. Determine the logistics on what materials are needed for the shut-down project, when they will arrive on-site, how they will arrive on-site, and who will be working on this equipment during the shut-down. Make sure equipment and materials are ordered early, so that the shut-down is not delayed. Consider how the equipment and materials will be stored until they are called upon during shut-down.
- ✓ Develop plans for quality assurance. This provides standard procedures for quality control techs, so that they can inspect new equipment after system shut-down has concluded, to be sure the equipment is running safely and efficiently.
- ✓ Using information from Phase I, develop the work package. A work package details the job scope, the number of laborers assigned to the shut-down project, the estimated number of labor hours needed for project execution, and scheduling of task completion. This includes a detailed, step-by-step instruction plan on how the project will be complete. Include safety steps and precautions to be taken, drawings of the project at-hand, and photos to support how each sub-project will be completed most effectively.

- ✓ Determine what steps of the shut-down will be completed using internal resources, and which project stages will external resources be necessary. For those jobs demanding external resources, begin fielding bids from contractors for such jobs. (Example: Contracting a crane company to remove valves from line.)
- ✓ Create contingency plans, to account for any risks or problems that may occur during plant maintenance shut-down.
- ✓ Determine any necessity work that must be done pre-shut-down. Complete those jobs, so that they are ready to accommodate the shut-down improvements, when called upon. (Example: If adding a production line, prepare new piping to run toward the inlet and outlet of new equipment.)
- ✓ If Phase II is done correctly, a full, detailed schedule of the plant maintenance shut-down will be complete, and cost figures will be estimated within approximately 10 percent of budget allocations.
- ✓ Have plans approved by both the shut-down steering committee and the company executive team. Once approved, communicate Phase II to each of the company's departmental sectors, to create project transparency.
- ✓ It is also important to consider the effects the shut-down may have on your customers and constituents. If the shut-down will have a direct impact on the customer, frequent and effective communication is crucial. Update your customers regularly throughout the process to reduce the risk of dissatisfaction and future loss of business.

Phase III: Execution of the Project

- ✓ As previously discussed, once the project begins, it is the inevitable that undetected and unpredictable findings will arise during inspection. On the fly, it is important to assess these issues to determine the necessity of their repair, the costliness of their repair, and how they will affect the overall scope of completion for the original project. Be sure to stay true to the work package, to avoid working over-budget, and to be sure the important projects are brought to fruition during the allotted project time schedule.
- ✓ Be sure the internal and external resources on the project are well-managed, so that the project is being executed efficiently.
- ✓ Update the work package schedule daily, so that resources who finish their tasks early can be re-delegated to assist on tasks that are understaffed, not begun, incomplete, or otherwise behind schedule. Prioritize which projects are more pertinent to the project's overall success, as well as which projects are more or less time-consuming. This creates a planned sequence for job tasks. Continuously update the package, so that communication across the project team is transparent for what projects have or have not been completed, and which projects are currently in progress.
- ✓ Track data to compare with the pre-determined KPIs – ie: actual vs. estimated labor hours, actual vs. estimated overtime hours, actual costs vs. budgeted costs, etc. This data is critical to project progression, in order to maximize costs and labor utilization. For example, if the project is developing too slowly and the staff is at maximum utilization plus ample overtime, it may be necessary to contract more resources to assist on the project. Oppositely, as the project comes to an end, often times, only a few tasks remain. In many instances, the crew becomes overstaffed for completing these minor tasks. KPI analysis allows the project supervisor to determine when

resources are not being fully utilized, so that they can make the decision to cut resources for project cost efficiency.

- ✓ Once improvements and repairs have been complete, the system must be tested to be sure all improvements are running as predicted.

Phase IV: Start Up & Turn Over

Part I: Handoff

- ✓ Once testing has been complete by the shut-down team, the operations team is introduced to the new system. Then, the operations team runs testing on the full asset base to be sure the process was actually improved. The shut-down team stands by as tests are performed, to provide technical support, if necessary.

Part II: Ramp Up

- ✓ Once testing has been complete by the operations team, trials runs are performed by the system, so that the equipment can be observed in-operations and adjustments can be made accordingly. This stage is arguably the most important aspect of plant maintenance shut-down, as it is the time when errors are most likely to occur, and it is the most important aspect of the project because it determines how the system as a whole will operate and stabilize, moving forward.

Part III: the Punch List

- ✓ Once the shut-down team and the operations team are satisfied with the results of the shut-down, the shut-down team does a final walk-through to assess what tasks on the project list were completed, and which ones were not. Because of budgetary issues and un-predictable issues, it's nearly impossible to finish all items on the punch list. However, by determine what items were not complete during this shut-down, it creates a starting point when planning the next system shut-down.

Phase V: Evaluation

- ✓ Demobilize the work site: Plan the logistics for returning any external resources or equipment. Determine how unused resources will be disposed. Clean the work site to prepare it for operations. Get rid of the equipment removed from the system. Tear down any trailers/offices constructed for the purpose of the maintenance shut-down (ie: Those assembled to house external work teams).
- ✓ Host a post-mortem meeting to summarize the success/failures of the shut-down project. Detail the work that was complete, what remains to be complete, and lessons learned on the project. Assess the KPIs and determine the efficiency of the project's completion, to learn from the data to better shut-down practices for next time. The premise is that if best practices can be determined, fewer problems and unforeseen complications will arise during upcoming projects, making the project streamlined of error or ambiguity.
- ✓ Finally, tie up the loose ends of the project. For bookkeeping purposes, close purchase orders, work orders, external resource contracts, or any other financial paperwork that must be processed for project completion. Keep records of how much material

was used versus quantities returned upon project completion, so that more accurate material quantities can be ordered when they are needed for the next shut-down project.

- ✓ Make a cost analysis document to directly compare estimated/budgeted costs versus actual costs. Based upon this analysis, draw conclusions on how the numbers can be more accurately aligned on future projects.
- ✓ Over time, until the next shut-down is to occur, continuously monitor the equipment that was improved during the previous shut-down. This helps to justify the effectiveness of decision making in previous shut-down(s), and gives insight on major equipment categories that are most impactful for improving the asset base.

Because career changes occur, it is unlikely that the same shut-down team will work on multiple projects – especially consecutively. This is why thorough and formal documentation is necessary throughout each phase of shut-down, as it serves as an "instruction manual" for the team(s) to follow. The key factors to successful plant maintenance shut-down are simple: Outstanding management, repeatability, and consistency. If the best practices are streamlined, understandable and attainable for any team, regardless of ever-changing resources, shut-down projects themselves will also be well-oiled machines.

RESPOND TO AN UNPLANNED SHUTDOWN

The highest pressure situation your maintenance department might ever encounter is a planned downtime. A large amount of work is scheduled into a small amount of time, but the deadline for resuming production is just around the corner.

There can be great gains to be made by increasing reliability or installing new equipment. However, there are risks. New problems can arise, and costs can mount. How do you make shutdowns a safer bet?

In project management context, the word risk is simply used as shorthand for "deviation from the project plan." Encountering at least some risk is unavoidable. The impact of that risk depends on how a shutdown has been planned.

Uncertainty about the magnitude of repairs needed, over-aggressive estimates, lack of experience, and a number of other issues can contribute to delays, cost overruns and lost productivity. Some of these factors can be eliminated, but most risks can only be managed.

Seeing Risk

The critical task here is to accurately project the magnitude of the risks involved in a shutdown and respond accordingly. As the project is outlined, several factors should be examined to develop a better view of the situation.

The basic rule is that the complexity of the task is directly related to the likelihood of encountering difficulty. In planning for a shutdown, the following factors may flag a process for being a likely delay.

Critical Path – By definition, a Critical Path task has the potential to cause serious delays. Any delay in activity on the Critical Path has the potential of delaying the whole project.

Predecessors – A task that depends on multiple tasks being completed first is subject to more possibilities for delay.

Aggressive Estimates – Setting high standards for productivity doesn't mean expecting the impossible. Unrealistic estimates can cause serious bottlenecks when later tasks get delayed by overruns in the initial stages of a shut down.
Unfamiliar Tasks – Have workers performed this task before? New equipment and turnover could create a situation where workers would be learning on the fly. Identifying training needs and calling in outside resources may be the difference between on time and behind schedule.
Final Work – At the end of a shutdown, your workforce has been under pressure and the finishing work can present a stumbling block. Proper load leveling can minimize this problem.
Rarity – Are the materials or labor needed for a specific task hard to obtain? Delay with supplying these needs can cause major delays. Project management reports should include a filter for specialists and resource availability.

Measuring Risk

Not all problems are created equal. Solving some might be fairly easy, others might bankrupt a company. Determining which need your most urgent attention is the comparison of three values: tolerance level, cost and probability.
Tolerance: Tolerance is evaluating the capability of your company to respond to risk without unacceptable consequences. Cash reserves, overdue orders, production goals, and regulatory requirements can all inform this discussion.
What might be an acceptable possible cost for an international operation with multiple plants could be catastrophic to a smaller custom manufacturer. Risk tolerance is not just a fiscal calculation, even if money is a major consideration here. It is a yardstick of the magnitude of various shutdown risks.
Parallel to the financial accounting needs to be an assessment of environmental, health, and safety concerns. Human lives can't be counted in the same way, but this doesn't mean that quantifying the potential for problems isn't important. Assume the worst, brainstorm for possibilities, identify consequences, and plan out scenarios in detail.
Cost: The additional cost of risk can be estimated by comparing the worst possible scenario against the planned outlay. If things begin to go wrong, what will it take to get things back under control? Costs aren't just limited to the immediate expenses of fixing a problem, but everything that adds up from the interruption. Will orders go unfulfilled? Contracts or customers lost? Will specialists need to be brought in? New equipment ordered?
Broad brainstorming is crucial here. Expertise from all corners helps build a complete picture of possible consequences and tally up the costs.
Precise calculation is not possible for every risk you will have identified, and some may simply need to be estimated. The priority here is to carefully consider the risks that have the greatest potential to cause disruption and delay.
Probability: Likelihood of an event is most accurately predicted based on prior data. Records from previous shutdowns and experienced employees can help guide this kind of analysis. But since shutdowns tend to be rare, not every kind of risk will have hard data associated with it.
The key here will be to make the best possible estimate based on experience. A reasoned estimate is more useful than a wild guess or no prediction at all. Thinking through the

possible chains of events will help identify likely trouble spots based on the criteria presented above.

Remember, the more complex a task, the greater the possibility of failure. Multiple inputs, critical supplies and talents, and time sensitivity all drive risk.

Let's not overlook PERT and Monte Carlo duration estimate methods – these allow you to enter worst case, expected, and best case scenarios (dollars and durations) for each task.

Project management software can then extrapolate the likelihood of a task's starting on a particular date, and Monte Carlo calculations can help give such results more detail and accuracy.

Tasks that are not very likely to begin on their planned date are, of course, more likely to fall further behind. Think of PERT as a way to quantify the confidence that a planner has in their duration estimates, and Monte Carlo calculations as a way to figure the cumulative effects of these uncertainties throughout the project.

Combine the probability that a risk will occur with the cost of the risk and compare that with your tolerance for acceptable costs and delays. If you feel that the task is involves risk your operation cannot afford, note this in a field in your list or project management software.

These risks must be managed. Risks that are better than acceptable can be left alone. Prioritize your list of risks, separating those that must be managed from those that do not.

Response Development

There are two fronts on which to act in responding to risk. Risks can be avoided or they can be made less costly when they do occur.

Avoidance is a first step. Now that your team is looking for risks, some problems can be entirely bypassed. Delays with the arrival of materials and or the lack of information on the repair of a piece of equipment can be remedied with foresight.

Some potential issues can be absorbed into the plan if they can't be prevented. One of the biggest possibilities for risk and delay comes out of unplanned repairs. Issues that arise during the shutdown tend to be prioritized because of the surprise factor.

While this might be necessary, it is far better to start out knowing the magnitude of work to be done. Have non-invasive tests been performed on equipment? Infra-red scans done to look for overheating? Vibration checks performed? Sound checks for compressed air leakage?

Think of all the ways that equipment can be assessed before shutdown and disassembly, so that you enter the shutdown with a clear picture of what needs to be done so that supplies and labor are ready.

Knowing about an issue in advance can mean the difference of a major delay while waiting for a part and having it arrive right on time. Once a problem is identified, planned and prepared for, it's no longer a risk, but a regular part of your planned maintenance.

But what about risks that aren't necessarily avoidable? Some issues can arise during the shutdown that can't be known in advance. Diagnostics have limits, and some equipment may not be possible to check until it is offline. Needed supplies might be delayed. Repair work may turn out to be more complicated than originally thought. The key here is mitigation.

Mitigation is the process of taking steps that reduce the impact of risks. This might mean building some extra worker hours into a schedule so that new issues can be addressed while planned work is still done on time.

It might mean having more spare parts on hand, should they be required as refurbishing takes place. Or it could be writing damages into a contract with an outside supplier to reimburse your company if materials are not delivered on time.

The goal is to make a risk less costly if it occurs and make the impact be within your tolerance. The amount that is reasonable to spend on mitigation efforts needs to be related to both the cost and the probability of the risk.

Some low cost measures can take care of some small risks, while a major outlay might be prudent to protect against a catastrophic risk.

Draw up contingency plans for what to do in the event that the risk does indeed take place – these minimize the cost and consequence of the risk by minimizing reaction time and maximizing response efficiency.

If a piece of equipment is in far worse shape than expected, the set of tasks required to bring it up to operational condition should be drawn up and saved for quick insertion into the project plan file, work packets already prepared, and parts either already on hand or ready to be ordered quickly without much hunting down of relevant information.

This allows work to begin as soon as possible. Since most risks in shutdowns come from unexpected emergent work, contingency planning is a great source of progress for managing shutdown risk.

For each risk that remains significant after these preparations have been made, identify a trigger or set of triggers that indicate that the risk has occurred or is about to occur. By identifying triggers, you minimize your reaction time for the implementation of contingency plans.

To determine triggers, call another brainstorming meeting with experts that are familiar with the risk. Find out how they would know that the risk has occurred, and then work back from there to the earliest indicator.

Try to find indicators that would be apparent in the project plan during updates, such as a particular pattern of overtime or the heavy use of a certain type of specialist resource. Build filters in your project management software that represent this behavior, so that during the project you can check once a day to see if these patterns are happening.

Be sure to assign responsibility for monitoring the risk if you don't do it yourself – supervisors and contractors also can be given access to project data. Each risk can only happen during the period that the relevant tasks are in progress, so build a risk-watch schedule.

In order to closely track possible indicators, you may need to gather more information than you would otherwise. For example, if the risk is the production and delivery of a critical material, you might request that the manufacturer notify you at each step of its production, just to make sure that it is on track.

The idea is not to eliminate all sources of risks, but to decide ahead of time what preparation one wants to take. High cost, high likelihood events obviously need to be considered first, and considered to be part of the main planning process.

Risk quantification can be an exact science or an exercise in vague wizardry, depending mostly on how much past information you have available.

The difficult judgment call is in separating out events based on a combination of the potential disruption and the chance that it will occur.

Protecting against long shot events with devastating consequences may be more worthwhile than spending excessive advance time dealing with minor issues that are more likely. The object of risk analysis is to plan for significant risks.

Risk Response Control

After you've implemented any risk elimination and mitigation measures and begun your shutdown, you need to monitor for two things: the triggers that you've already determined for expected risks, and the occurrence of unexpected risks.

Unexpected risks should of course be responded to quickly, and their causes well documented to assist in future shutdowns. Expected risks should be monitored using the risk schedule you developed.

Analyze project indicators, the plant floor, and communications from supervisors for evidence of triggers. If any triggers have happened, investigate further to see if the risk has indeed occurred, and if so then import your contingency plan into the project plan and rearrange task schedules as necessary to accommodate the extra work.

For major contingencies, save a new baseline to reflect the change in plans. Make note of the risk occurrence in reports as well.

If you put in the energy to complete these steps, you will have shorter, more tightly controlled shutdowns with fewer incidents – in short, the cost of planning to this degree is more than returned through improved project performance.

To summarize the steps in a comprehensive risk management program for shutdowns:

- ✓ Determine your tolerance for cost, customer relations, safety, and environmental risks.
- ✓ Filter for high-risk tasks.
- ✓ Using your shortened list, come up with environmental, health, and safety issues; as well as financial costs for each risk.
- ✓ Determine the probability that each risk would occur.
- ✓ Prioritize risks based on your tolerance and the combination of each risks' probability and the magnitude of its consequence.
- ✓ Come up with mitigation plans or contingency plans or both.
- ✓ For tasks with contingency plans, brainstorm a list of triggers that signify that a risk is turning sour.
- ✓ Monitor the project during execution for triggers and unexpected risks.
- ✓ Collect data and debrief after the shutdown. A history of previous problems encountered might help locate potential trouble spots in the future.

MAINTAIN ITEMS OF EQUIPMENT USED IN WATER TREATMENT PROCESSES

Introduction to Maintenance:

Machines, buildings and other service facilities are subject to deterioration due to their use and exposure to environmental conditions. If this process of deterioration is not checked, it may render them unserviceable. It is, therefore, necessary to attend to them from time to time, to repair and recondition them so as to enhance their life economically.

Maintenance aspect is more important specially in the case of machines due to their non-uniform pattern of wear and tear which depends on large number of factors.

Every machine is thoroughly tested and inspected by the manufacturers before selling it, and by the purchaser before it is put to use. When it is used, it will be subjected to wear and tear hence proper attention should be given to protect the machine and its components from undue wear and thus protect them from failures.

A proper attention means lubrication, cleaning, timely inspection and systematic maintenance. Maintenance of a machine means efforts directed towards the up-keep and the repair of that machine.

A major part of the expenditure is generally on men, material and maintenance in an industry. Every machine will require repairs even if it is best designed, hence the repair must be done at such a time when it may have least disruptions, i.e. machine may be repaired when it is not being used or its use may be postponed without affecting the production of the whole concern.

Therefore, checking of the machine is generally done when it is not in operation, so that the defect, if any, can be immediately and easily rectified without causing extensive damage to the plant.

In this way, we say that maintenance is responsible for the smooth and efficient working of an industry and helps in improving the productivity. It also helps in keeping the machines in a state of maximum efficiency with economy.

Realising the high importance of maintenance of plants and equipment's. National Productivity Council, undertook the survey of engineering industries, and found that due to failure of the plants, equipment and machineries, non-availability is 28 per cent. Looking to this high percentage of failures, it is essential that the engineering units should improve their maintenance system.

Maintenance can be defined as a combination of actions carried out to replace, repair, service or modify the components in a plant or equipment so that it will continue to operate at a specified "availability" for a specified period of time.

Maintenance management is concerned with the direction and organization of resources in order to control the availability and performance of plant to some specified level.

The maintenance management is therefore a restorative function to ensure availability and efficiency of the existing plant, equipment and buildings at an optimum level.

Plant and equipment maintenance plays an important role in production management because breakdown creates problems such as:

- ✓ Loss of productive time
- ✓ Re-scheduling of production
- ✓ Need for sub-contracting work

- ✓ Temporary work shortage, as during break down workers may not have work for them.

Types of Maintenance:

Generally, maintenance can be done in the following two ways:
Breakdown maintenance.
Preventive maintenance.
In the first case of maintenance, repair can be done after the breakdown occurs while in the second case maintenance is done on the basis of prediction or on the basis of periodical checking.

1. Break Down Maintenance:

Breakdown maintenance is defined as a maintenance activity conducted on a machine which has ceased functioning owing to shear or crushing or buckling or elongation or swelling or any other form of failure of any critical component of the said machine in order to enable the same to function as before by resorting to necessary replacement(s) of the same and/ or more number of components by new ones or usable old ones and/ or re-conditioning of the same within the minimum time period considering scope of work, available facilities and skill.
Breakdown of a machine can occur due to the following two reasons:

- ✓ Due to unpredictable failure of components which cannot be prevented.
- ✓ Due to gradual wear and tear of the parts, which can be eliminated to a large extent

By regular inspections, known as preventive maintenance. From experience it can be decided that, when a part should be replaced, so that breakdown can be avoided.
In breakdown maintenance, defects are rectified only when the machine cannot perform its function any longer, and the production department is compelled to call on the maintenance engineer for repairs. After repairing the defect, the maintenance engineers do not attend the machine again until another failure occurs.
In this type of maintenance, repair shall have to be done on failure, thus it may disrupt the whole production, if it is performing an important work. This method is expensive also due to increase of depreciation cost, payment to idle operators, overtime to the maintenance staff for doing the emergency repairs.

2. Preventive Maintenance:

Preventive Maintenance is defined as a maintenance activity conducted on a machine as per laid down schedule or frequency by making necessary or need-based replacement and/or reconditioning of component(s) within the pre-fixed time period of the said work in order to reduce and avert breakdown(s).
Preventive maintenance is sometimes termed as "planned maintenance" or "scheduled maintenance" or "systematic plant maintenance" etc. It is an extremely important function for the reduction of maintenance cost and to keep the good operational condition of equipment and hence increases the reliability.
Preventive maintenance aims to locate the sources of trouble and to remove them before the breakdown occurs. Thus it is based on the idea "prevention is better than cure". Scheduled

maintenance is always economical than unscheduled maintenance, as we all know that, "a stitch in time saves nine."
Best safeguard against costly breakdown is to inspect, lubricate and checkup the equipment as frequently as possible. To take full use of equipment and to maintain it in reliable condition, necessary measures should be taken to prevent overloading, dampness, negligence and misuse of machines.
Frequency of inspection should be decided on the basis of the importance of the machine wear and tear of the machine and its delicacy. This periodic inspection or checking helps to find out the reasons leading to breakdown and to rectify them, when they are in minor stages.
Thus the repair can be done when one wants to do it, i.e. when it has least effect on the production schedule. Further this repair requires lesser time as compared to that of breakdown repair and thus down time is reduced by doing preventive maintenance.

Objectives:

- ✓ Preventive maintenance has following main objectives:
- ✓ To obtain maximum availability of the plant by avoiding breakdown and by reducing the shutdown periods to a minimum.
- ✓ To keep the machine in proper condition so as to maintain the quality of the product.
- ✓ By minimising the wear and tear, preserve the value of the plant.
- ✓ To ensure for the safety of the workers.
- ✓ To keep the plant at the maximum production efficiency.
- ✓ To achieve all the above objectives with most economical combination.

Procedure for Maintenance:

Maintenance should be done considering all the above mentioned factors. Daily maintenance is done by the operators themselves. Before starting the work of their shift, cleaning, oiling and greasing should be done by the operators. For this purpose manufacturers used to issue maintenance instructions for their machines, which should strictly be followed.
Preventive maintenance of the machine depends largely on the operators. Hence, as far as possible, one operator be allotted for each machine, and when the same machine is used in more than one shift, one operator for each machine for each shift be allotted.

This system has following advantages:

- ✓ An operator gets used to the sound and working of his machine and notices any change immediately, which helps in investigation and rectification of the defect then and there. If operators are changed frequently, immediate check-up and timely repair cannot be possible.
- ✓ It is easy to pin-point operators with bad operating habits. To remove these habits training can be arranged or disciplinary actions can be taken as the case may be.
- ✓ The machine will remain in good conditions.
- ✓ Periodic maintenance is generally conducted by the maintenance crew, specially trained for this purpose. The period should be decided on the basis of past experience. Apart from this, operating instructions should carefully be followed by the operators.

In case any abnormal sound or behaviour is noticed in the machine, he should immediately brought this into the notice of maintenance crew, so that the defect can be rectified immediately. Care must be taken that it may not be left for the latter date.
Inspections and lubrication schedules should be strictly followed. Inspection schedule should include the inspection of tools, accessories and other equipments.

Complete work processes

Equipment Inspections

With regular inspection, you make sure your equipment is in top shape and can handle the toughest jobs. A trained technician can determine if small repairs will make a big difference and can suggest repairs to help your equipment run more efficiently. An equipment inspector may point out details your team might tend to overlook.
Most importantly, regular inspections ensure the safety of your workers. You can get projects done on schedule and with peace of mind, knowing your equipment is in good condition. When it comes down to it, there is no reason not to have regular inspections and get the most out of the investment you made in your heavy equipment. Still not convinced? Keep reading to learn more about inspections and why they are critical to your heavy equipment lifespan.

What is checked during and equipment inspection?

Heavy equipment inspections combine data collection and analysis with hands-on testing and examination for a thorough look at the equipment's condition. A complete inspection is an important preventive way to make sure equipment is safe for use and that all systems are working properly.

The Occupational Safety and Health Administration (OSHA) requires each piece of heavy equipment to pass inspection before use. If any of the safety features are in disrepair, you should not use the equipment. Employers are required to get unsafe equipment repaired to ensure worker safety.
Damaged or broken equipment requires immediate repair to prevent problems. According to OSHA, all heavy equipment must have:

- ✓ A working brake system, including emergency brake and parking brake

- ✓ Working headlights, taillights and brake lights
- ✓ An audible warning device, like a horn
- ✓ A windshield and windshield wipers in good condition

Although heavy equipment owners have the option of maintaining only the minimum to meet OSHA requirements, they shouldn't overlook other details if they want their equipment to last. Heavy equipment can last for years if properly maintained. Considering some heavy machinery costs more than a house, it is a smart move to take utmost care of these powerful tools. Get the most out of your investment by conducting regular inspections on your own or with a trusted technician.

MacAllister Machinery uses cutting-edge technology and hands-on expertise to inspect, collect, analyze, diagnose and monitor equipment. When combined with other information, like machine history and use, we have all the tools we need to suggest repairs and maintenance for optimal safety and performance. It is easy to access and view inspection results, too. Just log in to the Cat Inspect app or VisionLink to take the next step or review results.

What do inspectors look for?

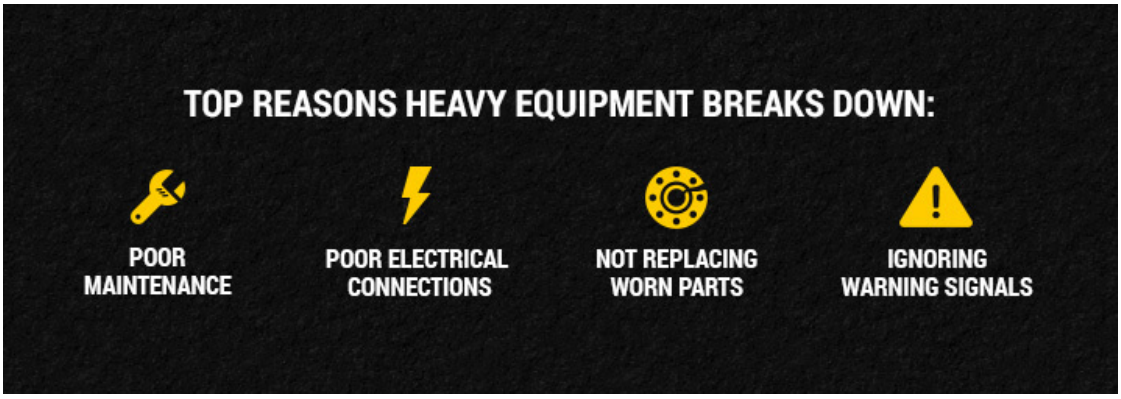
Heavy equipment inspectors check all the components of a piece of equipment, emphasizing safety. A technician can not only test for safety, but can also consider ways to increase equipment productivity and efficiency. Once you're certain of safety, it is up to you what you want to accomplish with your equipment. Our inspections are tailored to meet your specific needs.

In general, equipment inspectors will check the following components using both diagnostic tools and an expert eye:

- ✓ Roll-over protection structures, including seatbelts
- ✓ Gauges and lights
- ✓ Battery
- ✓ Engine performance
- ✓ Safety features such as deflectors and sweeps
- ✓ Steering components
- ✓ Brake systems
- ✓ Exhaust system
- ✓ Cooling system
- ✓ Fan belts
- ✓ Engine support
- ✓ Radiator guards
- ✓ Transmission function
- ✓ Tracks and rollers
- ✓ Rear hitch
- ✓ Oil level and condition
- ✓ Tires and wheels
- ✓ Glass and mirrors
- ✓ Undercarriage
- ✓ Hydraulic system

Heavy equipment is a significant investment, so it is worth fitting maintenance and inspections into your work schedule. You'll potentially save yourself thousands of dollars in repairs. Get ahead of the game and save yourself the trouble of dealing with failed equipment.
Sometimes, the value of expert advice is priceless. An expert is more likely to notice when parts or systems are damaged beyond what an untrained eye can spot. It is not uncommon for heavy equipment to break down, and the majority of the causes are preventable. Here are some of the top reasons heavy equipment breaks down.

- ✓ **Poor maintenance:** Failing to replace belts or forgetting to check oil levels, for example.
- ✓ **Poor electrical connections:** An inspector can detect electrical issues early, before equipment breaks down and causes you to lose work.
- ✓ **Not replacing worn parts:** By fixing only one broken part, you are only temporarily taking care of the issue. Other worn parts need to be inspected to prevent further damage and future costs.
- ✓ **Ignoring warning signals:** Always ask a technician to investigate a warning signal. Ignoring a warning signal can lead to major equipment damage or serious injury.



An inspector will run tests, collect diagnostic codes, analyze data and visually inspect the equipment to checks for leaks, broken or loose parts, excessively worn parts or any potential problem areas. With an inspection checklist in hand, either on a device or paper, a technician will make sure they don't miss anything, and they will teach your team what to look out for during daily checks.

What are the benefits of equipment inspections?

Equipment inspection is not something to dread. Inspection is an opportunity to save money, prevent injury and stand out from competitors. Your productivity is only as good as your equipment is, and you can't get very far with broken equipment or out-of-work employees. Regular inspections take productivity and safety to the next level, beyond mandatory inspections.

Heavy equipment is a powerful tool that undergoes a lot of different conditions and completes amazing tasks. With the incredible work a piece of equipment can do, like lifting tons, wear and tear are inevitable. Plus, no matter how great your team is, sometimes packed schedules can lead to equipment abuse and misuse. Worn or damaged components are not always apparent. Regular inspection makes sure equipment is still in great condition, despite being used by multiple workers under difficult conditions.

Considering the costs of heavy equipment repair and replacement, the pros of frequent inspection far outweigh the cons. If you wonder about the condition of your equipment, do not hesitate to contact a qualified technician immediately. Here are the reasons why.

1. Lower risk of workplace injuries

Regular inspections lower the chances of one of your workers getting injured. Unfortunately, injuries do happen on the job, and most of the time, they are preventable. Inspections are a preventive safety measure for you and your employees.

Consider that in 2016, there were 4,693 deaths in private industry, according to OSHA. About 21 percent of the deaths occurred in the construction industry. Excluding highway injuries, the leading causes of construction workers' deaths were the "fatal four" — falls, struck by an object, electrocution or caught between two pieces of machinery. Eliminating the fatal four could save 631 lives each year in America.

Now, consider how failing equipment could play a part in these statistics. A failed horn, brakes or any other important component could lead to a crash, or a vehicle driver striking another worker. A collision or failed system could cause a heavy object to fall and lead to injury or death. Or, a worker could become distracted by broken-down equipment and less aware of nearby workers, putting their safety at risk. If brakes fail or if equipment suddenly shuts down, it could easily cause a dangerous chain reaction to occur.

Although your equipment might be in great shape one day, you'll want to have it inspected after a tough job. If it does need a repair, don't wait — make repairs immediately and play it safe.

A. Lost Time

If a worker gets injured as a result of damaged equipment, chances are, they are going to miss some time. Common injuries relating to heavy equipment are often serious, such as amputations, spinal injuries, sprains, fractures and cuts.

Workers who suffer any of these injuries could be out for days. According to a 2015 Bureau of Labor Statistics news release, workers who sustained sprains or strains resulting from a workplace injury required 10 days off work, on average. Workers with fractures needed 31 days, and those who suffered amputations required 22 days or more.

Even less severe injuries could lead to lost time. To stay on schedule, you will have to find someone to make up for the lost worker. If you are not able to find someone, productivity can slow down substantially.

B. Restaffing Costs

If a worker is severely injured, they might need a long time to recover, or they may never return to the jobsite. In such a case, you will need to replace the worker with someone new. Whenever you hire a new employee, you take a chance. Even when the new hire is a good fit for your company, it almost always comes with a price. New workers usually need training and time to adapt. It could also take a while to find a worker who is right for the job.

According to a 2016 survey by the Society for Human Resource Management (SHRM), it takes 42 days to fill a job vacancy with a new employee, which is a lot of time with insufficient staff. New employees cost money, too. On average, it costs companies $4,129 to hire someone new.

Even if you think you've found the perfect worker, there is no guarantee they'll stick around to see a project through. According to the SHRM survey, the average annual turnover rate is 19 percent. Considering an employee who makes $8 an hour could wind up costing a company $3,500 in turnover costs, your best bet is to try to keep the employees you have. Inspecting your equipment regularly is just one aspect of best practices.

C. Higher Workers' Compensation Premiums

Workers' compensation means employers are required by law to pay for workers' compensation benefits if a worker gets hurt on the job. Injuries can be from one event or repeated injuries, such as those caused by regular exposure to chemicals or loud noises. Sometimes, workers' compensation even covers psychological stress.

When an employee files a workers' compensation claim, your workers' compensation premium increases as a result. Injury can also affect health care premiums. However, if your claim costs are lower than average compared to similar companies, your premium may decrease — more incentive to keep your equipment fully intact.

Regular inspection allows you to take care of your equipment and even greater care of your workers.

D. Possible Fines

Avoid fines and serious violations with regular inspections by ensuring safety at all times. Under OSHA law, employers are responsible for maintaining safe workplaces for their employees. If you ignore safety, you break the law.

For example, in 2012, OSHA cited a heavy equipment rental company in Hawaii for serious safety violations after a crane fatally crushed a worker. An OSHA inspector found outriggers meant to stabilize the crane were not extended, allowing the crane to tip. The company failed to inspect and keep a record of vital crane components. The company also allowed a worker to use the crane when it was displaying a warning indicator. Also, other equipment was not properly maintained or guarded to prevent amputation or injury. OSHA set fines totaling $70,000.

Not only did this company have hefty fines to pay, but they lost a worker and impacted their business name — all of which they could have prevented if they had put safety first. Clearly, it is not worth taking a chance when it comes to heavy equipment.

E. Could Be Held Liable

There are plenty of ways you could legally be liable if equipment fails and causes injury. For example, if a worker is injured and sent home, and if you hurriedly hire another worker to help your team finish a project on time, you might be putting yourself and workers at risk if the new employee is unqualified for the job. If the new worker causes harm to another worker, you could be held liable for hiring someone who brought danger to other employees.

Another way you could be liable as an employer is if you are aware your equipment needs repair, even if it had passed a mandatory inspection, but fail to repair it. If someone is injured, you could be liable for negligence.

2. Increase Productivity

Although safety is a priority, consider how damaged equipment can also affect productivity. When equipment fails, the workflow gets interrupted, and projects come to a halt. It's impossible to complete a job if even one piece of equipment has broken down.

When projects are interrupted, you might not be able to stick to your schedule and meet deadlines. It is important for customers to know they can depend on you, and regular inspections help make sure your equipment is reliable for you, your workers and your clients. To stay on schedule and meet your goals, you want to have all equipment working optimally.

Also, downtime is costly. According to Farm Industry News, downtime due to equipment breakdowns costs companies around $1,400 a day during planting season. Failure to get equipment inspected before use is the biggest reason the equipment breaks down.
In general, machinery failure is usually due to one of the following.

- ✓ **Thermally induced failure:** Equipment overheats, or extreme temps cause equipment to break down.
- ✓ **Mechanically induced failure:** It is easy to prevent this with inspection and replacing parts. Mechanically induced failure often happens due to overexertion, collision and misuse or abuse.
- ✓ **Erratic failure:** Occurs randomly due to harder-to-detect reasons, such as electrical issues or software malfunction. Erratic failure can be prevented with the help of diagnostic equipment used during inspection.

Equipment failure can be sudden or gradual. Inspections are important because you may not notice the seriousness of an issue until it's too late. By regularly having a professional check your equipment, you prevent disaster and make informed choices. You can replace parts when necessary and not wait until equipment breaks down in the middle of the workday to make repairs. As a result, you decrease unscheduled downtime and improve productivity. Your clients will be impressed when projects are safely finished on time.

3. Lower Repair Costs

With regular inspections performed by a trained technician, you will be able to make a repair before it leads to a much more expensive problem. Your equipment will run better, and you'll extend its lifespan significantly with inspections and maintenance. The better condition your equipment is in, the less time you'll need to spend on repairs, and the more work you can get done.
Ultimately, you will get a greater return on your investment if you run highly efficient equipment for a longer amount of time. Consider the circumstances in which you use the equipment. What is the environment? What are the weather conditions? You may need more inspections and maintenance than you might think.
Small repairs are often worth the time and cost because heavy equipment is not cheap to replace. Considering a bulldozer can range in price from $30,000 to more than $200,000, it only makes sense to properly maintain something so valuable.

When and why should you do inspections?

Inspections should be carried out daily, and should include a look at the following:

- ✓ Brakes and lights
- ✓ Tire pressure
- ✓ Fluid levels
- ✓ Mirrors and glass
- ✓ Seatbelts
- ✓ Horn
- ✓ Emergency stopping system
- ✓ Safety devices
- ✓ Steering
- ✓ Tire condition

- ✓ Fuel and oil leaks

Every day, team members should focus on making sure the equipment is safe before each use. However, certain conditions require a more thorough inspection, best performed by a trained technician. You should get your equipment professionally inspected when:

- ✓ It has been exposed to conditions that could cause damage and lead to harm
- ✓ Suspected damage has occurred
- ✓ It has experienced severe environmental conditions, such as when it is dusty, wet, muddy or has been in corrosive coastal environments
- ✓ It has been driven on unpaved roads or mountainous terrain
- ✓ It has had several operators
- ✓ There is any sign of needed repair shown through signals, noises or obvious damage
- ✓ You are about to do a tough job
- ✓ Your worksite is located far away from your shop
- ✓ You are about to buy a piece of used equipment or sell your equipment

When in doubt, get your equipment inspected by a trusted professional.

Keeping Jobsite Clean

It's not uncommon to see signs in workplaces reminding employees to clean up after themselves. If doing so is important in office kitchens, it's doubly important on construction sites. Keeping sites orderly and removing waste can help avert accidents, prevent damage and even boost morale among workers.

The strategies below are a good starting point for keeping a jobsite clean.

Establish a housekeeping program

Set up a housekeeping system that involves everyone on the team. Focus on the importance of cleaning and removing debris after it has been created, and assign specific tasks to specific people to create accountability.

To keep the site tidy, use the 5S system, a method of workplace organization invented in Japan that includes making sure everything has a designated place and removing items not in use. To encourage compliance, use toolbox talks to remind everyone of the benefits of a clean, organized jobsite, such as improved safety and efficiency.

Separate the scraps

Construction companies may be required to recycle materials like metal, wood and sometimes, concrete. In addition to federal regulations, you may need to follow state or regional recycling rules. And the contract might stipulate which materials or debris should be diverted from landfills, along with target diversion rates for non-hazardous solid waste.

Observe the rules and designate piles, bins and containers for leftover materials. Do this ahead of time so nothing that should be kept or recycled is accidentally thrown away. In general, while recycling containers should be easy to access, the fewer containers for each type of material the better in terms of keeping transportation costs low and minimizing jobsite obstructions. Consider hiring a company that does waste and recycling management for construction firms.

Eliminate waste at the source

The less waste that arrives or is created at the site, the less disposal and cleanup is necessary. Choose products with minimal packaging. Measure carefully so you order only the materials you need, in the optimal sizes. Buy quality materials so you throw out fewer warped studs, for instance. Embrace the use of prefabricated elements when possible.

Keep waste properly contained

Keeping a lid on waste, literally, is important, especially when the waste could spill, evaporate or smell. Containers and product drums should be sealed tightly. Use the right container for the type of hazardous waste. Mark the container to indicate its contents, and make sure the container is in good condition. Containers of used oil should be free of leaks, structural defects and severe rusting, for example. Use a locked compound if you're storing one near water or a drain.

All workers must be trained in the management of hazardous waste as it relates to their job function. Make sure everyone knows where to discard flammable and combustible materials.

Oily rags aren't just tripping hazards; they're also flammable. In fact, they can spontaneously combust. That's why they should be stored in a metal container with a cover, preferably a self-closing lid. Schedule frequent removal of hazardous waste to keep areas clean and prevent fires and accidents.

To discourage dumpster divers and any unauthorized use of your dumpster, consider a lock for it.

Manage dust safely

Use engineering and work practice controls such as dust collection systems to limit dust in the air during certain tasks, such as sawing or grinding concrete, stone or mortar. Reduce the amount of dust created by installing water systems that steam or spray a cutting blade.

Controlling respirable crystalline silica is especially important since it can cause incurable lung disease if inhaled. Per OSHA's silica dust compliance guide for small entities, don't allow dry brushing or dry sweeping unless methods such as wet sweeping and HEPA-filtered vacuuming are not feasible. Workers should of course have access to appropriate respiratory protection.

The last sweep

Last impressions count. Performing a final cleaning during closeout will leave a good impression on the client and possibly help you win more projects in the future. Create a checklist of tasks, such sweeping, mopping, cleaning all surfaces, washing windows and removing any remaining stickers. And don't forget trash removal.

If you established a good housekeeping routine at the beginning of the job, cleanup should be a relatively easy final step.

RECORD AND REPORT WATER SYSTEMS INFORMATION

Do you have your flight plan ready?

We can all visualize a trip to the airport and all it entails: going through security, waiting in the terminal, seeing whether your departure time has changed. There also are the worries of whether you've misplaced your passport or ticket, or even your boarding pass, which would keep you from boarding your flight.

In instances like this, having the proper documentation is vital to making the trip a smooth one. But it isn't just the passengers who need such documentation or checks. Even the crew and the airplane itself have documentation and checks that must be made before, during and after each flight to ensure the safety of the flight and its passengers.

This article is not about airplane safety, but the scenario described gives similar insight into the documentation, record-keeping compliance standards we have as managers, operators and maintenance technicians in successfully managing water plants and distribution systems. Many communities' largest public assets represented by water system components and investments made in them. Customers can see the water plant or the water tower, but usually have no idea of the distribution system, source water intake, water rights, staffing or rules and regulations associated with daily operation. If customers counted how many times per day they used water, it might surprise them. Our duties and responsibilities under the Safe Drinking Water Act, in essence, are to protect public health.

A Management Imperative

A well-managed water system will maintain proper records and documents regarding financial sustainability; water production and quality; federal and state agency regulations; asset management; energy costs; water loss; staff development; planning for infrastructure improvements; and measuring customer satisfaction.

Teamwork Structure

Most water systems are led by a board or council, so a water system manager is not the sole authority. An experienced manager should know their daily responsibility may cover financial duties, safety, training, water production costs, distribution problems, and regulatory compliance. This manager will have a plan where they can provide documentation for compliance, budgeting, infrastructure improvement plans and replacement costs to almost anyone who may ask, including their board or council. This manger will hire staff and have a management structure where they can give ownership to supervisors and staff in specific areas of responsibility. A few examples of responsibility designations are: Bookkeeper – billing and collections; Water Treatment Plant Supervisor – water production and quality; Distribution Supervisor – meter reading, line replacement or repair, water quality; Maintenance Supervisor – light duty to heavy duty maintenance tasks; and Laboratory supervisor or staff – records maintenance and other lab compliance responsibilities.

All of these staff positions will have similar responsibilities for monitoring, reporting, record keeping, due dates, compliance, notification requirements, investigation, and addressing enforcement actions by regulatory agencies. Compiling all this information to develop plans, budgets and compliance strategies will take time to understand. It will also take time to get to where a system can use these valuable, historical records to assist in future development.

Training is a Valuable Record

Training needs and self-training abilities will vary greatly with experience and the level of licenses of each operator or staff member. For new operators, pulling out the rule book and becoming knowledgeable about individual licenses, compliance, and regulations to succeed in acquiring the specific mandated licenses should be a division goal the system manager establishes. The ultimate goal is to help operators learn by doing – training them on existing rules, regulations, and policies in their daily job duties. They will learn as they do the job how to maintain proper records of it. The who, what, when, where and why of compliance are well-described by the U.S. Environmental Protection Agency (EPA), state environmental manuals, and training programs.

General Tips

With today's technology, a computer should be enough to store most records, but all staff may have different records to keep and store. Some records are old and are stored in various formats. Some records may be documents needed by someone at a future date or inspection.

Many documents are infrequently used, but if stored properly, they will keep stress levels down. Printed documents should be filed in lockable filing cabinets stored inside a room with a lock and not stuck in a corner where anybody can pick them up and forget to bring them back.

If you are just starting, don't feel bad about the order in which you keep your records. Just remember, you are developing a record system that will be used by you or someone else in the future to prove you completed a task. Once you start, you can always reorganize your filing system later. You never know what you might find when you do. I once went through files and came across a 1961 telegram from then-U.S. Senator Lyndon B. Johnson informing my board that funds had been approved to build the water system.

State or federal legislatively created documents for funding of water districts, water projects or systems are very important. These are called creation documents. Keep these documents in a secure place.

Going back to the telegram from Western Union, I think I can safely say our communication and documentation has dramatically changed over the years. Transforming these old documents into current standards of documentation is essential. Make sure you find the time to protect these types of records.

Water Systems Have Taken Off, Requiring Documentation

Like the airline analogy, airplanes have not been around for very long. We overlook the luxuries modern technology and ingenuity have brought us in the last 100 years. The American small water system has made improvements, much like the airline industry. Many of us have parents or grandparents who did not have a public water or wastewater system.

Water professionals have built up our public water systems over the past century. Waterborne diseases have decreased drastically, and Americans are living longer, as science and environmental knowledge have increased. The regulations to improve water quality have also significantly increased.

Over time, the American waterworks industry has made continuous advancement in delivering public drinking water supplies throughout the country, building upon new discoveries of water quality so that most communities have a specific quantity of safe drinking water at all times. The federal and state agencies have developed rules and regulations to guide water systems in the delivery of safe drinking water. Our agencies and water system staff have used records to track and continually make improvements in all areas of our public water systems.

The customers of public drinking water systems use our product an estimated 20 times daily or more. Let's not forget the water system infrastructure has built-in fire protection for customers and communities.

We ask a lot of our water professionals and operators who work with hazardous chemicals, equipment, climates, all hours of the day and night, and in our roads and streets. It would be nice to write that there are only 978,000 forms and records required and be specific about each, but most water systems are unique, whether groundwater or surface water or somewhere in between. Water systems have similar processes, but each plant and distribution system have been engineered with specialized equipment used to purify, transport or hold water at various stages. All have manufacturers' recommendations for proper maintenance, so documenting maintenance records is a must.

During the last 100 years, we have taken one of the most precious public resources and have created fantastic public water systems with water that is reliable and safe to drink. As you are sorting through records or forms as a water industry employee, operator or mayor, remember our main duty under the Safe Drinking Water Act is to protect the public health!

UNIT 15

APPLY ACCIDENT-EMERGENCY PROCEDURES

This unit involves the skills and knowledge required to apply accident emergency procedures, including responding to an incident, controlling and assisting at an accident or emergency site, finalizing accident-emergency processes, and completing records, reports and other required documentation

RESPOND TO THE INCIDENT

1. **Preparation**

Preparation is the key to effective incident response. Even the best incident response team cannot effectively address an incident without predetermined guidelines. A strong plan must be in place to support your team. In order to successfully address security events, these features should be included in an incident response plan:

- ✓ Develop and Document IR Policies: Establish policies, procedures, and agreements for incident response management.
- ✓ Define Communication Guidelines: Create communication standards and guidelines to enable seamless communication during and after an incident.
- ✓ Incorporate Threat Intelligence Feeds: Perform ongoing collection, analysis, and synchronization of your threat intelligence feeds.
- ✓ Conduct Cyber Hunting Exercises: Conduct operational threat hunting exercises to find incidents occurring within your environment. This allows for more proactive incident response.
- ✓ Assess Your Threat Detection Capability: Assess your current threat detection capability and update risk assessment and improvement programs.

The following resources may help you develop a plan that meets your company's requirements:

2. **Detection And Reporting**

The focus of this phase is to monitor security events in order to detect, alert, and report on potential security incidents.

- ✓ Monitor: Monitor security events in your environment using firewalls, intrusion prevention systems, and data loss prevention.
- ✓ Detect: Detect potential security incidents by correlating alerts within a SIEM solution.
- ✓ Alert: Analysts create an incident ticket, document initial findings, and assign an initial incident classification.
- ✓ Report: Your reporting process should include accommodation for regulatory reporting escalations.

3. **Triage And Analysis**

The bulk of the effort in properly scoping and understanding the security incident takes place during this step. Resources should be utilized to collect data from tools and systems for further analysis and to identify indicators of compromise. Individuals should have in-depth skills and a detailed understanding of live system responses, digital forensics, memory analysis, and malware analysis.
As evidence is collected, analysts should focus on three primary areas:

- ✓ Endpoint Analysis
    - o Determine what tracks may have been left behind by the threat actor.
    - o Gather the artifacts needed to build a timeline of activities.

    - Analyze a bit-for-bit copy of systems from a forensic perspective and capture RAM to parse through and identify key artifacts to determine what occurred on a device.
- ✓ Binary Analysis
    - Investigate malicious binaries or tools leveraged by the attacker and document the functionalities of those programs. This analysis is performed in two ways.
        - Behavioral Analysis: Execute the malicious program in a VM to monitor its behavior
        - Static Analysis: Reverse engineer the malicious program to scope out the entire functionality.
- ✓ Enterprise Hunting
    - Analyze existing systems and event log technologies to determine the scope of compromise.
    - Document all compromised accounts, machines, etc. so that effective containment and neutralization can be performed.

4. **Containment and Neutralization**

This is one of the most critical stages of incident response. The strategy for containment and neutralization is based on the intelligence and indicators of compromise gathered during the analysis phase. After the system is restored and security is verified, normal operations can resume.

- ✓ Coordinated Shutdown: Once you have identified all systems within the environment that have been compromised by a threat actor, perform a coordinated shutdown of these devices. A notification must be sent to all IR team members to ensure proper timing.
- ✓ Wipe and Rebuild: Wipe the infected devices and rebuild the operating system from the ground up. Change passwords of all compromised accounts.
- ✓ Threat Mitigation Requests: If you have identified domains or IP addresses that are known to be leveraged by threat actors for command and control, issue threat mitigation requests to block the communication from all egress channels connected to these domains.

5. **Post-Incident Activity**

There is more work to be done after the incident is resolved. Be sure to properly document any information that can be used to prevent similar occurrences from happening again in the future.

- ✓ Complete an Incident Report: Documenting the incident will help to improve the incident response plan and augment additional security measures to avoid such security incidents in the future.
- ✓ Monitor Post-Incident: Closely monitor for activities post-incident since threat actors will re-appear again. We recommend a security log hawk analyzing SIEM data for any signs of indicators tripping that may have been associated with the prior incident.

- ✓ Update Threat Intelligence: Update the organization’s threat intelligence feeds.
- ✓ Identify preventative measures: Create new security initiatives to prevent future incidents.
- ✓ Gain Cross-Functional Buy-In: Coordinating across the organization is critical to the proper implementation of new security initiatives.

CONTROL AND ASSIST AT ACCIDENT OR EMERGENCY SITE

How to Prevent an Accident at Construction Site

According to the Occupational Safety and Health Administration (OSHA), one out of every five workplace deaths is a construction worker. Construction, however, can be a safe occupation. Workers must be aware of the hazards, and use an effective safety and health program.

Here are some more specific ways construction employers and employees can prevent an accident at a construction site.

1. Provide safety training for all employees. Employers should educate employees on all workplace safety standards and the hazards that they may face while on the job. Workers need to review the health and safety policies for each job they are called to do. The written safety policy should include procedure and the name and location of a trained first aid responder. Employees should not operate any equipment they are not qualified or trained to use.
2. Hold frequent crew safety meetings. At some workplaces these meetings should be held daily, for example, if high-risk work is being done. Employees should be reminded to stay focused and relevant issues should be addressed. Real-life factual and job specific safety information tends to be more motivating for workers.
3. Utilize protective clothing and gear. Workers should always wear the recommended safety equipment for their jobs. This may be a hard hat, high-visibility clothing, goggles, gloves, steel-toed shoes, or a protective suit. In the summer, outdoor workers need wide brim hard hats, nape protectors, and long sleeve-lightweight shirts to protect them from the sun’s rays.
4. Keep the workspace clean. Keeping work areas clean and free of debris will lessen the chances of construction worker injuries and help prevent worksite accidents such as slips, trips, and falls. Employees should store tools and materials when finished with a job. Walkways should be kept clear of debris to prevent accidents that include slips and falls.
5. Maintain the equipment and tools. Before using a piece of equipment or machinery, workers must ensure it is in proper working order. Tools and machinery should be kept on a regular inspection schedule. Workers have been known to get trapped in or under heavy equipment that was not working properly. Broken parts and malfunctioning gear can also cause serious injuries and deaths.
6. Prevent falls. Falls are the leading cause of fatalities in the construction industry. It is important that workers are protected from falls on the job. The installation of fall protection systems can protect construction workers. These systems should consist of such items as guardrails, toe boards, screens, canopy structures or nets. Scaffolding can prevent falls, but must be installed properly to make sure it is

constructed well enough to hold the intended weight load. After it is put up, scaffolding must be inspected regularly.

7. Recognize the hazards and make a plan. Before any project starts, the site should be inspected for any unusual hazards. A risk assessment can protect workers' health and safety. After completing the risk assessment, a list of preventive measures should be made and implemented. It is important to ensure that all workers receive appropriate information, education, and training.
8. Be careful with vehicles. Many fatal accidents on work sites involve vehicles. Defensive driving, parking and backing should be practiced.
9. Use equipment in the manner prescribed. If construction tools or equipment is used in ways for which it is not designed, the manufacturer's built in safety features can no longer be relied on. Misusing equipment may also damage the equipment and cause employee injuries. The equipment itself should meet OSHA standards.
10. Follow OSHA guidelines and report any dangerous working conditions. Employers and employees who cut corners on the procedures and rules of OSHA increase the risks for construction site injuries. Any incidents or violations of OSHA regulations should be recorded and reported for the safety of all involved.

Assisting Injured Person

Introduction

First aid provides the initial attention to a person suffering an injury or illness. First aid in the workplace has a number of benefits including:

- ✓ saving lives
- ✓ preventing permanent disablement
- ✓ providing immediate support to the injured person
- ✓ improving safety awareness and preventing injury and illness in the workplace
- ✓ assist in the early return to work and rehabilitation.

The University provides a first aid service that satisfies the University's obligations under the Work Health and Safety Act 2011 and the First Aid in the Workplace Code of Practice 2014.

This Protocol requires that all injuries requiring first aid be treated and reported in accordance with the USC Near Miss, Hazard and Incident reporting guidelines and First Aid Procedures outlined in the USC Emergency Procedures Manual.

Objectives

The objective of this response protocol is to guide the University community:

- ✓ to determine appropriate trained first aider coverage for buildings and to select and appoint appropriate staff to fulfil the role of First Aid Officer
- ✓ to determine needs for first aid equipment, primarily first aid kits, for buildings
- ✓ to ensure that the equipment is maintained to facilitate rapid response to first aid situations
- ✓ in responding promptly and appropriately to first aid situations and other emergencies with a first aid aspect
- ✓ in making appropriate arrangements for first aid in field work and trips away from the University

- ✓ in making appropriate arrangements for first aid in situations where volunteers and/or members of the public participate in research activities, clinics, trials etc. where there is an increased risk of adverse health effects requiring first aid or emergency response
- ✓ in reporting incidents, injuries and illnesses as required by legislation
- ✓ to encourage activities to be undertaken that prevent injuries
- ✓ in disclosing health information that can assist in prompt and appropriate first aid response to foreseeable medical emergencies and to guide medical staff dealing confidentially with such disclosed health information.

Responsibilities

All school, department and section managers are responsible for:

- ✓ informing staff, students and visitors of local first aid arrangements including details of how to contact First Aid Officers. SafeUSC Officers are first aid officers and can be contacted by phoning Ext 1168
- ✓ provision of first aid kits and other essential first aid response equipment in relevant locations in buildings
- ✓ first aid arrangements for clinics, fieldwork, research activities and laboratories with particular hazards.

First Aid kits will normally only be installed in high risk work areas. A risk assessment must be conducted for the relevant locations/activities to ascertain if a first aid kit is required. The risk assessment is to be conducted by Asset Management Services in collaboration with Human Resources. Asset Management Services will be responsible for auditing and refurbishing first aid kits.

First Aid Officers are responsible for:

- ✓ providing first aid to people who are injured or ill in the workplace
- ✓ maintaining first aid kits after utilisation in a medical emergency
- ✓ recording treatments and reporting treatment and incidents
- ✓ maintaining a current first aid qualification
- ✓ participating in refresher training and competency development activities.

Role of first aid officers

In a first aid emergency a first aid officer is expected to take charge and may direct others on the scene to assist with managing the emergency until Emergency Services or more qualified personnel take over.

The role of the first aid officer is to initiate:

- ✓ the emergency treatment of injuries and illness
- ✓ arranging prompt and appropriate referral of casualties to medial aid if required
- ✓ coordinate emergency services response if required
- ✓ recording treatments and reporting incidents
- ✓ the maintenance of first aid equipment, and keeping clean, checking and restocking first aid kits if utilised.

First aid officers undertake regular refresher training. Refresher training includes practical components, such as Cardio-Pulmonary Resuscitation (CPR) practice and use of the Automated External Defibrillators (AEDs).

Legal protection of first aid officers

First aid officers are protected by vicarious liability when acting in good faith and discharging their responsibilities in accordance with their training. Vicarious liability means that employers are generally held responsible for the acts and omissions of their employees. The University appoints first aid officers to act on its behalf and discharge its responsibilities in relation to providing first aid. It is clear that in most situations where first aid officers render first aid in the workplace or otherwise in the course of their duties, they will be doing so as employees of the University and vicarious liability will apply.

In addition, at common law, people giving medical treatment to an injured person at an accident site in an emergency (a circumstance in which immediate medical treatment is required to save someone's life or prevent serious injury to health) cannot be sued for "assault". Permission to treat an injured person must always be obtained prior to treatment unless the person is unconscious.

Note, however, that protection from personal liability is not available if persons:

- ✓ render first aid when their judgement is impaired by drugs (including medications) or alcohol and they fail to exercise reasonable care and skill
- ✓ caused the injury or risk in the first place
- ✓ impersonate an emergency services worker or falsely represent their skill or expertise in responding to the situation.

Whilst the University of the Sunshine Coast is not responsible for providing first aid to non-University tenants in University-owned buildings, a first aid officer should be prepared to render first aid if called upon to attend an emergency in a tenanted area.

First response emergency medical action

As referred to in the USC Emergency Procedures:

1. Check the immediate area for signs of danger and remove or control it (if safe to do so) to avoid further risk to the casualty and yourself.
2. Do not move a casualty unless they are exposed to a life-threatening situation.
3. If required, contact the ambulance service by dialling 000. If you are unsure if an ambulance is required, call 000 and they will advise you.
4. Notify SafeUSC (Security) Ext 1168 or 5430 1168.
5. Remain with the casualty and administer first aid (if trained to do so) until assistance arrives.
6. Follow the instructions of relevant Emergency Services personnel or First Aid personnel.
7. Remember DRS ABCD of first aid:

- ✓ Danger
- ✓ Response

- ✓ Send for help after response
- ✓ Airway
- ✓ Breathing
- ✓ CPR (Start CPR, 30 chest compressions to 2 rescue breaths)
- ✓ Defibrillation

Debriefing following first aid treatments

First aid treatment may be traumatic or confronting for the person providing the treatment and or for bystanders witnessing the incident or injury. Anyone involved in a first aid incident who feels uncomfortable with the experience should be given the opportunity to debrief after the incident. Employee assistance counselling is available for staff by contacting Human Resources. Student Wellbeing provide counselling to students.

FINALIZE ACCIDENT – EMERGENCY PROCESS AND COMPLETE RECORDS

What is an Incident Report?

An incident report is a tool that documents any event that may or may not have caused injuries to a person or damage to a company asset. It is used to capture injuries and accidents, near misses, property and equipment damage, health and safety issues, security breaches and misconducts in the worksite.

What is the Purpose of Incident Reporting?

An incident report can be used in the investigation and analysis of an event. It includes the root cause and corrective actions to eliminate the risks involved and prevent similar future occurrences. Incident reports can also be used as safety documents that indicate potential risks and uncontrolled hazards found in the worksite.
An incident report can be used by:

- ✓ an authority to create a report of an incident;
- ✓ an employee to report an incident he/ she has witnessed;
- ✓ a member of the organization to raise awareness about an incident that has occurred in the worksite.

Incident reporting is the process of documenting all worksite injuries, near misses, and accidents. An incident report should be completed at the time an incident occurs no matter how minor an injury is. This article covers an in-depth explanation of the incident reporting procedure and the types of events you should report.

Top 3 Benefits of Incident Reporting at Work

Incident reporting has already been an established idea that is initially intended to promote and improve safety in the worksite. However, most of the employees still do not comply with this protocol. The management and their employees should know why incident reporting can not only improve an organization's safety but also help the business to stand out from others and most importantly, can help create a sound and healthy working environment and culture for workers.

1. **Immediate Reinforcement of Actions**

In an event when an incident happened at work, documenting and reporting the details to the management can induce the immediate and necessary measures to be taken. By doing this, worse situations and occurrences can be prevented. This also heightens the seriousness and gravity of any incident reminding all employees that these events should be reported whether big or small. Furthermore, taking action immediately also helps leaders and managers to magnify their responsibilities in ensuring a safer place for their employees.

2. **Hazards and Threats Communication and Awareness**

Communicating threats, risks, and hazards to all concerned and affected employees in an organization help raise awareness of possible dangers that may come. Doing so will help leaders and supervisors to ensure preventive measures are in place in case things should go wrong. This could be an essential tool for industries in which tasks are associated with the highest risks such as the construction, manufacturing, mining industries, and even offices which are prone to accidents because of the potential hazards that can be overlooked. More so, getting to understand these hazards can enforce everyone to be more proactive in spotting these threats and resolve them immediately.
Possible threats could be:

- ✓ High-risk jobs
- ✓ Equipment and machine damages
- ✓ Bad employee behavior (alcoholism, violence, sexual aggravation, bullying, etc)
- ✓ Infectious diseases
- ✓ Absence of proper PPE and controls
- ✓ Non-compliance

3. **Continuous Improvement of Processes**

An incident report provides a clear picture of what an organization should focus on resolving. It also gives valuable insights into what processes need to be changed, improved, or eliminated. This also helps the management to implement new policies and regulations to be able to determine the efficacy of these changes to safety and quality. This could also mean critical assessments of whether the employees would need more skills training or better equipment provision.

What is the Difference Between a Police Report and an Incident Report?

These two terms are often perceived as of the same kind. However, the main difference falls on the one who completes it. Obviously, a police report is a detailed documentation of a crime written by an officer or any representative of a police department who was present at the crime scene. On the other hand, an incident report can be written by anyone, as mentioned above, who wants to report any events that might or might not have caused harm to someone or something. Police reports require an investigation to follow, while an incident report can be used as a supporting document to an investigation or analysis of events.

What is Considered an Incident?

Generally, an incident is defined as any event, condition, or situation which:

- ✓ Causes disruption or interference to an organization;
- ✓ Causes significant risks that could affect members within an organization;

- ✓ Impacts on the systems and operation of worksites; and/ or
- ✓ Attracts negative media attention or a negative profile for the worksite

When Should You Write an Incident Report?

The rule of thumb is that as soon as an incident occurs, an incident report should be completed. Minor injuries should be reported and taken as equally important as major injuries are. These injuries may get worse and lead to more serious injuries or health issues. Employers, managers, and safety officials should be aware of the different situations and events that should be reported.
Here are 4 types of incidents you should report:

- ✓ **Sentinel events** – these are unexpected occurrences that resulted in serious physical or psychological injury or death (e.g. slips, trips and falls, natural disasters, vehicle accidents, disease outbreak, etc.).
  - Employee injury incident
  - Environmental incident
  - Property damage incident
  - Vehicle incident
  - Fire incident
- ✓ **Near misses** – these are situations where the people involved had no injuries but could have been potentially harmed by the risks detected.
- ✓ **Adverse events** – related to medicine, vaccines, and medical devices. These events occur when an act of commission or omission harmed a patient rather than from the existing disease or condition.
- ✓ **No harm events** – these are incidents that need to be communicated across an organization to raise awareness of any harm that may happen.

How to Write an Incident Report

An incident report should state all the essential information about the accident or near-miss. It should contain the following key elements to ensure that all facts and necessary details are complete and properly documented. Take a look at some incident report samples here.
An incident report should be:

- ✓ Accurate
  all data must be clear and specific. Most inaccuracies are due to typos and simple grammar and spelling errors (e.g. incorrect details of names of people involved, date and time of the incident, contact numbers, etc.). Provide more specific details of what you are referring to and avoid any vague statements that may cause confusion. Lastly, always proofread your report before submission to see errors that you might have overlooked.
- ✓ Factual
  an incident report should be objective and supported by facts. Avoid including emotional, opinionated, and biased statements in the incident report. It should provide both sides of the story and should not favor one side. However, if there's a need to include statements from witnesses or patients, make sure to quote them.
- ✓ Complete
  Ensure that all essential questions (what, where, when, why, and how) are covered

in the incident report. Record not only the people who were injured and what caused the accident to happen, but also include details such as people who witnessed and reported the incident or those who will conduct an investigation. Anticipate what other significant details will be needed for any future study and investigation.

- ✓ Graphic
  Photos, diagrams, and illustrations should be included as supporting evidence. Take many photos of the injury, damage, and surrounding environment. This supplements the facts stated and provides more clarity to be easily understood by the recipient.
- ✓ Valid
  Upon completion, those who are involved in the incident (e.g. victim, witnesses, manager, reporter, etc.) should sign off to testify and validate all the information that was mentioned in the incident report. This confirms that the incident report is truthful and unquestionable.

What Needs to Be Included in an Incident Report?

Keeping your incident report factual would require you to know the different types of information that you can gather during the incident reporting process. Here's a list of facts that would guide you during the documentation of an incident:

General information – the most fundamental information needed in an incident report such as specific location, time and date of the incident. This will also be a piece of valuable information if further investigation is needed.

Setting or environment – pertains to physical and environmental conditions that may have contributed to the incident. This could also entail the potential hazards found in the area of the incident.

Affected people – the names of the people involved, their title or position, and their department.

Injuries and the severity – include the type of injury, its severity, and body parts that were injured.

Witnesses – pertains to statements of people present during the incident.

Administered treatment – includes the initial treatment, aid, or any medications given to the affected individuals. This information is essential to understand employee recovery and the like.

Property and equipment damages – pertain to certain assets, materials, facilities, and equipment that were damaged during the incident.

Events – the story of the incident and the details why it turned out to be an incident.

Actions of people involved during the incident – the motion of the involved people at the exact time the incident occurred.

Incident Report Sample Format

The layout of information in an incident report form may vary depending on a number of factors. As a general rule, you should write incident reports in the third person since its purpose is to be objective; stating only facts and avoiding the inclusion of opinions and biases. Below is a sample incident reporting format you can use for your operations. It contains all the essential information you would need to include in order to complete an effective incident report:

- ✓ **Introduction**
  The first part of the incident report form covers the who, what, when, and where of the incident:
  - Include the names of all the people involved in the incident. If names are not available, you can instead cite the person's role in relation to the incident e.g. the customer, the guest
  - Summarize the incident itself in no more than three sentences e.g. a printer caught fire causing minimal damage to a room
  - Include the time and date of occurrence. An estimate works if the exact time could not be noted
  - Note the location of the incident and be exact if possible e.g. the Mercato Conference Room, 19th floor Building A.
- ✓ **Body**
  this is where you lay out all of the incident's details in a comprehensive manner. Talk about the incident from start to finish, ensuring details are laid out in chronological order to avoid confusion. Make sure to include the who, what, when, and where mentioned in the introduction when they are mentioned.
- ✓ **Conclusion**
  Was the incident resolved? How? If the incident was not resolved, explain why, and provide the steps that need to be taken in order to resolve it.
- ✓ **Signoff**
  Include the full name and signature of the incident report writer for accountability and record-keeping.

What to do After Completing an Incident Report

The incident report should be submitted to an investigation team to further study and look for deeper causes. An investigation should be conducted by those who are competent in collecting and analyzing information and evidence gathered from the incident report. Those conducting the investigation should be knowledgeable in occupational health and safety fundamentals.

The purpose of investigating an incident is not to find fault but to determine the root cause and develop corrective actions to prevent similar incidents from happening. An investigation also helps fulfill regulatory requirements (such as OSHA 300 Forms in the United States) and determines the costs involved with property or equipment damage (if any).

Better Record Keeping of Incident Reports

Incident reports should be properly kept as they are an important record of every organization. Creating incident reports can be time-consuming and requires rigorous documentation of the incident. However, understanding the purpose of incident reporting will help the organization determine the root cause of an incident and set corrective measures to eliminate potential risks. iAuditor is the world's #1 inspection app and can be used to streamline the completion and record-keeping of incident reports. With the iAuditor mobile app and web platform you can:

- ✓ Perform paperless incident reports on your hand-held device
- ✓ Take unlimited photo evidence attached to your incident reports
- ✓ Gather witness statements using auto-dictation
- ✓ Capture electronic signatures
- ✓ Generate detailed incident reports without leaving the site
- ✓ Unlimited secure cloud storage and easy record keeping of all incidents for regulatory purposes

UNIT 16

TROUBLE SHOOTING OF CONTROL SYSTEMS

This unit covers finding and rectifying faults in process control apparatus and systems. The unit encompasses safe working practices, interpreting process and circuit diagrams, applying knowledge of process controls to logical fault-finding procedures, conducting repairs, safety and functional testing and completing the necessary service documentation

FIND FAULTS

To expertly troubleshoot electrical equipment, problems must be solved by replacing only defective equipment or components in the least amount of time. One of the most important factors in doing this, is the approach used. An expert troubleshooter uses a system or approach that allows them to logically and systematically analyze a circuit and determine exactly what is wrong.

The approach described here is a logical, systematic approach called the 5 Step Troubleshooting Approach. It is a proven process that is highly effective and reliable in helping to solve electrical problems.

This approach differs from troubleshooting procedures in that it does not tell you step by step how to troubleshoot a particular kind of circuit. It is more of a thinking process that is used to analyze a circuit's behavior and determine what component or components are responsible for the faulty operation. This approach is general in nature allowing it to be used on any type of electrical circuit.

In fact, the principles covered in this approach can be applied to many other types of problem solving scenarios, not just electrical circuits.

The 5 Step Troubleshooting Approach consists of the following:

- ✓ Preparation
- ✓ Step 1 Observation
- ✓ Step 2 Define Problem Area
- ✓ Step 3 Identify Possible Causes
- ✓ Step 4 Determine Most Probable Cause
- ✓ Step 5 Test and Repair
- ✓ Follow-up

Preparation

Before you begin to troubleshoot any piece of equipment, you must be familiar with your organization's safety rules and procedures for working on electrical equipment. These rules and procedures govern the methods you can use to troubleshoot electrical equipment (including your lockout/tagout procedures, testing procedures etc.) and must be followed while troubleshooting.

Next, you need to gather information regarding the equipment and the problem. Be sure you understand how the equipment is designed to operate. It is much easier to analyze faulty operation when you know how it should operate. Operation or equipment manuals and drawings are great sources of information and are helpful to have available. If there are equipment history records, you should review them to see if there are any recurring problems. You should also have on-hand any documentation describing the problem. (i.e., a work order, trouble report, or even your notes taken from a discussion with a customer.)

Step 1 - Observe

Most faults provide obvious clues as to their cause. Through careful observation and a little bit of reasoning, most faults can be identified as to the actual component with very little testing. When observing malfunctioning equipment, look for visual signs of mechanical damage such as indications of impact, chafed wires, loose components or parts laying in the bottom of the cabinet. Look for signs of overheating, especially on wiring, relay coils, and printed circuit boards.

Don't forget to use your other senses when inspecting equipment. The smell of burnt insulation is something you won't miss. Listening to the sound of the equipment operating may give you a clue to where the problem is located. Checking the temperature of components can also help find problems but be careful while doing this, some components may be alive or hot enough to burn you.

Pay particular attention to areas that were identified either by past history or by the person that reported the problem. A note of caution here! Do not let these mislead you, past problems are just that, past problems, they are not necessarily the problem you are looking for now. Also, do not take reported problems as fact, always check for yourself if possible. The person reporting the problem may not have described it properly or may have made their own incorrect assumptions.

When faced with equipment which is not functioning properly you should:

- ✓ Be sure you understand how the equipment is designed to operate. It makes it much easier to analyze faulty operation when you know how it should operate;
- ✓ Note the condition of the equipment as found. You should look at the state of the relays (energized or not), which lamps are lit, which auxiliary equipment is energized or running etc. This is the best time to give the equipment a thorough inspection (using all your senses). Look for signs of mechanical damage, overheating, unusual sounds, smells etc.;
- ✓ Test the operation of the equipment including all of its features. Make note of any feature that is not operating properly. Make sure you observe these operations very carefully. This can give you a lot of valuable information regarding all parts of the equipment.

Step 2 - Define Problem Area

It is at this stage that you apply logic and reasoning to your observations to determine the problem area of the malfunctioning equipment. Often times when equipment malfunctions, certain parts of the equipment will work properly while others not.

The key is to use your observations (from step 1) to rule out parts of the equipment or circuitry that are operating properly and not contributing to the cause of the malfunction.

You should continue to do this until you are left with only the part(s) that if faulty, could cause the symptoms that the equipment is experiencing.

To help you define the problem area you should have a schematic diagram of the circuit in addition to your noted observations.

Starting with the whole circuit as the problem area, take each noted observation and ask yourself "what does this tell me about the circuit operation?" If an observation indicates that a section of the circuit appears to be operating properly, you can then eliminate it from the problem area. As you eliminate each part of the circuit from the problem area, make sure to identify them on your schematic. This will help you keep track of all your information.

Step 3 - Identify Possible Causes

Once the problem area(s) have been defined, it is necessary to identify all the possible causes of the malfunction. This typically involves every component in the problem area(s).

It is necessary to list (actually write down) every fault which could cause the problem no matter how remote the possibility of it occurring. Use your initial observations to help you do this. During the next step you will eliminate those which are not likely to happen.

Step 4 - Determine Most Probable Cause

Once the list of possible causes has been made, it is then necessary to prioritize each item as to the probability of it being the cause of the malfunction. The following are some rules of thumb when prioritizing possible causes.

Although it could be possible for two components to fail at the same time, it is not very likely. Start by looking for one faulty component as the culprit.

The following list shows the order in which you should check components based on the probability of them being defective:

- ✓ First look for components which burn out or have a tendency to wear out, i.e. mechanical switches, fuses , relay contacts, or light bulbs. (Remember, that in the case of fuses, they burn out for a reason. You should find out why before replacing them.)
- ✓ The next most likely cause of failure are coils, motors, transformers and other devices with windings. These usually generate heat and, with time, can malfunction.
- ✓ Connections should be your third choice, especially screw type or bolted type. Over time these can loosen and cause a high resistance. In some cases this resistance will cause overheating and eventually will burn open. Connections on equipment that is subject to vibration are especially prone to coming loose.
- ✓ Finally, you should look for is defective wiring. Pay particular attention to areas where the wire insulation could be damaged causing short circuits. Don't rule out incorrect wiring, especially on a new piece of equipment.

Step 5 - Test And Repair

Testing electrical equipment can be hazardous. The electrical energy contained in many circuits can be enough to injure or kill. Make sure you follow all your companies safety precautions, rules and procedures while troubleshooting.

Once you have determined the most probable cause, you must either prove it to be the problem or rule it out. This can sometimes be done by careful inspection however, in many cases the fault will be such that you cannot identify the problem component by observation and analysis alone. In these circumstances, test instruments can be used to help narrow the problem area and identify the problem component.

There are many types of test instruments used for troubleshooting. Some are specialized instruments designed to measure various behaviors of specific equipment, while others like the multimeters are more general in nature and can be used on most electrical equipment. A typical multimeter can measure AC and DC Voltages, Resistance, and Current.

A very important rule when taking meter readings is to predict what the meter will read before taking the reading. Use the circuit schematic to determine what the meter will read if the circuit is operating normally. If the reading is anything other than your predicted value, you know that this part of the circuit is being affected by the fault.

Depending on the circuit and type of fault, the problem area as defined by your observations, can include a large area of the circuit creating a very large list of possible and probable causes. Under such circumstances, you could use a 'divide and eliminate' testing approach to eliminate parts of the circuit from the problem area. The results of each test provides information to help you reduce the size of the problem area until the defective component is identified.

Once you have determined the cause of the faulty operation of the circuit you can proceed to replace the defective component. Be sure the circuit is locked out and you follow all safety procedures before disconnecting the component or any wires.

After replacing the component, you must test operate all features of the circuit to be sure you have replaced the proper component and that there are no other faults in the circuit. It can be very embarrassing to tell the customer that you have repaired the problem only to have him find another problem with the equipment just after you leave.

Follow Up

Although this is not an official step of the troubleshooting process it nevertheless should be done once the equipment has been repaired and put back in service. You should try to determine the reason for the malfunction.

- ✓ Did the component fail due to age?
- ✓ Did the environment the equipment operates in cause excessive corrosion?
- ✓ Are there wear points that caused the wiring to short out?

- ✓ Did it fail due to improper use?
- ✓ Is there a design flaw that causes the same component to fail repeatedly?
- ✓ Through this process further failures can be minimized. Many organizations have their own follow-up documentation and processes. Make sure you check your organization's procedures.

Adopting a logical and systematic approach such as the 5 Step Troubleshooting Approach can help you to troubleshoot like an expert!

COMPLETION AND REPORT FAULT FINDING RECTIFICATION ACTIVITIES

Reporting Outcomes

General Instructions for Reporting Outcomes/Impacts

Outcomes/Impacts are benefits or desirable changes in individuals, families or organizations, or in a group, population or area, that you achieved through one of your Projects/Programs. Describe how the Project/Program generated an outcome and/or made or contributed to an impact.

Outcomes/Impacts can be changes in:

1. Learning: Knowledge, awareness, or skills gained by others.
2. Action: New methods/tools or behaviors/practices adopted by others.
3. Policy or Decision-Making: Science-based information applied to decision-making and results from policy engagement (including influencing any stage of the policy process).
4. Conditions

- ✓ **Social or Health Conditions** - Health and safety status of a group or population; and the social environment for a group or population -- including relationships among individuals, organizations and agencies, and public policies and regulations.
- ✓ **Economic Conditions** - Financial resources and obligations of a group or population, including income, expenses and assets; and the economic environment for a group or population, including employment, productivity, and governmental revenue and expenditures.
- ✓ **Environmental or Physical Conditions** - Status of the natural environment, including quantity and quality of natural resources, and quantity and quality of natural and agricultural products.

A given Outcome such as "10% decrease in incidence of food-borne illness in the general county population" may occur only once. Alternatively an Outcome such as "10% gain in knowledge of science vocabulary among middle-school students participating in a CE Science Exploration Workshop" may occur on several occasions with different individuals in different situations. Thus, you can report on a given Outcome as many times as you wish, specifying the date(s) for which you observed each occurrence.

To Report on an Outcome

If you haven't yet selected a project/program, you will then see a list of all of your projects/programs; click the appropriate program for which you wish to report an outcome.
If you have previously selected a project/program, you will see a screen with options for entering outcomes, along with any previously entered outcomes for the selected project/program, as well as opportunity to select a different project/program. If you wish to select a different project/program to enter outcomes for, choose it from the drop-down list under Select Project/Program.
The display below the Project/Program Title shows the four types of Outcomes that can be reported.
You will see listed under each Outcome type heading, any Anticipated Outcomes that you specified in your Annual Plan and any Supplemental Outcomes that you entered in your Annual Report, for the selected Project/Program.
To Report an Occurrence of an Outcome
Click the Anticipated Outcome you want to report on. You will then see a screen where you can enter appropriate details about this occurrence of the Outcome. If you have previously reported any occurrences of this Outcome, you will see a display of all your previous records of occurrence of this Outcome in the upper portion of the screen.
Enter the appropriate details about the Outcome occurrence you are reporting in the boxes in the lower portion of the screen.

Enter the date(s) for the Time Period during which you observed the occurrence of the outcome.
For No. of Individuals/Units/Acres and/or % of Group/Pop/Area Realizing Change, specify how many individuals or what amount of area (acres), or what percent of the total group/population/area experienced the change on this occurrence. If your Outcome is defined in terms of change in a social, health, or economic indicator (e.g., incidence of disease, average income, total household debt for a population or demographic group at large) or an environmental or physical indicator for a geographic area (e.g. air quality and groundwater quality indices), enter the total population size or geographic area (acreage) in the "No." box.
If you enter a percent in the "%" box, you must enter the total group/population size or area (acreage) in the box for "Total No./Size of Group/Pop/Area."
Enter the description of benefit/change realized, group/population/area affected, and/or any additional information, in the narrative text box.
To Define a Supplemental Outcome not among Anticipated Outcomes
If you want to report an occurrence of an Outcome that you did not specify as an Anticipated Outcome in your Annual Plan and have not yet reported on, click the Report a New Supplemental Outcome choice under the heading for the type of change represented by the Outcome. You will then see a screen where you can enter appropriate details about this Supplemental Outcome. If you have previously reported any Supplemental Outcomes for the selected Outcome Type, you will see a display of all your previous of this Outcome in the upper portion of the screen.

- ✓ Enter the date(s) for the *Time Period* during which you observed the occurrence of the outcome.
- ✓ For *No. of Individuals/Units/Acres and/or % of Group/Pop/Area Realizing Change*, specify how many individuals or what amount of area (acres), or what percent of the total group/population/area experienced the change on this occurrence. If your Outcome is defined in terms of change in a social, health, or economic indicator (e.g., incidence of disease, average income, total household debt for a population or demographic group at large) or an environmental or physical indicator for a geographic area (e.g. air quality and groundwater quality indices), enter the total population size or geographic area (acreage) in the "*No.*" box.
- ✓ If you enter a percent in the "%" box, you must enter the total group/population size or area (acreage) in the box for "*Total No./Size of Group/Pop/Area.*"

Enter the description of benefit/change realized, group/population/area affected, and/or any additional information, in the narrative text box.
Description of Group/Population/Area that Experienced the Benefit/Change

Identify the group or population, or area that experienced change as a result of your Project/Program -- i.e., the group or population whose knowledge, attitude/intention, skill, behavior/practice, or conditions (social/health, economic, or environmental/physical) improved, or the geographic area or physical set (such as land or water bodies of a particular type) for which environmental/physical conditions improved. If you targeted an underserved clientele segment you should specify the underserved segment in your description.

Following are examples of group, population, and area descriptions for Outcomes:

- ✓ Residents of the county
- ✓ Youth ages 9-19
- ✓ Youth who participated in the Y.E.S. program
- ✓ Farm owners/operators
- ✓ Limited-resource strawberry farmers
- ✓ Prune growers who completed the IPM short course
- ✓ Public agencies and organizations concerned with land-use issues
- ✓ Low-income families with children
- ✓ Streams in the Russian River watershed
- ✓ Ranchland in the county

Description of Benefit/Change Realized

Describe the specific change in individuals, families, organizations, or conditions that your Project/Program brought about. Describe, in quantitative terms if possible, one of the following (depending on the type of Outcome):

The specific Knowledge gained
Examples:

- ✓ Knowledge of five techniques for improving sanitation in the kitchen
- ✓ 30% more knowledge of science vocabulary
- ✓ Understanding of how post-harvest factors affect fruit quality
- ✓ Awareness of new regulations governing disposal of hazardous wastes

The specific change in Attitude or Intention
Examples:

- ✓ Be more inclined to cut back on irrigation at hull split to reduce hull rot
- ✓ Plan to use at least one recommended technique for water conservation
- ✓ Feel more favorable toward careers in science
- ✓ Perceive private-public partnerships to be a high priority

The particular Skill gained
Examples:

- ✓ Ability to visually identify common garden insect pests with 90% accuracy
- ✓ 10% increase in speed in shearing
- ✓ Ability to determine per unit cost of common grocery items
- ✓ Ability to use a tensiometer to determine for irrigation schedules

The specific change in Behavior or Practice
Examples:

- ✓ Implement water quality management plans, covering a total of 150,000 acres
- ✓ Adopt at least four recommended food safety practices
- ✓ Develop a business plan for producing and direct marketing grass-fed beef
- ✓ Implement conservation tillage on 50% of the total tomato acreage

The specific change in Social or Health Conditions
Examples:

- ✓ 10% decrease in incidence of food-borne illness
- ✓ Reduction of 50% in cases of back injury
- ✓ 20% increase in voluntary compliance with regulations
- ✓ Increase in participation in local government and civic organizations

The specific change in Economic Conditions
Examples:

- ✓ Annual savings of $300,000 in costs for hand weeding
- ✓ Average reduction of 20% in monthly spending on food
- ✓ 1,000 fewer worker-days/year lost due to illness

- ✓ 500 new jobs created

The specific change in Environmental or Physical Conditions
Examples:

- ✓ 25% reduction in average shallow groundwater nitrate concentration
- ✓ 8,000 acres of agricultural land protected in land trusts
- ✓ 50% reduction in incidence of non-persistent, aphid-borne viruses
- ✓ Restoration of riparian habitats

Time Period during Which you Observed the Occurrence of the Outcome
Enter the date(s) for the Time Period during which you observed the occurrence of the outcome.*No. of Individuals/Cases/Units and/or % of Group/Pop/Area Realizing Change*

Specify how many individuals or what amount of area (acres), or what percent, of the total group/population/area experienced the change you are reporting. If you described the Outcome in terms of change in a social, health, or economic indicator (e.g., incidence of disease, average income, total household debt for a population or demographic group at large) or an environmental or physical indicator for a geographic area (e.g. air quality and groundwater quality indices), enter the total population size or geographic area (acreage) in the "No." box.

If you enter a percent in the "%" box, you must enter the total group/population size or area (acreage) in the box for "Total No./Size of Group/Pop/Area."

Comments: If you wish, you may record any additional observations or notes about this Outcome in the Additional Comments box.

Cleaning the jobsite
It’s not uncommon to see signs in workplaces reminding employees to clean up after themselves. If doing so is important in office kitchens, it’s doubly important on construction sites. Keeping sites orderly and removing waste can help avert accidents, prevent damage and even boost morale among workers.

The strategies below are a good starting point for keeping a jobsite clean.

Establish a housekeeping program

Set up a housekeeping system that involves everyone on the team. Focus on the importance of cleaning and removing debris after it has been created, and assign specific tasks to specific people to create accountability.

To keep the site tidy, use the 5S system, a method of workplace organization invented in Japan that includes making sure everything has a designated place and removing items not in use. To encourage compliance, use toolbox talks to remind everyone of the benefits of a clean, organized jobsite, such as improved safety and efficiency.

Separate the scraps

Construction companies may be required to recycle materials like metal, wood and sometimes, concrete. In addition to federal regulations, you may need to follow state or regional recycling rules. And the contract might stipulate which materials or debris should be diverted from landfills, along with target diversion rates for non-hazardous solid waste.

Observe the rules and designate piles, bins and containers for leftover materials. Do this ahead of time so nothing that should be kept or recycled is accidentally thrown away. In general, while recycling containers should be easy to access, the fewer containers for each type of material the better in terms of keeping transportation costs low and minimizing jobsite obstructions. Consider hiring a company that does waste and recycling management for construction firms.

Eliminate waste at the source

The less waste that arrives or is created at the site, the less disposal and cleanup is necessary. Choose products with minimal packaging. Measure carefully so you order only the materials you need, in the optimal sizes. Buy quality materials so you throw out fewer warped studs, for instance. Embrace the use of prefabricated elements when possible.

Keep waste properly contained

Keeping a lid on waste, literally, is important, especially when the waste could spill, evaporate or smell. Containers and product drums should be sealed tightly. Use the right container for the type of hazardous waste. Mark the container to indicate its contents, and make sure the container is in good condition. Containers of used oil should be free of leaks, structural defects and severe rusting, for example. Use a locked compound if you're storing one near water or a drain.

All workers must be trained in the management of hazardous waste as it relates to their job function. Make sure everyone knows where to discard flammable and combustible materials.

Oily rags aren't just tripping hazards; they're also flammable. In fact, they can spontaneously combust. That's why they should be stored in a metal container with a cover, preferably a self-closing lid. Schedule frequent removal of hazardous waste to keep areas clean and prevent fires and accidents.

To discourage dumpster divers and any unauthorized use of your dumpster, consider a lock for it.

Manage dust safely

Use engineering and work practice controls such as dust collection systems to limit dust in the air during certain tasks, such as sawing or grinding concrete, stone or mortar. Reduce the amount of dust created by installing water systems that steam or spray a cutting blade.

Controlling respirable crystalline silica is especially important since it can cause incurable lung disease if inhaled. Per OSHA's silica dust compliance guide for small entities, don't allow dry brushing or dry sweeping unless methods such as wet sweeping and HEPA-filtered vacuuming are not feasible. Workers should of course have access to appropriate respiratory protection.

The last sweep

Last impressions count. Performing a final cleaning during closeout will leave a good impression on the client and possibly help you win more projects in the future. Create a checklist of tasks, such sweeping, mopping, cleaning all surfaces, washing windows and removing any remaining stickers. And don't forget trash removal.

If you established a good housekeeping routine at the beginning of the job, cleanup should be a relatively easy final step.

Repair the Equipment

Introduction to Maintenance:

Machines, buildings and other service facilities are subject to deterioration due to their use and exposure to environmental conditions. If this process of deterioration is not checked, it may render them unserviceable. It is, therefore, necessary to attend to them from time to time, to repair and recondition them so as to enhance their life economically.
Maintenance aspect is more important specially in the case of machines due to their non-uniform pattern of wear and tear which depends on large number of factors.
Every machine is thoroughly tested and inspected by the manufacturers before selling it, and by the purchaser before it is put to use. When it is used, it will be subjected to wear and tear hence proper attention should be given to protect the machine and its components from undue wear and thus protect them from failures.
A proper attention means lubrication, cleaning, timely inspection and systematic maintenance. Maintenance of a machine means efforts directed towards the up-keep and the repair of that machine.
A major part of the expenditure is generally on men, material and maintenance in an industry. Every machine will require repairs even if it is best designed, hence the repair must be done at such a time when it may have least disruptions, i.e. machine may be repaired when it is not being used or its use may be postponed without affecting the production of the whole concern.
Therefore, checking of the machine is generally done when it is not in operation, so that the defect, if any, can be immediately and easily rectified without causing extensive damage to the plant.

In this way, we say that maintenance is responsible for the smooth and efficient working of an industry and helps in improving the productivity. It also helps in keeping the machines in a state of maximum efficiency with economy.
Realising the high importance of maintenance of plants and equipment's. National Productivity Council, undertook the survey of engineering industries, and found that due to failure of the plants, equipment and machineries, non-availability is 28 per cent. Looking to this high percentage of failures, it is essential that the engineering units should improve their maintenance system.
Maintenance can be defined as a combination of actions carried out to replace, repair, service or modify the components in a plant or equipment so that it will continue to operate at a specified "availability" for a specified period of time.
Maintenance management is concerned with the direction and organization of resources in order to control the availability and performance of plant to some specified level.
The maintenance management is therefore a restorative function to ensure availability and efficiency of the existing plant, equipment and buildings at an optimum level.
Plant and equipment maintenance plays an important role in production management because breakdown creates problems such as:

- ✓ Loss of productive time
- ✓ Re-scheduling of production
- ✓ Need for sub-contracting work
- ✓ Temporary work shortage, as during break down workers may not have work for them.

Types of Maintenance:

Generally, maintenance can be done in the following two ways:
1. Breakdown maintenance.
2. Preventive maintenance.
In the first case of maintenance, repair can be done after the breakdown occurs while in the second case maintenance is done on the basis of prediction or on the basis of periodical checking.

1. Break Down Maintenance:

Breakdown maintenance is defined as a maintenance activity conducted on a machine which has ceased functioning owing to shear or crushing or buckling or elongation or swelling or any other form of failure of any critical component of the said machine in order to enable the same to function as before by resorting to necessary replacement(s) of the same and/ or more number of components by new ones or usable old ones and/ or re-conditioning of the same within the minimum time period considering scope of work, available facilities and skill.
Breakdown of a machine can occur due to the following two reasons:

- ✓ Due to unpredictable failure of components which cannot be prevented.
- ✓ Due to gradual wear and tear of the parts, which can be eliminated to a large extent by regular inspections, known as preventive maintenance. From experience it can be decided that, when a part should be replaced, so that breakdown can be avoided.

In breakdown maintenance, defects are rectified only when the machine cannot perform its function any longer, and the production department is compelled to call on the maintenance engineer for repairs. After repairing the defect, the maintenance engineers do not attend the machine again until another failure occurs.

In this type of maintenance, repair shall have to be done on failure, thus it may disrupt the whole production, if it is performing an important work. This method is expensive also due to increase of depreciation cost, payment to idle operators, overtime to the maintenance staff for doing the emergency repairs.

2. Preventive Maintenance:

Preventive Maintenance is defined as a maintenance activity conducted on a machine as per laid down schedule or frequency by making necessary or need-based replacement and/or reconditioning of component(s) within the pre-fixed time period of the said work in order to reduce and avert breakdown(s).

Preventive maintenance is sometimes termed as “planned maintenance” or “scheduled maintenance” or “systematic plant maintenance” etc. It is an extremely important function for the reduction of maintenance cost and to keep the good operational condition of equipment and hence increases the reliability.

Preventive maintenance aims to locate the sources of trouble and to remove them before the breakdown occurs. Thus it is based on the idea “prevention is better than cure”. Scheduled maintenance is always economical than unscheduled maintenance, as we all know that, “a stitch in time saves nine.”

Best safeguard against costly breakdown is to inspect, lubricate and checkup the equipment as frequently as possible. To take full use of equipment and to maintain it in reliable condition, necessary measures should be taken to prevent overloading, dampness, negligence and misuse of machines.
Frequency of inspection should be decided on the basis of the importance of the machine wear and tear of the machine and its delicacy. This periodic inspection or checking helps to find out the reasons leading to breakdown and to rectify them, when they are in minor stages.

Thus the repair can be done when one wants to do it, i.e. when it has least effect on the production schedule. Further this repair requires lesser time as compared to that of breakdown repair and thus down time is reduced by doing preventive maintenance.

Objectives:

- ✓ Preventive maintenance has following main objectives:
- ✓ To obtain maximum availability of the plant by avoiding breakdown and by reducing the shutdown periods to a minimum.
- ✓ To keep the machine in proper condition so as to maintain the quality of the product.
- ✓ By minimising the wear and tear, preserve the value of the plant.

- ✓ To ensure for the safety of the workers.
- ✓ To keep the plant at the maximum production efficiency.
- ✓ To achieve all the above objectives with most economical combination.

Procedure for Maintenance:

Maintenance should be done considering all the above mentioned factors. Daily maintenance is done by the operators themselves. Before starting the work of their shift, cleaning, oiling and greasing should be done by the operators. For this purpose manufacturers used to issue maintenance instructions for their machines, which should strictly be followed.
Preventive maintenance of the machine depends largely on the operators. Hence, as far as possible, one operator be allotted for each machine, and when the same machine is used in more than one shift, one operator for each machine for each shift be allotted.

This system has following advantages:

- ✓ An operator gets used to the sound and working of his machine and notices any change immediately, which helps in investigation and rectification of the defect then and there. If operators are changed frequently, immediate check-up and timely repair cannot be possible.
- ✓ It is easy to pin-point operators with bad operating habits. To remove these habits training can be arranged or disciplinary actions can be taken as the case may be.
- ✓ The machine will remain in good conditions.
- ✓ Periodic maintenance is generally conducted by the maintenance crew, specially trained for this purpose. The period should be decided on the basis of past experience. Apart from this, operating instructions should carefully be followed by the operators.

In case any abnormal sound or behaviour is noticed in the machine, he should immediately bring this into the notice of maintenance crew, so that the defect can be rectified immediately. Care must be taken that it may not be left for the latter date.
Inspections and lubrication schedules should be strictly followed. Inspection schedule should include the inspection of tools, accessories and other equipment.

Complete work processes

Equipment Inspections

With regular inspection, you make sure your equipment is in top shape and can handle the toughest jobs. A trained technician can determine if small repairs will make a big difference and can suggest repairs to help your equipment run more efficiently. An equipment inspector may point out details your team might tend to overlook.
Most importantly, regular inspections ensure the safety of your workers. You can get projects done on schedule and with peace of mind, knowing your equipment is in good condition. When it comes down to it, there is no reason not to have regular inspections and get the most out of the investment you made in your heavy

equipment. Still not convinced? Keep reading to learn more about inspections and why they are critical to your heavy equipment lifespan.

What is checked during and equipment inspection?

Heavy equipment inspections combine data collection and analysis with hands-on testing and examination for a thorough look at the equipment's condition. A complete inspection is an important preventive way to make sure equipment is safe for use and that all systems are working properly.

The Occupational Safety and Health Administration (OSHA) requires each piece of heavy equipment to pass inspection before use. If any of the safety features are in disrepair, you should not use the equipment. Employers are required to get unsafe equipment repaired to ensure worker safety.
Damaged or broken equipment requires immediate repair to prevent problems. According to OSHA, all heavy equipment must have:

- ✓ A working brake system, including emergency brake and parking brake
- ✓ Working headlights, taillights and brake lights
- ✓ An audible warning device, like a horn
- ✓ A windshield and windshield wipers in good condition

Although heavy equipment owners have the option of maintaining only the minimum to meet OSHA requirements, they shouldn't overlook other details if they want their equipment to last. Heavy equipment can last for years if properly maintained. Considering some heavy machinery costs more than a house, it is a smart move to take utmost care of these powerful tools. Get the most out of your investment by conducting regular inspections on your own or with a trusted technician.
MacAllister Machinery uses cutting-edge technology and hands-on expertise to inspect, collect, analyze, diagnose and monitor equipment. When combined with other information, like machine history and use, we have all the tools we need to suggest repairs and maintenance for optimal safety and performance. It is easy to access and view inspection results, too. Just log in to the Cat Inspect app or VisionLink to take the next step or review results.

What do inspectors look for?

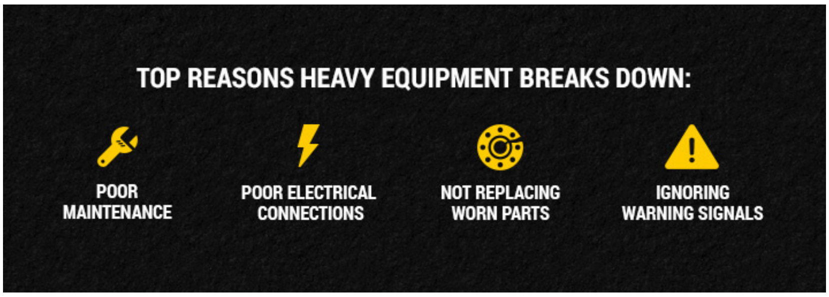
Heavy equipment inspectors check all the components of a piece of equipment, emphasizing safety. A technician can not only test for safety, but can also consider ways to increase equipment productivity and efficiency. Once you're certain of safety, it is up to you what you want to accomplish with your equipment. Our inspections are tailored to meet your specific needs.
In general, equipment inspectors will check the following components using both diagnostic tools and an expert eye:

- ✓ Roll-over protection structures, including seatbelts
- ✓ Gauges and lights
- ✓ Battery
- ✓ Engine performance
- ✓ Safety features such as deflectors and sweeps
- ✓ Steering components
- ✓ Brake systems
- ✓ Exhaust system
- ✓ Cooling system
- ✓ Fan belts
- ✓ Engine support
- ✓ Radiator guards
- ✓ Transmission function
- ✓ Tracks and rollers
- ✓ Rear hitch
- ✓ Oil level and condition
- ✓ Tires and wheels
- ✓ Glass and mirrors
- ✓ Undercarriage
- ✓ Hydraulic system

Heavy equipment is a significant investment, so it is worth fitting maintenance and inspections into your work schedule. You'll potentially save yourself thousands of dollars in repairs. Get ahead of the game and save yourself the trouble of dealing with failed equipment.

Sometimes, the value of expert advice is priceless. An expert is more likely to notice when parts or systems are damaged beyond what an untrained eye can spot. It is not uncommon for heavy equipment to break down, and the majority of the causes are preventable. Here are some of the top reasons heavy equipment breaks down.

- ✓ **Poor maintenance:** Failing to replace belts or forgetting to check oil levels, for example.
- ✓ **Poor electrical connections:** An inspector can detect electrical issues early, before equipment breaks down and causes you to lose work.
- ✓ **Not replacing worn parts:** By fixing only one broken part, you are only temporarily taking care of the issue. Other worn parts need to be inspected to prevent further damage and future costs.
- ✓ **Ignoring warning signals:** Always ask a technician to investigate a warning signal. Ignoring a warning signal can lead to major equipment damage or serious injury.



An inspector will run tests, collect diagnostic codes, analyze data and visually inspect the equipment to checks for leaks, broken or loose parts, excessively worn parts or any potential problem areas. With an inspection checklist in hand, either on a device or paper, a technician will make sure they don't miss anything, and they will teach your team what to look out for during daily checks.

What are the benefits of equipment inspections?

Equipment inspection is not something to dread. Inspection is an opportunity to save money, prevent injury and stand out from competitors. Your productivity is only as good as your equipment is, and you can't get very far with broken equipment or out-of-work employees. Regular inspections take productivity and safety to the next level, beyond mandatory inspections.

Heavy equipment is a powerful tool that undergoes a lot of different conditions and completes amazing tasks. With the incredible work a piece of equipment can do, like lifting tons, wear and tear are inevitable. Plus, no matter how great your team is, sometimes packed schedules can lead to equipment abuse and misuse. Worn or damaged components are not always apparent. Regular inspection makes sure equipment is still in great condition, despite being used by multiple workers under difficult conditions.

Considering the costs of heavy equipment repair and replacement, the pros of frequent inspection far outweigh the cons. If you wonder about the condition of your equipment, do not hesitate to contact a qualified technician immediately. Here are the reasons why.

1. **Lower risk of workplace injuries**

Regular inspections lower the chances of one of your workers getting injured. Unfortunately, injuries do happen on the job, and most of the time, they are preventable. Inspections are a preventive safety measure for you and your employees.

Consider that in 2016, there were 4,693 deaths in private industry, according to OSHA. About 21 percent of the deaths occurred in the construction industry. Excluding highway injuries, the leading causes of construction workers' deaths were the "fatal four" — falls, struck by an object, electrocution or caught between two pieces of machinery. Eliminating the fatal four could save 631 lives each year in America.

Now, consider how failing equipment could play a part in these statistics. A failed horn, brakes or any other important component could lead to a crash, or a vehicle driver striking another worker. A collision or failed system could cause a heavy object to fall and lead to injury or death. Or, a worker could become distracted by broken-down equipment and less aware of nearby workers, putting their safety at risk. If brakes fail or if equipment suddenly shuts down, it could easily cause a dangerous chain reaction to occur.

Although your equipment might be in great shape one day, you'll want to have it inspected after a tough job. If it does need a repair, don't wait — make repairs immediately and play it safe.

A. Lost Time

If a worker gets injured as a result of damaged equipment, chances are, they are going to miss some time. Common injuries relating to heavy equipment are often serious, such as amputations, spinal injuries, sprains, fractures and cuts.
Workers who suffer any of these injuries could be out for days. According to a 2015 Bureau of Labor Statistics news release, workers who sustained sprains or strains resulting from a workplace injury required 10 days off work, on average. Workers with fractures needed 31 days, and those who suffered amputations required 22 days or more.
Even less severe injuries could lead to lost time. To stay on schedule, you will have to find someone to make up for the lost worker. If you are not able to find someone, productivity can slow down substantially.

B. Restaffing Costs

If a worker is severely injured, they might need a long time to recover, or they may never return to the jobsite. In such a case, you will need to replace the worker with someone new. Whenever you hire a new employee, you take a chance. Even when the new hire is a good fit for your company, it almost always comes with a price. New workers usually need training and time to adapt. It could also take a while to find a worker who is right for the job.
According to a 2016 survey by the Society for Human Resource Management (SHRM), it takes 42 days to fill a job vacancy with a new employee, which is a lot of time with insufficient staff. New employees cost money, too. On average, it costs companies $4,129 to hire someone new.
Even if you think you've found the perfect worker, there is no guarantee they'll stick around to see a project through. According to the SHRM survey, the average annual turnover rate is 19 percent. Considering an employee who makes $8 an hour could wind up costing a company $3,500 in turnover costs, your best bet is to try to keep the employees you have. Inspecting your equipment regularly is just one aspect of best practices.

C. Higher Workers' Compensation Premiums

Workers' compensation means employers are required by law to pay for workers' compensation benefits if a worker gets hurt on the job. Injuries can be from one event or repeated injuries, such as those caused by regular exposure to chemicals or loud noises. Sometimes, workers' compensation even covers psychological stress.

When an employee files a workers' compensation claim, your workers' compensation premium increases as a result. Injury can also affect health care premiums. However, if your claim costs are lower than average compared to similar companies, your premium may decrease — more incentive to keep your equipment fully intact.

Regular inspection allows you to take care of your equipment and even greater care of your workers.

D. Possible Fines

Avoid fines and serious violations with regular inspections by ensuring safety at all times. Under OSHA law, employers are responsible for maintaining safe workplaces for their employees. If you ignore safety, you break the law.

For example, in 2012, OSHA cited a heavy equipment rental company in Hawaii for serious safety violations after a crane fatally crushed a worker. An OSHA inspector found outriggers meant to stabilize the crane were not extended, allowing the crane to tip. The company failed to inspect and keep a record of vital crane components. The company also allowed a worker to use the crane when it was displaying a warning indicator. Also, other equipment was not properly maintained or guarded to prevent amputation or injury. OSHA set fines totaling $70,000.

Not only did this company have hefty fines to pay, but they lost a worker and impacted their business name — all of which they could have prevented if they had put safety first. Clearly, it is not worth taking a chance when it comes to heavy equipment.

E. Could Be Held Liable

There are plenty of ways you could legally be liable if equipment fails and causes injury. For example, if a worker is injured and sent home, and if you hurriedly hire another worker to help your team finish a project on time, you might be putting yourself and workers at risk if the new employee is unqualified for the job. If the new worker causes harm to another worker, you could be held liable for hiring someone who brought danger to other employees.

Another way you could be liable as an employer is if you are aware your equipment needs repair, even if it had passed a mandatory inspection, but fail to repair it. If someone is injured, you could be liable for negligence.

2. INCREASE PRODUCTIVITY

Although safety is a priority, consider how damaged equipment can also affect

productivity. When equipment fails, the workflow gets interrupted, and projects come to a halt. It's impossible to complete a job if even one piece of equipment has broken down.
When projects are interrupted, you might not be able to stick to your schedule and meet deadlines. It is important for customers to know they can depend on you, and regular inspections help make sure your equipment is reliable for you, your workers and your clients. To stay on schedule and meet your goals, you want to have all equipment working optimally.

Also, downtime is costly. According to Farm Industry News, downtime due to equipment breakdowns costs companies around $1,400 a day during planting season. Failure to get equipment inspected before use is the biggest reason the equipment breaks down.
In general, machinery failure is usually due to one of the following.

- ✓ **Thermally induced failure:** Equipment overheats, or extreme temps cause equipment to break down.
- ✓ **Mechanically induced failure:** It is easy to prevent this with inspection and replacing parts. Mechanically induced failure often happens due to overexertion, collision and misuse or abuse.
- ✓ **Erratic failure:** Occurs randomly due to harder-to-detect reasons, such as electrical issues or software malfunction. Erratic failure can be prevented with the help of diagnostic equipment used during inspection.

Equipment failure can be sudden or gradual. Inspections are important because you may not notice the seriousness of an issue until it's too late. By regularly having a professional check your equipment, you prevent disaster and make informed choices. You can replace parts when necessary and not wait until equipment breaks down in the middle of the workday to make repairs. As a result, you decrease unscheduled downtime and improve productivity. Your clients will be impressed when projects are safely finished on time.

3. Lower Repair Costs

With regular inspections performed by a trained technician, you will be able to make a repair before it leads to a much more expensive problem. Your equipment will run better, and you'll extend its lifespan significantly with inspections and maintenance. The better condition your equipment is in, the less time you'll need to spend on repairs, and the more work you can get done.
Ultimately, you will get a greater return on your investment if you run highly efficient equipment for a longer amount of time. Consider the circumstances in which you use the equipment. What is the environment? What are the weather conditions? You may need more inspections and maintenance than you might think.
Small repairs are often worth the time and cost because heavy equipment is not cheap to replace. Considering a bulldozer can range in price from $30,000 to more than $200,000, it only makes sense to properly maintain something so valuable.

When and why should you do inspections?

Inspections should be carried out daily, and should include a look at the following:

- ✓ Brakes and lights

- ✓ Tire pressure
- ✓ Fluid levels
- ✓ Mirrors and glass
- ✓ Seatbelts
- ✓ Horn
- ✓ Emergency stopping system
- ✓ Safety devices
- ✓ Steering
- ✓ Tire condition
- ✓ Fuel and oil leaks

Every day, team members should focus on making sure the equipment is safe before each use. However, certain conditions require a more thorough inspection, best performed by a trained technician. You should get your equipment professionally inspected when:

- ✓ It has been exposed to conditions that could cause damage and lead to harm
- ✓ Suspected damage has occurred
- ✓ It has experienced severe environmental conditions, such as when it is dusty, wet, muddy or has been in corrosive coastal environments
- ✓ It has been driven on unpaved roads or mountainous terrain
- ✓ It has had several operators
- ✓ There is any sign of needed repair shown through signals, noises or obvious damage
- ✓ You are about to do a tough job
- ✓ Your worksite is located far away from your shop
- ✓ You are about to buy a piece of used equipment or sell your equipment

When in doubt, get your equipment inspected by a trusted professional.

UNIT 17

APPLY SUSTAINABLE AND EFFECIENT OPERATIONS

This unit covers identifying, implementing and monitoring strategies for sustainable resource use. Moreover, accessing and evaluating the current resources and knowing how to utilize while reviewing the effective methods to reduce resource usages

Four Pillars of Sustainability

What is sustainability? The principles of sustainability are the foundations of what this concept represents. Therefore, sustainability is made up of four pillars: social, human, economic, and environmental. These principles are also informally used as profit, people and planet.

Sustainability Issues

Energy and Emissions:

We reduce emissions of greenhouse gases by increasing energy efficiency and selecting cleaner and renewable energy sources. We reduce energy use by constructing only the facilities we need and by building, renovating, maintaining, and operating them to use energy efficiently throughout their life. As campus community members, we seek to reduce energy use in our daily lives, in our work, and in our travel and to be mindful of the impacts of our choices.

Natural Resources:

We reduce our effects on water systems by minimizing use and by managing storm-water runoff. When materials are required, we select sustainability harvested sources to preserve natural resources. We protect the local habitat by limiting the physical growth of the college. We work to develop built landscapes in ways that support natural ecological functions by protecting existing ecosystems and regenerating ecological capacity where it has been lost. We provide opportunities for members of the community to interact with and appreciate the environment.

Procurement, Consumption, and Waste:

We reduce, reuse, and recycle materials. We work to understand and decrease the environmental impacts of the use, production, transportation, and disposal of items we purchase. We select vendors committed to sustainable practices throughout the life cycle of their products, and we prefer to buy locally.

Quality of the Built Environment:

We build and maintain buildings that provide safe, comfortable, and healthy environments for students, faculty, and staff through effective use of day-lighting, ventilation, and connections with the natural environment. We work to improve our understanding of toxic materials used on campus and to reduce their presence in labs, art studios, and building and maintenance materials as well as in cleaning, landscaping, and pest-control.

ASSESS AND EVALUATE CURRENT RESOURCE UTILIZATION

Resource management is a complex process, especially in an enterprise with shared, geographically dispersed resources. According to The 2017 Project and Portfolio Management Landscape report, almost half of organizations report they are stuck in silos. With so many approaches to work, it should make sense that resource management approaches can also vary. Regardless, there are three capabilities every resource management software should include:

- ✓ Capacity and Demand Management: Optimize resource utilization by prioritizing high value work with available resource capacity
- ✓ Resource Utilization: Ensure that the right resources are available to support your strategic goals
- ✓ Progress and Time Tracking: Ensure that progress can be tracked, which can be especially valuable when using time tracking. Compare planned effort vs. actual effort to improve estimates and better understand where your resources are truly spending their time.

Using an effective enterprise resource management system that delivers these three capabilities will enable your organization to:

- ✓ Obtain a realistic view of both demand and capacity to deliver
- ✓ Manage and prioritize work requests and set appropriate expectations with key stakeholders
- ✓ Determine true resource availability
- ✓ Put the right resources on the right work at the right time
- ✓ Understand what roles and/or skill sets to hire to fulfill stakeholder commitments
- ✓ Increase and improve communication between project and resource managers and team members
- ✓ Spot problems earlier in the process
- ✓ Provide objective methods to prioritizing work ensuring demand is balanced against capacity to deliver
- ✓ Connect strategy to execution

✓ Deliver programs that drive innovation and transformational change

Where to Start with Resource Management Tools

Using the right resource management tools for your organization is essential. Organizations often rely on spreadsheets for resource management because of their ease of use, simplicity, and ability to set up a file quickly. However, keeping multiple or even shared spreadsheets up to date doesn't scale well and often becomes infeasible.

Using a manual, ad-hoc approach to resource management is labor intensive, leads to inaccurate and stale data, inhibits organizational agility, and produces unrealistic views of demand and capacity. It also fails to account for smaller work items on the demand side during the traditional intake process. For example, having to make a small tweak to something already implemented or helping others on (potentially lower priority) work.

As a result, when starting new work, you may already be behind without knowing it!

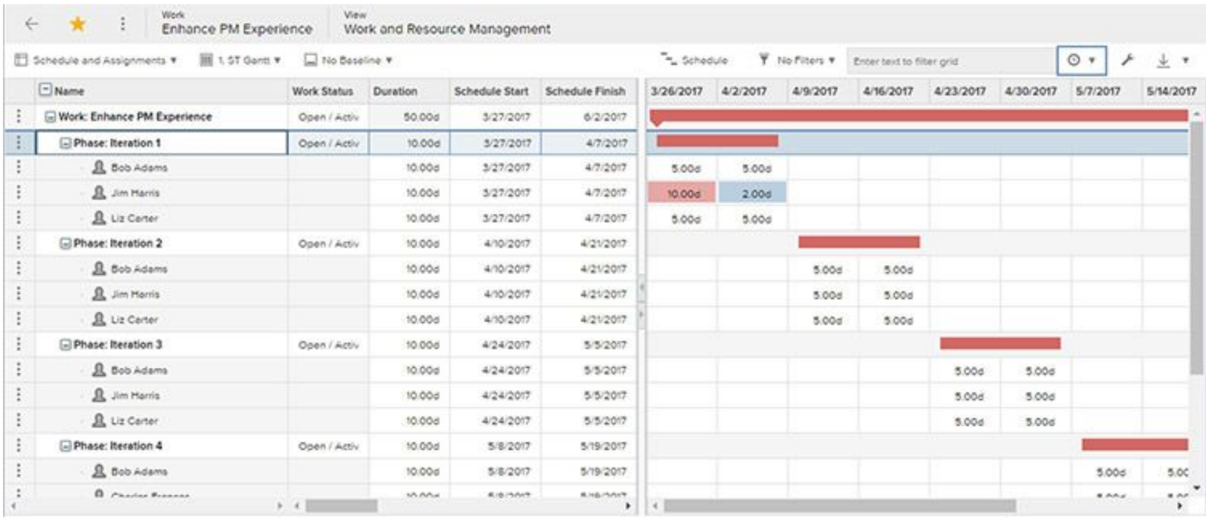
Regardless of the approach and tools used, organizations must determine how to balance their resources' capacity and demand. Here's a curated list of the top 12 resource management best practices to consider.

Top 12 Resource Management Best Practices

1. **Understand which resources are in short supply and focus on them**

   ✓ Often, you can employ the 80/20 rule, where basically 80% of the effects (or resource constraints) come from 20% of the resources. These are the people in high demand to do the work.

   ✓ Focus on these constrained resources, and plan around their availability, to help avoid bottlenecks and unnecessary delays.



2. **Agree on a common approach to prioritizing work across shared resources**

   ✓ Create an agreed-upon scoring/evaluation process in advance to help facilitate objective decision making, rather than fall victim to the "squeaky wheel" problem

   ✓ Monitor unplanned work that can steal from your capacity and create hidden delays

   ✓ Keep in mind that overcommitting people can lead to quality problems and a reduction in overall throughput

3. **Embrace different ways of working across the organization and resources**

- ✓ Different types of work, and even different groups within your organization, may benefit from a specific methodology
- ✓ As such, ensure that the tools and selected approaches align and create efficiencies
- ✓ At higher levels, a more standardized roll up can provide the metrics needed for a comprehensive view of your organization
- ✓ This will enable your organization to plan, manage, and deliver work – utilizing a range of methodologies such as traditional or milestone-driven, iterative, Agile, and even collaborative work

4. **Realize resource management is an ongoing process**

- ✓ Recognize that conflicts will occur because unexpected events and changes are inevitable (and more frequently than we would like!)
- ✓ Work together to resolve resource conflicts based on your immediate and downstream priorities

5. **Manage work and resources uses a blend of granularities**

- ✓ Planning work, managing assignments, and reporting time doesn't all have to utilize the same granularity. Find the balance that works for each situation.
- ✓ Planning work is often the most granular, while time reporting may be elevated to simplify the reporting process of those tracking time, which leads to a greater level of accuracy
- ✓ When assigning resources to work, long-term assignments often work best at the high-levels while near-term assignments tend to be well understood allowing for more detailed planning

6. **Plan work**

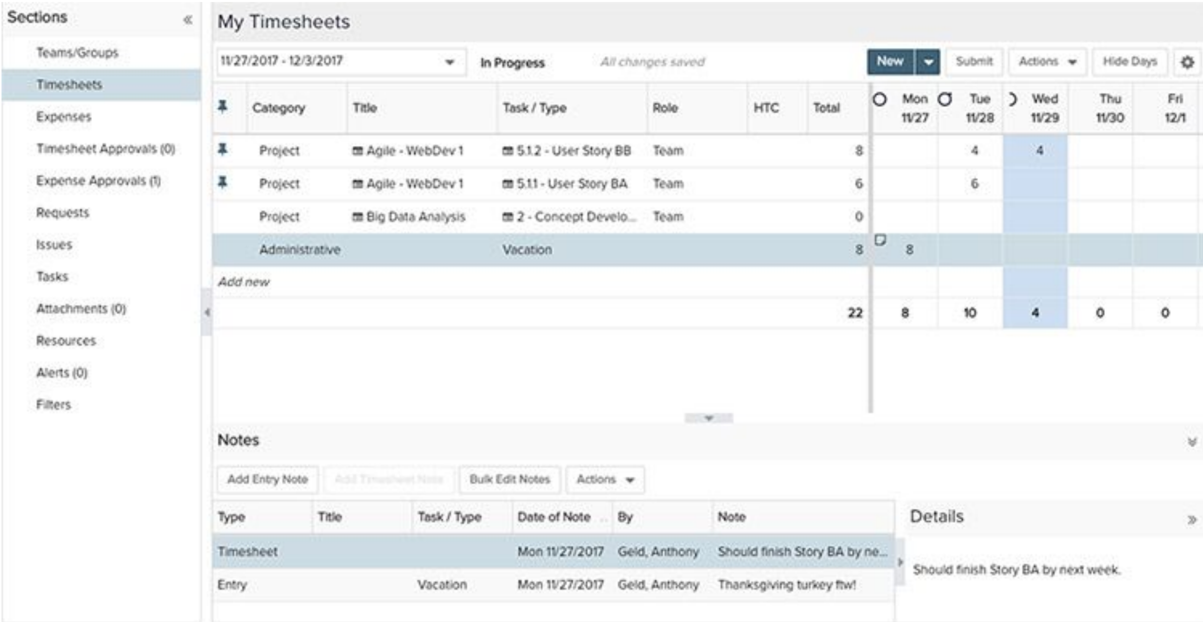
Consider traditional tasks with start/finish dates and durations for formally defined work and less formal lists to handle lightweight assignments
Align projects and other work to the strategic outcomes they are meant to support
Utilize automated processes where possible to reduce administration

7. **Manage resource assignments**

- ✓ Use high-level buckets at the project or phase level as a starting point if resource management is new to your organization
- ✓ Remember that one-size doesn't fit all and varies usage based on specific, constrained resources or groups. For example, DBAs may be shared and overutilized so you may want to increase the level of detail to minimize conflicts.
- ✓ Ensure that your resource management usage decisions can evolve as needs and challenges change over time

8. **Report time**

- ✓ Remember that different groups may be more reluctant to time reporting, so keep things simple and easy (especially in the beginning)
- ✓ Further ease adoption by tracking time in the execution tool of your resources' choice
- ✓ Utilize actuals to assess performance and understand trends to improve future planning



9. **Apply assignment types that align to your business needs**

- ✓ Utilize unnamed, role-based resources for long-term planning, or when the specific resource isn't known in advance
- ✓ Soft-booking of named resources can benefit medium-term planning and prioritization processes
- ✓ Hard-book named resources for the short-term when detailed information is known

10. Account for non-project time

- ✓ Ensure that administrative time, paid time off, etc. are accounted for when planning in both the long and short terms
- ✓ Don't forget about unexpected project activities; be sure to provide a mechanism to capture this time – otherwise you will lose visibility to this reduction of capacity
- ✓ Realize there will be a natural time loss from common, everyday items, such as administrative tasks (e.g., email, general meetings, etc.)

11. Avoid or limit multi-tasking

- ✓ Multi-tasking sounds efficient, but often results in lower overall productivity
- ✓ Try to limit the number of parallel tasks and your resources will perform better

12. Keep your most valuable assets and resources productive and happy

- ✓ Last but certainly not least, take care of your resources because turnover causes a tremendous loss in productivity/capacity
- ✓ Offer training programs and don't over-utilize to reduce burnout

The Rewards of Good Resource Management

Great resource management software and following these best practices can lead to significant improvements in your resource management. This will ideally translate to higher productivity and satisfaction levels across your teams and individuals.

As a result, you'll be able to:

- ✓ Centralize demand intake and optimize project portfolio and resource capacity to deliver your organization's strategic initiatives
- ✓ Get the right people working on the right projects at the right time
- ✓ Align your resources to changes in the market and management demands
- ✓ Keep your projects on track, on time, and on budget

The Planview Solution

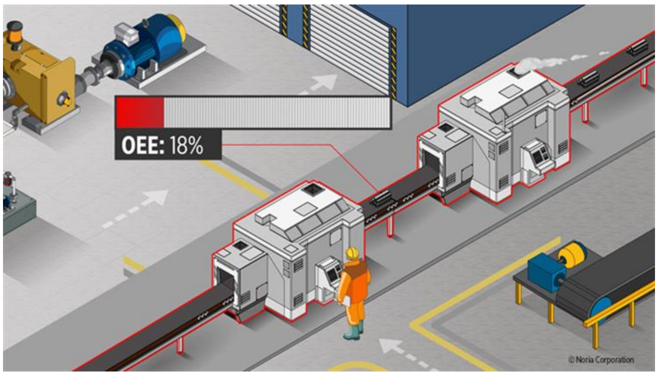
Whether you are just getting started or are continuing along a resource management journey and advancing to the next level, Planview can help with a data-driven, enterprise-wide solution. Based on our 29 years of experience partnering with global customers, we can help your organization optimize your resource management to create capacity for innovation and transformation.

Today's organizations are under pressure to drive innovation and transformation, given the reality of constrained people and financial resources. By integrating strategy, planning and delivery, Planview's Work and Resource Management solution for Portfolio and Resource Management enables PMOs to optimize their portfolios, balance capacity against demand, link plans and resources to projects, and manage the underlying financials. Stakeholders can visualize portfolio performance against plans and make decisions that ensure resources deliver the highest value projects for the business.

MONITOR AND REVIEW EFFECTIVENESS OF WAYS TO REDUCE RESOURCE USAGE

Maintain Plant Effectiveness

What is Overall Equipment Effectiveness (OEE)?

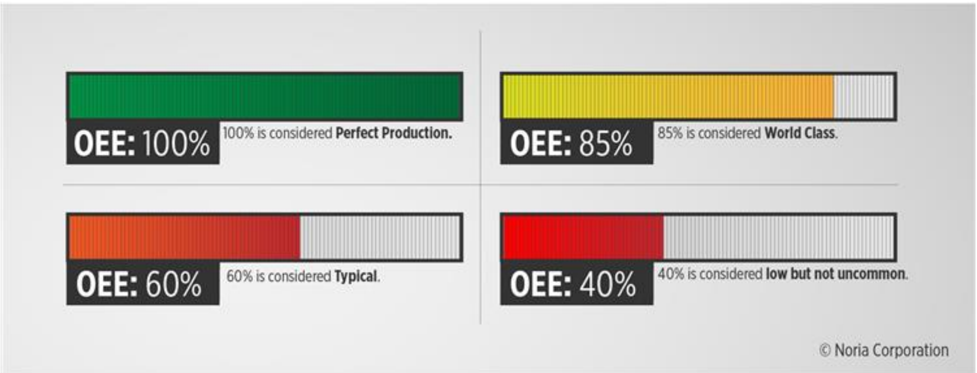


Overall equipment effectiveness (OEE) is a term used to evaluate how efficiently a manufacturer's operation is being used. In other words, overall equipment effectiveness helps you notice a problem in your operations, identify which percentage of manufacturing time is actually productive and fix it while giving you a standardized gauge for tracking progress. The goal for measuring your OEE is continuous improvement.

How to Use Overall Equipment Effectiveness (OEE) to Measure Manufacturing Productivity

Overall equipment effectiveness is a powerful figure. It provides a lot of information in one number, so there are multiple ways OEE is used to measure manufacturing productivity. When calculated and interpreted correctly, it can significantly maximize your production. Overall equipment effectiveness is used as a benchmark to compare any given production to industry standards, in-house equipment or other shifts working on the same piece of equipment. Standard OEE benchmarks are as follows:

- ✓ An OEE score of 100 percent is considered perfect production, meaning you're only manufacturing quality parts as quickly as possible with no downtime.
- ✓ An OEE score of 85 percent is considered world class for discrete manufacturers and is a sought-after long-term goal.
- ✓ An OEE score of 60 percent is typical for discrete manufacturers and shows there is considerable room for improvement.
- ✓ An OEE score of 40 percent is considered low but not uncommon for manufacturers just starting to track and improve performance. In most cases, a low score can easily be improved through easy-to-apply measures.



Overall Equipment Effectiveness is not only a great tool for managers but can have a significant impact on employees working the plant floor. Plant floor metrics can include:

- ✓ **Target** - A real-time production target
- ✓ **Actual** - The actual production count
- ✓ **Efficiency** - The ratio of target to actual; the percentage of how far ahead or behind production is
- ✓ **Downtime** - This includes all unplanned stoppage time for each shift and is updated in real-time.

Overall Equipment Effectiveness: Terms to Know

Before we discuss overall equipment effectiveness further, there are some important terms to be aware of.

- ✓ **Fully Productive Time** - Production time after all losses are subtracted
- ✓ **Planned Production Time** - The total time your equipment or system is expected to produce
- ✓ **Ideal Cycle Time** - The time it takes to manufacture one part
- ✓ **Run Time** - The time your system is scheduled for production and is running
- ✓ **Total Count** - The total of all parts produced including those with defects
- ✓ **Good Count** - Parts produced that meet quality-control standards
- ✓ **Good Parts** - Parts produced that meet standards and don't need to be redone

- ✓ **Quality** - This refers to manufactured parts that don't meet quality-control standards, including ones that need to be reworked. It is calculated as *Quality = Good Count / Total Count.*
- ✓ **Performance** - This takes into account the number of times there are slowdowns or brief stops in production. A perfect performance score in OEE terms means your operation is running as quickly as possible. It is calculated as *Performance = (Ideal Cycle Time x Total Count) / Run Time.*
- ✓ **Availability** - This takes into account planned and unplanned stoppage time. A perfect availability score means your operation is constantly running during planned production times. It is calculated as *Availability = Run Time / Planned Production Time.*

How to Calculate Overall Equipment Effectiveness (OEE)

Before calculating overall equipment effectiveness, it's important to denote the difference between the terms *effectiveness* and *efficiency* when discussing OEE.

Effectiveness is the relationship between what could technically be produced and what is actually produced at the end of a production period. For example, if your machinery is capable of making 100 products an hour and it only makes 80, then it is 80 percent effective.

However, this doesn't tell us how *efficient* the machinery is because we didn't consider things like the number of operators, energy and the materials needed to reach 80 percent effectiveness. For example, if your machinery runs 60 percent effective with one employee and becomes 75 percent effective with two employees, the effectiveness increases by 25 percent, but efficiency decreases to 50 percent based on labor.

There are two main ways to calculate OEE:

- ✓ **Simple Calculation:** The easiest way to calculate OEE is the ratio of fully productive time to planned production time. It looks like this: *OEE = (Good Count x Ideal Cycle Time) / Planned Production Time.*
- ✓ **Preferred Calculation:** This type of OEE calculation is based on the three OEE factors discussed earlier – availability, performance and quality (good count). It looks like this: *Availability x Performance x Quality = OEE*. This is the preferred calculation method because not only do you get your OEE score showing how well

you're doing, but you get three numbers (availability, performance and quality) showing what caused your losses.

What Are the Six Big Losses When It Comes to Overall Equipment Effectiveness (OEE)?

Perhaps the biggest goal of implementing an OEE program is to reduce or eliminate the most common causes of machine- or equipment-based productivity loss, known as the six big losses. These six losses are broken down into the three main OEE categories (availability, performance and quality).

Availability Loss	**Equipment Failure**
	Setup and Adjustments
Performance Loss	Idling and Minor Stops
	Reduce Speeds
Quality Loss	Process Defects
	Reduced Yield

Available Losses

- ✓ **Equipment Failure:** This is equipment that is not running when it is scheduled for production, causing unplanned downtime. Machine breakdowns, unplanned maintenance stops and tooling failure are common examples.
- ✓ **Setup and Adjustments:** This is production downtime due to changeovers, machine and tooling adjustments, planned maintenance, inspections and setup/warmup time.

Performance Losses

- ✓ **Idling and Minor Stops:** Sometimes called small stops, idling and minor stops are when equipment stops for a short period of time. This can be caused by jams, flow obstructions, wrong settings or cleaning. These issues are usually resolved by the operator.
- ✓ **Reduced Speed:** Sometimes referred to as slow cycles, reduced speed is when equipment runs at speeds slower than the ideal cycle time (the fastest possible time). Worn out or poorly maintained equipment due to poor lubrication practices, substandard materials and bad environmental conditions are common causes of reduced speed.

Quality Losses

- ✓ **Process Defects:** This refers to any defective part manufactured during stable production, including scrapped parts and parts that can be reworked. Incorrect machine settings and operator or equipment errors are common reasons for process defects.

- ✓ **Reduced Yield:** Reduced yield refers to defective parts made from startup until stable production is achieved. Like process defects, this can mean scrapped parts and parts that can be reworked. Reduced yield most commonly occurs after changeovers, incorrect settings and during machine warmups.

Five Benefits of Using Overall Equipment Effectiveness (OEE) to Improve Production

Implementing an overall equipment effectiveness strategy is a powerful advantage in achieving your production targets. It allows you to take a proactive approach by tweaking manufacturing processes in real time, reducing downtime, increasing capacity, reducing costs, improving quality and increasing efficiency. Let's take a look at 10 benefits of OEE.

- ✓ **Return of Investment (ROI) for Equipment:** Companies invest heavily in machinery, so it's important to maximize the return on this investment. If you can use an OEE strategy to produce 15 percent more product on the same equipment in the same amount of time, it can greatly impact your bottom line.
- ✓ **Increase Competitiveness:** Manufacturers always strive to reduce losses during production to achieve maximum competitiveness. Using data from an OEE report helps you identify bottlenecks or weaknesses in production, allowing you to take immediate action.
  Quality and competitiveness go hand-in-hand, and OEE's quality metric can help you identify problems in production causing scrap or rework parts.
- ✓ **Cutting Machinery Costs:** An OEE strategy helps you understand your equipment's actual performance so you know whether it is working efficiently. It also alerts you to issues that may lead to future breakdowns and repairs. Overall equipment effectiveness lets you anticipate potential machine failure, reducing maintenance costs and downtime.
- ✓ **Maximize Workforce Productivity:** Use OEE to see why you experience operator downtime, reveal productivity data and pinpoint long changeovers or setup times. Information like this helps you appropriately allot resources, identify where excess capacity is occurring and determine where you need new hires.
- ✓ **Easily Visualize Performance:** Overall equipment effectiveness emphasizes visibility, letting you visualize production problems instead of having to rely on your best guess. By highlighting the biggest sources of productivity losses into one single percentage, everyone can see what's working and where improvement is needed.

Overall Equipment Effectiveness (OEE): A Case Study

Based out of Fort Collins, Colorado, New Belgium Brewing company started as a small-batch hobby brewery and quickly became the nation's third biggest craft brewery (eighth overall) by 2012. Making popular beers such as Fat Tire amber ale, New Belgium quickly found itself struggling to keep up with demand, especially when it came to bottling. With their brewing operations quickly reaching capacity, New Belgium was struggling to identify efficiencies and inefficiencies in their bottling lines. Their goals quickly shifted toward improving OEE. The goals were as follows:

- ✓ Increase the brewery's ability take advantage of more manufacturing capabilities.
- ✓ Improve Overall Equipment Effectiveness (OEE) so quality products are being produced, production efficiency is managed and make sure the production line is available during scheduled downtimes, package changes and maintenance procedures.
- ✓ Operate the brewery at full capacity and double case production.

New Belgium faced a few challenges when it came to meeting their OEE goals. It didn't have any way to view real-time information during unscheduled downtimes on various equipment, causing slowdowns; The production team were constantly reacting to unscheduled downtime on certain assets; and the bottling operation didn't have the ability to predict capabilities, which would allow them to effectively place brewery staff in certain areas to help meet specific production goals.

Over a five-year span, the brewery implemented a series of manufacturing automation initiatives, including an upgrade to their manufacturing automation software system to help streamline its bottling production and figure out its maximum potential. After an audit, the brewery quickly realized its existing lines are capable of producing 294,000 cases a week, but were only producing 150,000 cases a week due to scheduled and unscheduled downtime.

This issue, coupled with its still archaic manual data recording process, which involved managing paper production logs and spreadsheets, wasn't cutting it when it came to keeping up with the level of production the brewery was facing. They realized using a software-based system for production greatly helped in managing the various beer mixes and packaging options, as well as accurately managing scheduled and unscheduled downtime.

Upgrading their automation system also allowed for the massive amounts of data that was being collected to be put into context, making it easier to analyze and be turned int actionable information. This greater visibility of the overall production picture led to a real understanding of the actual production capacity, which helped predictable order fulfillment.

Finally, New Belgium needed a way to react more quickly to unscheduled downtime. Thanks to the data from the upgraded software, the brewery realized it need to increase its maintenance team by 60 percent. They added a process improvement and analysis team, educated key staff in Kaizen processes and trained other team members in Six Sigma to react to issues more quickly.

New Belgium needed an effective way to gather, processes and analyze data to better benefit its overall business production. It had a significant impact on the brewery's OEE:

- ✓ OEE increased from 45 to 65 percent in a little over two years.
- ✓ Downtime was decreased by over 50 percent.
- ✓ Scheduled run time efficiency increased by 25 to 30 percent.
- ✓ Production weeks broke records by producing 190,000 to 200,000 cases consistently.
- ✓ Packaging area capacity was extended to around 1.3 million barrels a year.
- ✓ The brewery maintained lower operating costs by delaying capital investments.

CONDUCT ROUTINE CHECKS OF PERFORMANCE EFFICIENCY

10 Ways to Improve the Performance Management Process Ways to Improve the Performance Management Process

When someone mentions performance management or reviews at your organization, what is the typical response: Do employees and managers cringe? Do they avoid completing performance-related tasks? Do visions of tracking down incomplete appraisal forms come to mind?

Forward-thinking companies are taking steps to address this negative view of performance management. They are implementing innovative solutions that ensure the process delivers real results and actually improves employee performance and the business' bottom line.

In this guide, you'll find 10 practical steps that can be used to improve the performance management processes at your organization.

1. **Set goals effectively**

Goals are the basis of an effective performance management process. There are two key elements to consider when developing goals. First, are goals written clearly and objectively? Second, are they directly contributing to the achievement of business strategy?

Typically, the process begins with departmental managers setting goals for their departments, based upon organization-wide goals, which support the general business strategy. Making departmental goals accessible to all managers ensures there is no overlap, reduces conflict, and allows members of different departments to see where they support each other and ensure they are not working at cross purposes. Each manager in turn shares the overall goals with his/her department and meets with employees to identify individual performance goals and plans.

When setting goals, key job expectations and responsibilities should act as the main guide and reference. Goals should be set that not only address what is expected, but also how it will be achieved. For example, the "what" covers quality or quantity expected, deadlines to be met, cost to deliver, etc. The "how" refers to the behavior demonstrated to achieve outcomes, for example, focus on customer service. In addition, some organizations choose to include competencies within performance expectations, to reinforce the link to business strategy, vision and mission.

An accepted framework to use to help write effective goals is SMART:

S – Specific
M – Measurable
A – Achievable/Attainable
R – Results-Oriented/Realistic/Relevant
T – Time-Bound

The inclusion of the above criteria results in a goal that is understandable and easily visualized and evaluated. Making a goal specific, measurable, and time bound contributes to the ability to make progress on the goal and track that progress. Some managers choose to further define goals with a start and finish date with milestones in between. As we have mentioned, goals must be achievable and realistic. An unachievable goal is just that. An employee knows when he/she does not stand a chance of reaching it, and their effort to achieve the goal will be affected. In addition, goals must reflect conditions that are under the employee's control and the R's (results oriented, realistic and relevant) should definitely consider these conditions. Sometimes the focus on the outcome of the goals can overshadow the necessary steps to achieve them. Action plans to support each goal can include documentation of the steps necessary to achieve a goal. By keeping goals relevant, a manager reinforces the importance of linking to strategic objectives and communicating why the goal is important. Some organizations have suggested the use of SMARTA, or SMARTR with the additional A standing for aligned and the R standing for reward.

A focus on objective, behavioral-based, and observable outcomes that are job-related helps ensure fairness of the process and reduces discrepancy. Although sometimes difficult to hear, objective feedback supported with regular documentation is difficult to dispute. This is also where an understanding of the organization's overall objectives and goals and how individual efforts contribute becomes essential. If for example, an individual understands that their actions support an area of the business then it is easier to understand the impact when deadlines are not met. Using the SMART framework provides clarity up front to employees who will be evaluated against these goals.

2. **Begin with performance planning**

Using established goals as a basis, performance planning sets the stage for the year by communicating objectives, and setting an actionable plan to guide the employee to successfully achieve goals.

Performance planning, as with all other steps, is a collaborative process between the manager and employee, although there will always be some elements that are non-negotiable. Begin with the job description and identify major job expectations; expectations then can be clarified for each major area.

Under each key contribution area, it is important to identify long-term and short-term goals, along with an action plan around how they will be achieved. Goals can be weighted to identify priorities. Discuss specific details related to how progress against goals will be evaluated. Next steps include determining any obstacles that would stand in the way of these goals being achieved. If an obstacle is knowledge, skills or behavior – a plan should be developed to overcome, i.e. training, mentoring, etc.

Using the performance plan as a reference document, the employee and manager then should regularly monitor progress against goals, problem-solve road blocks, re-assess goals, change goals as business direction changes, and re-evaluate training and resource needs. This is where the conversation is critical and often where the follow-through sometimes falls down. Performance planning and ongoing performance feedback are critical because they facilitate continuous improvement and aid open communication.

3. **Create an ongoing process**

Performance management – including goal setting, performance planning, performance monitoring, feedback and coaching – should be an ongoing and continuous process, not a once or twice-yearly event. Feedback that is delivered when it is most relevant enhances learning and provides the opportunity to make any adjustments needed to meet objectives. The attitude towards ongoing feedback is also crucial. If there is organizational support for building constructive feedback into the fabric of day-to-day interactions, then the environment will encourage development and drive goal-directed performance improvement.

4. **Improve productivity through better goal management**

Regular goal tracking allows for the opportunity to provide feedback as needed, make adjustments to performance plans, tackle obstacles and prepare contingencies for missed deadlines. Without a mechanism to regularly track progress against goals, the ongoing, cyclical nature of the process falls apart and productivity dips.

Goal progress discussions, along with all performance feedback, should be delivered with respect and should be objective and supportive. Specific examples provide clarity and help the employee focus on future improvements. It is crucial that the manager listens to the employee's perspective and incorporates the employee's observations into future plans – the employee often experiences roadblocks the manager may not see.

5. **Gather information from multiple sources**

Gathering performance information from a variety of sources increases objectivity and ensures all factors impacting performance are considered. This information should include objective data like sales reports, call records or deadline reports. Other valuable information includes: feedback from others, results of personal observation, documentation of ongoing dialogue, records of any external or environmental factors impacting performance. Many reviews also include an employee self-evaluation. Other documents that help define performance objectives include: past performance appraisals, current departmental and organizational objectives and documented standards related to career goals.

In order to gather feedback from other employees, organizations will often use a 360° feedback process. Along with the completion of a self-assessment, selected peers, subordinates, and manager(s) are asked to contribute feedback around pre-identified areas. The feedback is based upon specifically identified skills or competencies and the final results are compared against the employee's self-assessment. This type of feedback increases self-awareness and in some cases is used to support the performance evaluation process.

Objectivity is essential when evaluating performance and it begins with clarity about job expectations and evaluation methods. Certain checks and balances can be built in to ensure objectivity. Managers commonly make mistakes when they conduct evaluations and the first step to minimizing those errors is to acknowledge they exist. Consistent processes organization-wide contribute to fairness and objectivity. Access to information allows others to check the validity of the process. Obviously, not all employees need access to other employees' performance appraisal results, but processes like calibration meetings will help ensure consistency. In the calibration process, managers with employees in similar positions meet and discuss the appraisals before they are finalized and shared with the employees. A calibration meeting helps establish the reasons individuals are awarded various performance rankings, educates managers about the process across the organization and promotes consistency. It also provides validation for manager's decisions, if appropriate.

Reporting is very valuable to assess the fairness and consistency of the process. For example, it can be used to compare ratings from one division to the next or from one manager to the next. People analytics and technologies like machine learning are also helpful in removing bias from performance appraisals and evaluation.

6. **Document, document, document**

Note-taking must be consistent and include all significant occurrences, positive or negative. Documentation is important to support performance decisions, and notes should be written with the intent to share. In addition to documenting the details of an occurrence, any subsequent follow up should be detailed.

The performance log is a record that the manager keeps for each employee and is a record of performance "events." The maintenance of a performance log serves a number of purposes. The manager can record successes or performance that requires improvement. When it comes time to complete the appraisal, the manager has a historical record of events and will not have to rely on recent memory. In addition, this documentation can be used to support performance decisions or ratings. But it also can be used as a reminder for the manager – if the log has no recordings for a period of time, perhaps it is time to check in. If an employee does exceptionally well, or meets deadlines consistently, the log can be used as a reminder to provide recognition for a job well done. In addition, if a manager notices an area of deficiency, the log can serve as a reminder and a record of circumstances. The performance log can also act as a reminder for coaching, i.e. record of upcoming tasks, manager can make note to discuss with the employee to ensure he/she is prepared for the individual for a task ahead, and then follow up discussion can promote learning and continuous improvement.

This log should be objective and based on observable, job-related behaviors – including successes, achievements and, if applicable, any documentation related to disciplinary actions taken.

7. **Prepare and train your managers**

Managing the performance of another individual is not an easy task and requires many skills. Training may be required to ensure managers feel adequately prepared to effectively complete all the tasks related to performance management. This is especially the case for newly promoted supervisors. Managers need to understand human behavior, how to motivate, how to develop, provide coaching and deal with conflict. To a great extent, managers must be observers and able to assess a situation, provide motivation and identify problems that interfere with performance. In addition, managers must understand that individuals at different levels of comfort, ability and experience with their jobs will require different levels of input, support and supervision. A manager who feels adequately prepared to provide and receive feedback, deliver a performance evaluation and conduct a performance evaluation meeting will be a major contributor to a successfully functioning process.

8. **Perfect the performance review**

The employee performance appraisal or review should be a summary of all that has been discussed. Based upon job expectations and key areas of contribution, and previously discussed goals and evaluation methods, the appraisal should be a written confirmation of what has already been discussed with the employee.

The form should include key job responsibilities, current project work, relevant competencies, goals and achievements. Previously completed performance appraisals should be used as reference documents. It should also contain an area to allow employees to record their comments and input. All comments included on the appraisal form need to be job-related and based upon observable behaviors.

For the appraisal meeting, it is imperative to prepare ahead of time. Schedule an appropriate place and time with no interruptions. Ensure the employee has the information necessary to allow them to prepare adequately. Begin the discussion with job requirements and strengths/ accomplishments. The focus, as pointed out previously, should be forward looking. The way the manager approaches this meeting conveys a message related to its importance and should be approached with the appropriate level of seriousness and an open mind. The manager must be prepared in regard to what he/she wants to discuss, but just as importantly must be prepared to listen.

Many suggest that it is important to first define the purpose of the meeting and provide an agenda. A factual discussion with a focus on job-related behaviors will keep the discussion objective. At the end of the meeting, key points should be summarized. It is important to note that the employee will be asked to sign the appraisal, whether or not there is agreement.

9. **Link performance with rewards and recognition**

More and more, organizations are linking performance to compensation. This link, however, cannot effectively be established without the existence of sound performance management processes that are seen as fair and equitable.

Clear documentation of progress against performance expectations also allows proper recognition for a job well done. This can be provided a number of ways, i.e. formal recognition events, informal public recognition or privately delivered feedback.

It is important also to note the benefits of a consistent pay-for-performance process across the organization. A consistent process creates a sense of fairness and significantly increases job satisfaction. Employees need to know that if an individual in one department is identified as a top performer and compensated accordingly, then an employee performing at the same level in another department will receive similar rewards.

10. **Encourage full participation and success**

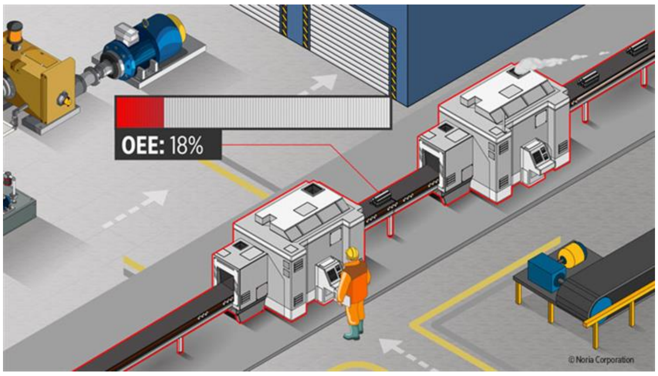
The performance management process must add value, otherwise problems with resistance and non-participation will surface. In addition, the process itself must be as efficient and simple as possible. Automated reminders and scheduling tools can help keep the process on track.

Another element that contributes to success is upper-level management support. This support needs to take not only the form of verbal support, but also through participation in the same performance management process for evaluations. In addition, consider the current culture of your organization when it comes to performance appraisals and performance management. Is the atmosphere supportive of an effective process? Is there a culture of open, honest communication – or are employees fearful when they make a mistake? Employees must be able to honestly discuss performance and consider how to make improvements in order to move forward.

Another thing to consider is a mechanism to evaluate the process itself, whether it consists of an annual survey, focus groups, manager feedback, reporting, or a combination of these and other methods.

Maintain plant effectiveness

What is Overall Equipment Effectiveness (OEE)?

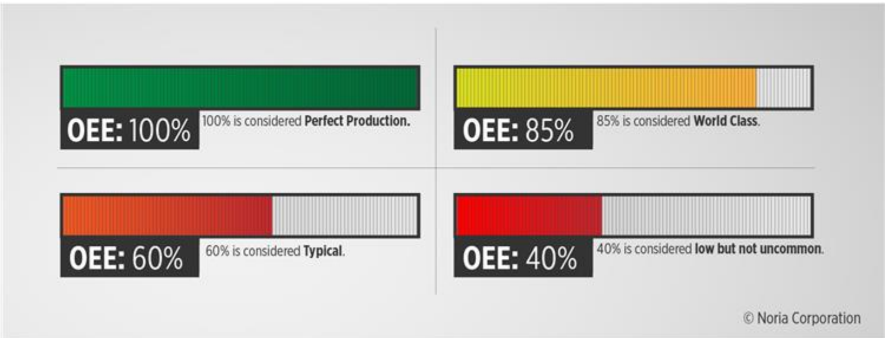


Overall equipment effectiveness (OEE) is a term used to evaluate how efficiently a manufacturer's operation is being used. In other words, overall equipment effectiveness helps you notice a problem in your operations, identify which percentage of manufacturing time is actually productive and fix it while giving you a standardized gauge for tracking progress. The goal for measuring your OEE is continuous improvement.

How to Use Overall Equipment Effectiveness (OEE) to Measure **Manufacturing Productivity**

Overall equipment effectiveness is a powerful figure. It provides a lot of information in one number, so there are multiple ways OEE is used to measure manufacturing productivity. When calculated and interpreted correctly, it can significantly maximize your production. Overall equipment effectiveness is used as a benchmark to compare any given production to industry standards, in-house equipment or other shifts working on the same piece of equipment. Standard OEE benchmarks are as follows:

- ✓ An OEE score of 100 percent is considered perfect production, meaning you're only manufacturing quality parts as quickly as possible with no downtime.
- ✓ An OEE score of 85 percent is considered world class for discrete manufacturers and is a sought-after long-term goal.
- ✓ An OEE score of 60 percent is typical for discrete manufacturers and shows there is considerable room for improvement.
- ✓ An OEE score of 40 percent is considered low but not uncommon for manufacturers just starting to track and improve performance. In most cases, a low score can easily be improved through easy-to-apply measures.



Overall Equipment Effectiveness is not only a great tool for managers but can have a significant impact on employees working the plant floor. Plant floor metrics can include:

- ✓ **Target** - A real-time production target
- ✓ **Actual** - The actual production count
- ✓ **Efficiency** - The ratio of target to actual; the percentage of how far ahead or behind production is
- ✓ **Downtime** - This includes all unplanned stoppage time for each shift and is updated in real-time.

Overall Equipment Effectiveness: Terms to Know

Before we discuss overall equipment effectiveness further, there are some important terms to be aware of.

- ✓ **Fully Productive Time** - Production time after all losses are subtracted
- ✓ **Planned Production Time** - The total time your equipment or system is expected to produce
- ✓ **Ideal Cycle Time** - The time it takes to manufacture one part
- ✓ **Run Time** - The time your system is scheduled for production and is running
- ✓ **Total Count** - The total of all parts produced including those with defects
- ✓ **Good Count** - Parts produced that meet quality-control standards
- ✓ **Good Parts** - Parts produced that meet standards and don't need to be redone
- ✓ **Quality** - This refers to manufactured parts that don't meet quality-control standards, including ones that need to be reworked. It is calculated as *Quality = Good Count / Total Count.*
- ✓ **Performance** - This takes into account the number of times there are slowdowns or brief stops in production. A perfect performance score in OEE terms means your operation is running as quickly as possible. It is calculated as *Performance = (Ideal Cycle Time x Total Count) / Run Time.*
- ✓ **Availability** - This takes into account planned and unplanned stoppage time. A perfect availability score means your operation is constantly running during planned production times. It is calculated as *Availability = Run Time / Planned Production Time.*

How to Calculate Overall Equipment Effectiveness (OEE)

Before calculating overall equipment effectiveness, it's important to denote the difference between the terms *effectiveness* and *efficiency* when discussing OEE.

Effectiveness is the relationship between what could technically be produced and what is actually produced at the end of a production period. For example, if your machinery is capable of making 100 products an hour and it only makes 80, then it is 80 percent effective.

However, this doesn't tell us how *efficient* the machinery is because we didn't consider things like the number of operators, energy and the materials needed to reach 80 percent effectiveness. For example, if your machinery runs 60 percent effective with one employee and becomes 75 percent effective with two employees, the effectiveness increases by 25 percent, but efficiency decreases to 50 percent based on labor.

There are two main ways to calculate OEE:

- ✓ **Simple Calculation:** The easiest way to calculate OEE is the ratio of fully productive time to planned production time. It looks like this: *OEE = (Good Count x Ideal Cycle Time) / Planned Production Time.*
- ✓ **Preferred Calculation:** This type of OEE calculation is based on the three OEE factors discussed earlier – availability, performance and quality (good count). It looks like this: *Availability x Performance x Quality = OEE*. This is the preferred calculation method because not only do you get your OEE score showing how well you're doing, but you get three numbers (availability, performance and quality) showing what caused your losses.

What Are the Six Big Losses When It Comes to Overall Equipment Effectiveness (OEE)?

Perhaps the biggest goal of implementing an OEE program is to reduce or eliminate the most common causes of machine- or equipment-based productivity loss, known as the six big losses. These six losses are broken down into the three main OEE categories (availability, performance and quality).

Availability Loss	**Equipment Failure**
	Setup and Adjustments
Performance Loss	Idling and Minor Stops
	Reduce Speeds
Quality Loss	Process Defects
	Reduced Yield

Available Losses

- ✓ **Equipment Failure:** This is equipment that is not running when it is scheduled for production, causing unplanned downtime. Machine breakdowns, unplanned maintenance stops and tooling failure are common examples.
- ✓ **Setup and Adjustments:** This is production downtime due to changeovers, machine and tooling adjustments, planned maintenance, inspections and setup/warmup time.

Performance Losses

- ✓ **Idling and Minor Stops:** Sometimes called small stops, idling and minor stops are when equipment stops for a short period of time. This can be caused by jams, flow obstructions, wrong settings or cleaning. These issues are usually resolved by the operator.

- ✓ **Reduced Speed:** Sometimes referred to as slow cycles, reduced speed is when equipment runs at speeds slower than the ideal cycle time (the fastest possible time). Worn out or poorly maintained equipment due to poor lubrication practices, substandard materials and bad environmental conditions are common causes of reduced speed.

Quality Losses

- ✓ **Process Defects:** This refers to any defective part manufactured during stable production, including scrapped parts and parts that can be reworked. Incorrect machine settings and operator or equipment errors are common reasons for process defects.
- ✓ **Reduced Yield:** Reduced yield refers to defective parts made from startup until stable production is achieved. Like process defects, this can mean scrapped parts and parts that can be reworked. Reduced yield most commonly occurs after changeovers, incorrect settings and during machine warmups.

Five Benefits of Using Overall Equipment Effectiveness (OEE) to Improve Production

Implementing an overall equipment effectiveness strategy is a powerful advantage in achieving your production targets. It allows you to take a proactive approach by tweaking manufacturing processes in real time, reducing downtime, increasing capacity, reducing costs, improving quality and increasing efficiency. Let's take a look at 10 benefits of OEE.

- ✓ **Return of Investment (ROI) for Equipment:** Companies invest heavily in machinery, so it's important to maximize the return on this investment. If you can use an OEE strategy to produce 15 percent more product on the same equipment in the same amount of time, it can greatly impact your bottom line.
- ✓ **Increase Competitiveness:** Manufacturers always strive to reduce losses during production to achieve maximum competitiveness. Using data from an OEE report helps you identify bottlenecks or weaknesses in production, allowing you to take immediate action.
  Quality and competitiveness go hand-in-hand, and OEE's quality metric can help you identify problems in production causing scrap or rework parts.
- ✓ **Cutting Machinery Costs:** An OEE strategy helps you understand your equipment's actual performance so you know whether it is working efficiently. It also alerts you to issues that may lead to future breakdowns and repairs. Overall equipment effectiveness lets you anticipate potential machine failure, reducing maintenance costs and downtime.
- ✓ **Maximize Workforce Productivity:** Use OEE to see why you experience operator downtime, reveal productivity data and pinpoint long changeovers or setup times. Information like this helps you appropriately allot resources, identify where excess capacity is occurring and determine where you need new hires.
- ✓ **Easily Visualize Performance:** Overall equipment effectiveness emphasizes visibility, letting you visualize production problems instead of having to rely on your

best guess. By highlighting the biggest sources of productivity losses into one single percentage, everyone can see what's working and where improvement is needed.

Overall Equipment Effectiveness (OEE): A Case Study

Based out of Fort Collins, Colorado, New Belgium Brewing company started as a small-batch hobby brewery and quickly became the nation's third biggest craft brewery (eighth overall) by 2012. Making popular beers such as Fat Tire amber ale, New Belgium quickly found itself struggling to keep up with demand, especially when it came to bottling. With their brewing operations quickly reaching capacity, New Belgium was struggling to identify efficiencies and inefficiencies in their bottling lines. Their goals quickly shifted toward improving OEE. The goals were as follows:

- ✓ Increase the brewery's ability take advantage of more manufacturing capabilities.
- ✓ Improve Overall Equipment Effectiveness (OEE) so quality products are being produced, production efficiency is managed and make sure the production line is available during scheduled downtimes, package changes and maintenance procedures.
- ✓ Operate the brewery at full capacity and double case production.

New Belgium faced a few challenges when it came to meeting their OEE goals. It didn't have any way to view real-time information during unscheduled downtimes on various equipment, causing slowdowns; The production team were constantly reacting to unscheduled downtime on certain assets; and the bottling operation didn't have the ability to predict capabilities, which would allow them to effectively place brewery staff in certain areas to help meet specific production goals.

Over a five-year span, the brewery implemented a series of manufacturing automation initiatives, including an upgrade to their manufacturing automation software system to help streamline its bottling production and figure out its maximum potential. After an audit, the brewery quickly realized its existing lines are capable of producing 294,000 cases a week, but were only producing 150,000 cases a week due to scheduled and unscheduled downtime.

This issue, coupled with its still archaic manual data recording process, which involved managing paper production logs and spreadsheets, wasn't cutting it when it came to keeping up with the level of production the brewery was facing. They realized using a software-based system for production greatly helped in managing the various beer mixes and packaging options, as well as accurately managing scheduled and unscheduled downtime.

Upgrading their automation system also allowed for the massive amounts of data that was being collected to be put into context, making it easier to analyze and be turned int actionable information. This greater visibility of the overall production picture led to a real understanding of the actual production capacity, which helped predictable order fulfillment.

Finally, New Belgium needed a way to react more quickly to unscheduled downtime. Thanks to the data from the upgraded software, the brewery realized it need to increase its maintenance team by 60 percent. They added a process improvement and analysis team, educated key staff in Kaizen processes and trained other team members in Six Sigma to react to issues more quickly.

New Belgium needed an effective way to gather, processes and analyze data to better benefit its overall business production. It had a significant impact on the brewery's OEE:

- ✓ OEE increased from 45 to 65 percent in a little over two years.
- ✓ Downtime was decreased by over 50 percent.
- ✓ Scheduled run time efficiency increased by 25 to 30 percent.
- ✓ Production weeks broke records by producing 190,000 to 200,000 cases consistently.
- ✓ Packaging area capacity was extended to around 1.3 million barrels a year.
- ✓ The brewery maintained lower operating costs by delaying capital investments.

PERFORM PREVENTIVE MAINTENANCE PROCEDURES

Equipment has become more complex with the application of advanced technologies and automation systems in recent years. Thus, high technical knowledge is required and technicians, technical tools and special instruments are necessary for implementing preventive maintenance of the equipment. Unlike O&M contractors, manufacturers can provide such skilled staff and special tools. The manufactures can provide safe and secure maintenance based on their long experience and abundant information on their products. Preventive maintenance after expiry of warranty period should be availed from the manufacturers continuously.

A good maintenance programme is essential for a pumping station to operate continuously at peak design efficiency. A successful maintenance programme will cover everything from mechanical equipment, such as pumps, valves, scrapers and other moving equipment, to the care of the plant grounds, buildings and structures. For preventive maintenance, it is advisable to follow a schedule for the maintenance of the equipment.

The schedule covers recommendations for checks and remedial actions to be observed at different intervals such as daily, monthly, quarterly, bi-annually and annually. Operators should receive training to obtain more knowledge of characteristics and structure of machinery and to improve their maintenance skill.

- ✓ Mechanical Maintenance: Mechanical maintenance is of prime importance, as the equipment must be kept in good operating condition for the plant to maintain peak performance. Manufacturers provide information on the mechanical maintenance of their equipment. Operators should thoroughly read manuals on the plant equipment, understand the procedures, and contact the manufacturer or the local representative if there are any questions. The instructions should be followed very carefully when performing maintenance on equipment. Operators also must recognise tasks that maybe beyond their capabilities or repair facilities, and should request assistance when needed.
- ✓ Maintenance of Civil Structures: Building maintenance is another programme that should be maintained on a regular schedule. Buildings in a treatment plant are usually built of sturdy materials to last for many years.

  Buildings must be kept in good condition by repairs. For selecting paint for a treatment plant, it is always a good idea to have a painting expert help the operator select the types of paint needed to protect the buildings from deterioration. The expert also will have some good ideas as to colour schemes to help blend the plant in with the surrounding area. Consideration should also be given to the quality of paint. A good quality, more expensive material will usually give better service over a longer period of time than the economy-type products. Building maintenance programmes depend on the age, type and use of a building. New buildings require a thorough check to ensure that essential items are available and are working properly. Older buildings require careful observation and prompt attention to detect leaks, breakdowns and replacements beforehand. Attention must be given to the maintenance requirements of many items in all plant buildings, such as electrical systems, plumbing, heating, cooling, ventilating, floors, windows, roofs, and drainage around the buildings. Regularly scheduled examinations and necessary maintenance of these items can prevent many costly and time-consuming problems in the future.

In each plant building, periodically check all stairways, ladders, catwalks and platforms for adequate lighting, head clearance, and sturdy and convenient guardrails. Protective devices should be around all moving equipment.

Whenever any repairs, alterations or additions are made, avoid building accident traps such as pipes laid on top of floors or hung from the ceiling at head height, which could create serious safety hazards.

Keep all buildings clean and orderly. Supervisory work should be done on a regular schedule.

All tools and plant equipment should be kept clean and in their proper place. Floors, walls and windows should be cleaned at regular intervals to maintain a neat appearance.

- ✓ Valve Maintenance: Valves should be lubricated regularly (according to the manufacturer's instructions), and valve stems should be rotated regularly to ensure ease of operation. These activities should be part of a regular pump-maintenance programme.
- ✓ Electric Actuator Maintenance
    - Declutch and operate the manual hand wheel.
    - Check oil level and top up, if required.
    - Re-grease the grease lubricated bearing and gear trains, as applicable.
    - Check the insulation resistance of the motor.
    - Check for undue noise and vibration and take necessary rectification measures.
    - Tighten limit switch cam ends. Check for setting and re-adjust, if necessary.
    - Examine all components and wiring thoroughly and rectify as necessary.
    - Change oil or grease in the gearbox and thrust bearing.
    - Check the condition of the gears and replace them if teeth are worn out.
- ✓ Flow Meter Maintenance: Each individual sensing meter will have its own maintenance requirements. The single most important item to be considered in sensor maintenance is good housekeeping. Always keep sensors and all instrumentation very clean. Good housekeeping and the act of providing preventive maintenance for each of the various sensors, includes ensuring that foreign bodies do not interfere with the measuring device. Check for and remove deposits that will build up from normal use. Repair the sensor or measuring device whenever it is damaged.

- ✓ External connections between the sensing and conversion and readout devices should be checked to ensure such connections are clean and connections are firm. Be sure no foreign obstruction will interfere or promote wear. On mechanical connections, grease as directed; on hydraulic or pneumatic connections, disconnect and ensure free flow in the internal passage.
- ✓ Maintenance of Pumps: The maintenance schedule should list out items to be attended to at different periods, such as daily, semi-annually, annually and as needed.
    - Daily Observations
        - Leakage through packing
        - Bearing temperature
        - Undue noise or vibration
        - Pressure, voltage and current readings
    - Semi-annual Inspection
        - Free movement of the gland of the stuffing box
        - Cleaning and oiling of the gland bolts
        - Inspection of packing and repacking, if necessary
        - Alignment of the pump and the drive
        - Cleaning of oil-lubricated bearings and replenishing fresh oil.
        - If bearings are grease-lubricated, the condition of the grease should be checked and replaced with correct quantity, if necessary.
        - An anti-friction bearing should have its housing packed with grease so that the void spaces in the bearings and the housing are 1/2 to 2/3 filled with grease. A fully packed housing will cause the bearing to overheat and will result in reduced life of the bearing.
    - Annual Inspection
        - Cleaning and examination of all bearings for flaws developed, if any
        - Examination of shaft-sleeves for wear or scour.
        - Checking clearances

      Clearances at the wearing rings should be within the limits recommended by the manufacturer. Excessive clearances indicate a drop in the efficiency of the pump. If the wear is only on one side, it means misalignment. Not only should the misalignment be corrected, but also the causes of the misalignment should be investigated and the clearances reset to the values recommended by the manufacturers. If the clearance on wear is seen to be 0.2 or 0.25mm more than the original clearance, the wearing ring should be renewed or replaced to obtain the original clearance.

      These are to be done by the equipment representative.

        - Impeller-hubs and vane-tips should be examined for any pitting or erosion.
        - End-play of the bearings should be checked.
        - All instruments and flow-meters should be re-calibrated.
        - Pump should be tested to ensure proper performance is being obtained.

        - In the case of vertical turbine pumps, the inspection can be bi-annual. Annual inspection is not advisable because it involves disturbing the alignment and clearances.
    - Annual Maintenance and Repairs
        - Consumables and lubricants

Adequate stock of items as packing glands, belts, lubricating oils, greases should be maintained.

- ✓ Replacement of spares: To avoid downtime, a stock of fast-moving spares should be maintained. A set of recommended spares for two years of trouble-free operation should be ordered along with the pump.
- ✓ Repair workshop: The repair workshop should be equipped with tools such as bearing-pullers, clamps, pipe-wrenches, and other general-purpose machinery such as welding set grinder, blower, drilling machine, etc.

UNIT 18

PERFORM CHEMICAL CLEANING

This unit of competency describes the skills and knowledge required to prepare process equipment for cleaning in place or in-line. It applies to food processing equipment that is fixed in place and cannot be moved to a cleaning station. It requires the operator to initiate, monitor and control variables during cleaning

PREPARE FOR CLEANING

Hazard Identification and Assessment

One of the "root causes" of workplace injuries, illnesses, and incidents is the failure to identify or recognize hazards that are present, or that could have been anticipated. A critical element of any effective safety and health program is a proactive, ongoing process to identify and assess such hazards.
To identify and assess hazards, employers and workers:

- ✓ Collect and review information about the hazards present or likely to be present in the workplace.
- ✓ Conduct initial and periodic workplace inspections of the workplace to identify new or recurring hazards.
- ✓ Investigate injuries, illnesses, incidents, and close calls/near misses to determine the underlying hazards, their causes, and safety and health program shortcomings.
- ✓ Group similar incidents and identify trends in injuries, illnesses, and hazards reported.
- ✓ Consider hazards associated with emergency or nonroutine situations.
- ✓ Determine the severity and likelihood of incidents that could result for each hazard identified, and use this information to prioritize corrective actions.

Some hazards, such as housekeeping and tripping hazards, can and should be fixed as they are found. Fixing hazards on the spot emphasizes the importance of safety and health and takes advantage of a safety leadership opportunity. To learn more about fixing other hazards identified using the processes described here, see "Hazard Prevention and Control."

Action item 1: Collect existing information about workplace hazards

Information on workplace hazards may already be available to employers and workers, from both internal and external sources.

How to accomplish it

Collect, organize, and review information with workers to determine what types of hazards may be present and which workers may be exposed or potentially exposed. Information available in the workplace may include:

- ✓ Equipment and machinery operating manuals.
- ✓ Safety Data Sheets (SDS) provided by chemical manufacturers.
- ✓ Self-inspection reports and inspection reports from insurance carriers, government agencies, and consultants.
- ✓ Records of previous injuries and illnesses, such as OSHA 300 and 301 logs and reports of incident investigations.
- ✓ Workers' compensation records and reports.
- ✓ Patterns of frequently-occurring injuries and illnesses.
- ✓ Exposure monitoring results, industrial hygiene assessments, and medical records (appropriately redacted to ensure patient/worker privacy).
- ✓ Existing safety and health programs (lockout/tagout, confined spaces, process safety management, personal protective equipment, etc.).

- ✓ Input from workers, including surveys or minutes from safety and health committee meetings.
- ✓ Results of job hazard analyses, also known as job safety analyses.

Information about hazards may be available from outside sources, such as:

- ✓ OSHA, National Institute for Occupational Safety and Health (NIOSH), and Centers for Disease Control and Prevention (CDC) websites, publications, and alerts.
- ✓ Trade associations.
- ✓ Labor unions, state and local occupational safety and health committees/coalitions ("COSH groups"), and worker advocacy groups.
- ✓ Safety and health consultants.

Action item 2: Inspect the workplace for safety hazards

Hazards can be introduced over time as workstations and processes change, equipment or tools become worn, maintenance is neglected, or housekeeping practices decline. Setting aside time to regularly inspect the workplace for hazards can help identify shortcomings so that they can be addressed before an incident occurs.

How to accomplish it

- ✓ Conduct regular inspections of all operations, equipment, work areas and facilities. Have workers participate on the inspection team and talk to them about hazards that they see or report.
- ✓ Be sure to document inspections so you can later verify that hazardous conditions are corrected. Take photos or video of problem areas to facilitate later discussion and brainstorming about how to control them, and for use as learning aids.
- ✓ Include all areas and activities in these inspections, such as storage and warehousing, facility and equipment maintenance, purchasing and office functions, and the activities of on-site contractors, subcontractors, and temporary employees.
- ✓ Regularly inspect both plant vehicles (e.g., forklifts, powered industrial trucks) and transportation vehicles (e.g., cars, trucks).
- ✓ Use checklists that highlight things to look for. Typical hazards fall into several major categories, such as those listed below; each workplace will have its own list:
    - General housekeeping
    - Slip, trip, and fall hazards
    - Electrical hazards
    - Equipment operation
    - Equipment maintenance
    - Fire protection
    - Work organization and process flow (including staffing and scheduling)
    - Work practices
    - Workplace violence
    - Ergonomic problems
    - Lack of emergency procedures

- ✓ Before changing operations, workstations, or workflow; making major organizational changes; or introducing new equipment, materials, or processes, seek the input of workers and evaluate the planned changes for potential hazards and related risks.

Note: Many hazards can be identified using common knowledge and available tools. For example, you can easily identify and correct hazards associated with broken stair rails and frayed electrical cords. Workers can be a very useful internal resource, especially if they are trained in how to identify and assess risks.

Action item 3: Identify health hazards

Identifying workers' exposure to health hazards is typically more complex than identifying physical safety hazards. For example, gases and vapors may be invisible, often have no odor, and may not have an immediately noticeable harmful health effect. Health hazards include chemical hazards (solvents, adhesives, paints, toxic dusts, etc.), physical hazards (noise, radiation, heat, etc.), biological hazards (infectious diseases), and ergonomic risk factors (heavy lifting, repetitive motions, vibration). Reviewing workers' medical records (appropriately redacted to ensure patient/worker privacy) can be useful in identifying health hazards associated with workplace exposures.

How to accomplish it

- ✓ Identify chemical hazards –review SDS and product labels to identify chemicals in your workplace that have low exposure limits, are highly volatile, or are used in large quantities or in unventilated spaces. Identify activities that may result in skin exposure to chemicals.
- ✓ Identify physical hazards –identify any exposures to excessive noise (areas where you must raise your voice to be heard by others), elevated heat (indoor and outdoor), or sources of radiation (radioactive materials, X-rays, or radiofrequency radiation).
- ✓ Identify biological hazards –determine whether workers may be exposed to sources of infectious diseases, molds, toxic or poisonous plants, or animal materials (fur or scat) capable of causing allergic reactions or occupational asthma.
- ✓ Identify ergonomic risk factors –examine work activities that require heavy lifting, work above shoulder height, repetitive motions, or tasks with significant vibration.
- ✓ Conduct quantitative exposure assessments –when possible, using air sampling or direct reading instruments.
- ✓ Review medical records –to identify cases of musculoskeletal injuries, skin irritation or dermatitis, hearing loss, or lung disease that may be related to workplace exposures.

Note: Identifying and assessing health hazards may require specialized knowledge. Small businesses can obtain free and confidential occupational safety and health advice services, including help identifying and assessing workplace hazards, through OSHA's On-site Consultation Program.

Action item 4: Conduct incident investigations

Workplace incidents –including injuries, illnesses, close calls/near misses, and reports of other concerns– provide a clear indication of where hazards exist. By thoroughly investigating incidents and reports, you will identify hazards that are likely to cause future

harm. The purpose of an investigation must always be to identify the root causes (and there is often more than one) of the incident or concern, in order to prevent future occurrences.

How to accomplish it

- ✓ Develop a clear plan and procedure for conducting incident investigations, so that an investigation can begin immediately when an incident occurs. The plan should cover items such as:
    - o Who will be involved
    - o Lines of communication
    - o Materials, equipment, and supplies needed
    - o Reporting forms and templates
- ✓ Train investigative teams on incident investigation techniques, emphasizing objectivity and open-mindedness throughout the investigation process.
- ✓ Conduct investigations with a trained team that includes representatives of both management and workers.
- ✓ Investigate close calls/near misses.
- ✓ Identify and analyze root causes to address underlying program shortcomings that allowed the incidents to happen.
- ✓ Communicate the results of the investigation to managers, supervisors, and workers to prevent recurrence.

Effective incident investigations do not stop at identifying a single factor that triggered an incident. They ask the questions "Why?" and "What led to the failure?" For example, if a piece of equipment fails, a good investigation asks: "Why did it fail?" "Was it maintained properly?" "Was it beyond its service life?" and "How could this failure have been prevented?" Similarly, a good incident investigation does not stop when it concludes that a worker made an error. It asks such questions as: "Was the worker provided with appropriate tools and time to do the work?" "Was the worker adequately trained?" and "Was the worker properly supervised?"

Note: OSHA has special reporting identifys for work-related incidents that lead to serious injury or a fatality (29 CFR 1904.39). OSHA must be notified within 8 hours of a work-related fatality, and within 24 hours of an amputation, loss of an eye, or inpatient hospitalization.

Action item 5: Identify hazards associated with emergency and nonroutine situations

Emergencies present hazards that need to be recognized and understood. Nonroutine or infrequent tasks, including maintenance and startup/shutdown activities, also present potential hazards. Plans and procedures need to be developed for responding appropriately and safely to hazards associated with foreseeable emergency scenarios and nonroutine situations.

How to accomplish it

- ✓ Identify foreseeable emergency scenarios and nonroutine tasks, taking into account the types of material and equipment in use and the location within the facility. Scenarios such as the following may be foreseeable:
    - Fires and explosions
    - Chemical releases
    - Hazardous material spills
    - Startups after planned or unplanned equipment shutdowns
    - Nonroutine tasks, such as infrequently performed maintenance activities
    - Structural collapse
    - Disease outbreaks
    - Weather emergencies and natural disasters
    - Medical emergencies
    - Workplace violence

Action item 6: Characterize the nature of identified hazards, identify interim control measures, and prioritize the hazards for control

The next step is to assess and understand the hazards identified and the types of incidents that could result from worker exposure to those hazards. This information can be used to develop interim controls and to prioritize hazards for permanent control.

How to accomplish it

- ✓ Evaluate each hazard by considering the severity of potential outcomes, the likelihood that an event or exposure will occur, and the number of workers who might be exposed.
- ✓ Use interim control measures to protect workers until more permanent solutions can be implemented.
- ✓ Prioritize the hazards so that those presenting the greatest risk are addressed first. Note, however, that employers have an ongoing obligation to control all serious recognized hazards and to protect workers.

Note: "Risk" is the product of hazard and exposure. Thus, risk can be reduced by controlling or eliminating the hazard or by reducing workers' exposure to hazards. An assessment of risk helps employers understand hazards in the context of their own workplace and prioritize hazards for permanent control.

OPERATE AND MONITOR THE CLEANING PROCESS

The 'o' and the 'm' in operation and maintenance of water and wastewater treatment plants

According to Sullivan in 2010, "Operations and Maintenance are the decisions and actions regarding the control and upkeep of property and equipment." Operations are the activities to make sure the plant produces the desired quality and quantity of treated water and meets the current legislation, while maintenance are the activities to make sure the plant equipment continues to work efficiently to achieve the operational objectives.

Water and wastewater treatment plants are no longer traditional plants; monitoring is not just taste, odor, iron and manganese; water treatment facilities are more complex now a days, new technologies have emerged, raw water is more difficult to treat, the treatment requires more innovative solutions, there is an increasing demand for services, diminishing resources, rising service expectations of customers and increasingly stringent regulatory requirements. This all leads to analyzing and enhancing the way we look at operation and maintenance in the water and wastewater industry and the treatment facilities that should be developed and expanded to accommodate these dramatic changes.

Another reason is the growing trend in outsourcing the operation and maintenance of water and wastewater treatment plants. O&M is outsourced for the main following reasons:

- ✓ You are better
- ✓ You are less expensive
- ✓ The client can transfer operational headache (risk) to you, allowing them to focus on their core business

There are many books and articles talking about operation and maintenance and some are talking about the water treatment plant operation, but it seems that we are missing that comprehensive approach between them to successful operation and maintenance. This article will provide a comprehensive approach on the 'O' and the 'M' in the operation and maintenance of water and wastewater treatment plants.

The operation and maintenance of water and wastewater plants has been generally been broken up in to five main critical elements; operation, maintenance, engineering, training and administration – also known as OMETA .

The new approach is broken down to eight critical elements; WH&S plan, Scope of service, Operation plan, asset and maintenance plan, people, analytical protocols, communication and reporting, and administration.

The main objective of all elements is to support the effectiveness of the fundamental core element; operation and maintenance.

All of these elements should be well defined before starting an implementation process and analyze should be undertaken as to how these elements are linked to form a sound program structure. However the link is very obvious – O&M work together. These elements are analyzed below.

1. **WH&S Plan**

This is primarily a communication tool between the company and its employees, customer and contractors, to ensure that relevant site information is regularly updated between all parties and that safety is monitored, recorded and acted upon.

Benefits (why it matters):

- ✓ Protect people and equipment
- ✓ Reduce downtime and absenteeism
- ✓ Legal compliance
- ✓ Increase the skills and awareness of safety to all involved

Suggested components of WH&S plan:

A WH&S plan should include but not be limited to the following:

- ✓ Site Safety Manual;
- ✓ Safety Training;
- ✓ Safety Audits;
- ✓ Housekeeping Audits;
- ✓ Safety Meetings;
- ✓ Safety Reports (Near miss, incidents, observation, etc.);
- ✓ Customer Specific Requirements;
- ✓ Work permits;
- ✓ Safety procedures (Lock-Out Tag-Out "LOTO", confined space, working at heights, etc.);
- ✓ Statement of responsibilities;
- ✓ Incident Management;
- ✓ Site Safety Rules; and
- ✓ Identifying and managing risk.

2. **Scope of Service**

This primarily defines what, when and where work will happen, supply responsibilities and liability for deliverables.

Benefits (why it matters):

- ✓ Clearly define deliverables to the team
- ✓ Base for O&M planning
- ✓ Inputs and outputs are clearly defined and executed to delight customers

The scope of service is usually extracted from the operation and maintenance contract; it defines the main objectives of the O&M service provided to the internal or external customers.

The scope of service should include the following as a minimum:

- ✓ Take Of Points (TOPs) – these are the points where the scope of service starts and ends;
- ✓ The raw water quality or influent window/s;
- ✓ The treated water quality limits and KPI's;
- ✓ Reporting requirements both internal, external and regulatory;
- ✓ Legislation and regulatory requirements;
- ✓ Services Performed;
- ✓ Maintenance Performed;
- ✓ Overall Key Performance Indicators;

- ✓ Liabilities;
- ✓ HR requirements;
- ✓ Billing details;
- ✓ Contacts list; and
- ✓ Organisational charts & responsibilities.

3. **Operations Plan**

This is the primary main operational objective which is to make sure the plant is operating in producing the design quality and quantity efficiently and consistently.

Benefits (why it matters):

- ✓ Enhance tracking and decision making and control of KPIs;
- ✓ Provide optimal operating efficiency;
- ✓ Reduce waste;
- ✓ Support proactive operation;
- ✓ Support continuous process improvement and optimization; and
- ✓ Reduce operating errors

The operations plan should include but not be limited to the following:

- ✓ Operating Schedules;
- ✓ Operating KPIs;
- ✓ Data collection and monitoring;
- ✓ Responses with corrective actions;
- ✓ Standard Operating Procedures (SOP);
- ✓ Work Instructions;
- ✓ Checklists / Task Lists;
- ✓ Operator Logs;
- ✓ Product / Process Change Processes;
- ✓ Chemical details (dosage, preparation, storage and inventory);
- ✓ Process balance sheets;
- ✓ Operation Sequence Charts (OSC); and
- ✓ System settings & alarms list.

Once operating quantifiable parameters such as pressure, pressure drop, flow, temperature, pH level, turbidity and visual checks are properly defined, they are considered indicators that a control device is functioning as designed in accordance with the Operation Plan. Operating limits for each parameter may initially be suggested by the equipment manufacturer but may later be modified by the facility based on experience or operation during a performance test and operation of the plant.

Data collection is only one part of plant and equipment operational monitoring. Cumulative data collected should be used to produce beneficial information, represent key performance indicators and further enhance the defined operating parameters.

Proactive operation schedules include seasonal changes, shutdown periods, peak demand, low consumption periods, water quality changes and public holidays are all important factors to monitor and manage to increase overall plant efficiency. A response plan should be developed to deal with such different occasions and adjust the plant until the team gains more experience with such future proactive operation instances.

Important factors about data logging:

- ✓ When and what data is collected;
- ✓ How often it is collected depends on the criticality of the process;
- ✓ Using online or manually collected data;
- ✓ Transferring data into information summarized by KPIs;
- ✓ Using the information to control and correct deviations; and
- ✓ Consult with the equipment manufacturer.

4. **Asset & Maintenance Plan**

The asset and maintenance plan is primarily the processes and structure to ensure that equipment continues to deliver maximum value throughout its expected life and at the lowest cost.

Benefits (why it matters):

- ✓ Protect asset value;
- ✓ Reduce down times;
- ✓ Reduce breakdowns;
- ✓ Increase operational performances;
- ✓ Increase resource utilisation; and
- ✓ Improve profit and profitability

Maintenance items can include; inspections, cleanings, lubrications, adjustments, replacements and calibrations. Maintenance procedures may initially be suggested by the equipment manufacturer but may later be modified by the facility based upon experience.

Other important elements in the maintenance plan are:

- ✓ Asset list which includes; asset name, description, asset number, location, criticality, condition, usefulness and value. The asset list will give the operator an understanding of the physical asset capability to meet the stakeholder's expectations and regulatory requirements;
- ✓ Implementing maintenance best practices such as; 5S, Failure Mode Effect Analysis (FMEA) or Root Cause Analysis (RCA);
- ✓ Proactive maintenance programs, especially for critical equipment;
- ✓ Preventive maintenance programs which can include; cleaning, calibration, oil change, greasing and replacing consumables;
- ✓ Critical spare parts list included items such as; correct quality, correct quantity, correct time, correct cost and correct supplier;
- ✓ Tracked Work Orders;
- ✓ Useful maintenance software such as 'CMMS' or even a similar style maintenance spreadsheet;
- ✓ Tools list and the inclusion of some tools for proactive maintenance; and
- ✓ Spare parts inventory.

5. **People**

This primarily includes managing employees and contractors.

Benefits (why it matters)

- ✓ Right person, in the right place;
- ✓ Continuous people development based on requirement; and
- ✓ Increase employee's satisfaction

Important items to address in managing people include:

- ✓ Training based on skills matrix and training matrix;
- ✓ On Job Training (OJT);
- ✓ On Boarding and induction;
- ✓ Communication;
- ✓ Selection Process;
- ✓ Performance reviews;
- ✓ Job Description and responsibilities; and
- ✓ Recognition and motivation.

6. **Analytical Protocols**

This is primarily defined as the quality monitoring of process efficiency.

Benefits (why it matters)

- ✓ Optimizes processes and chemical dosing
- ✓ Supporting decision making to control KPI's
- ✓ Proactive actions
- ✓ Regulatory requirements
- ✓ Reporting basis

In addition to the quality monitoring, the analytical protocol should also include the response plan to any deviation from control limit/s.

7. **Communication and Reporting**

This is primarily addressed as the communication of KPIs to the stakeholders and regulators.

Benefits (why it matters)

- ✓ Forms basis for measurable business value
- ✓ Provides mutual agreement of value delivered
- ✓ Allows tracking and implementation of Best Standard Operation procedures
- ✓ Fulfilling regulatory requirements
- ✓ Identifies opportunities for improvement and expansion

Reporting may include:

- ✓ KPI Communication;
- ✓ Operational Activities;
- ✓ Maintenance Activities;
- ✓ Safety Compliance;
- ✓ Non-Conformance Actions;
- ✓ Profit and Loss "P&L"; and
- ✓ Improvement of projects capital output.

8. **Administration**

Administration are all the supporting activities to main structure of O&M, this include:

- ✓ Procurement
- ✓ Contracts management
- ✓ Budgeting
- ✓ Book keeping
- ✓ Public communication

Benefits (why it matters)

- ✓ Effective management
- ✓ Control of KPIs
- ✓ Support meting regulatory and contractual requirement
- ✓ Better public awareness
- ✓ Provide a documents repository

Key Success Factors to the 'O' and the 'M' in Operation and Maintenance

1. The size and complexity of the plan should match the size and complexity of the plan;
2. Know your team skills and capabilities for effective resource utilization and understanding of training needs;
3. Develop clear key performance indicators and metrics to measure cost and progress;
4. Obtain senior management support and engagement;
5. Program sponsor with authority to change;
6. People, process, then equipment;
7. Balance quick wins with continuous improvement;
8. Focus on the trouble areas;
9. Engage people with trust and respect; and
10. Update stakeholders continuously on the progress

Operating in Shifts

Good communication between teams working on plants is an important contributor to safety.
When a team hands over responsibility to another (as takes place during shift handover) there is always the possibility of an important detail being overlooked.
The handover process relies on good communication to ensure continuity. Any weakness in this communication can introduce safety risk. The result might be a serious accident that could have been avoided.

Shift handover

Changing shifts is a requirement in any continuous process. While plants can operate 24X7, people need to take breaks. Shift handover should be regarded as a high-risk process because it cannot be automated and relies on human behavior. The goal of the handover process is to maintain continuity and the formal transfer of responsibility and accountability between the respective parties.

Work that takes place across shifts

A shift roster is typically set up in advance to accommodate the need for people to work to a schedule. Shift changeover times are planned in advance. The reality of day to day operations is that certain tasks like critical repairs, or unloading bulk raw materials happen on their own time scale. These tasks, sometimes involving different teams can take place during two or more shifts. Other, bigger tasks such as a major repair might take place over days, weeks or even months.

Shift handover procedure

To ensure continuity and minimize errors, a standard procedure is implemented for shift handover. Each company will develop their own procedure in line with their operational requirements. In practice we have observed that there is little standardization of these handover procedures between companies, and while some follow a very rigorous and defined process, others merely rely on individuals to communicate effectively.

Risks associated with shift handover

Considering that a typical shift is either 8 or 12 hours long, changeover happens 1095 or 730 times during the year, in other words there are 730 or 1095 high risk opportunities for miscommunication leading to safety incidents. Making sure that the changeover process itself is defined and managed properly is a priority area to focus on when looking for ways to improve safety on the plant.
Several studies into shift handover have been done to better understand ways to improve the procedures. One such HSE study analysed a number of incidents involving planned maintenance work and found that the following shift handover related risks were contributing factors to accidents and fatalities:

- ✓ In some of the incidents, planned maintenance work continued over a shift change.
- ✓ Thorough [coordination and] communication of such work should be afforded a very high priority.
- ✓ Operator support [logs] were not designed to capture key information reliably and unambiguously.
- ✓ A lack of procedures which specified how to conduct an effective shift handover was evident.
- ✓ Inaccurate and unreliable carry-forward of written information from shift to shift was evident. For example, reference to a temporary safety system over-ride was not carried forward.

The permit to work and shift handover

In typical industrial environments the permit to work makes sure that communication takes place between all people involved in dangerous, non-routine tasks on the plant.
So, what should happen to these permits at shift handover?
Two approaches are possible:

- ✓ The permit is closed off and a new permit issued by the incoming shift for the work to continue.
- ✓ A shift handover procedure is implemented that ensures that responsibility is transferred from the outgoing to the incoming persons on the permit document itself.

The first approach takes more time but forces a fresh review of the job and helps ensure that communication takes place. The second approach is more streamlined but runs the risk that something important has changed that is not adequately interrogated by the responsible persons at changeover.

In practice there is often confusion as to which of the two approaches is best within a single company, and the procedures also differ between industries. Unsurprisingly for example, in the nuclear industry a much more structured handover process is followed than for example in chemicals manufacturing.

The HSE study [1] also found an interesting disconnect. In a survey of chemicals plant personnel, the majority of fitters and superintendents were of the view that a new permit should be issued at changeover, while the majority of managers believed that the work should carry on using the same permit. This lack of alignment should be of concern as it seems as there is scope for confusion.

What constitutes a good shift handover procedure?

A good shift changeover procedure should be based on the following design principles:

- ✓ Formal written communication around each handover should be documented in a simple, secure, structured logbook, ideally electronic.
- ✓ Information between shifts should also communicate the "why" and not just the "what".
- ✓ Information between shifts should be communicated between experienced competent persons who understand the process and work being done.
- ✓ Relevant information should be highly visible to all affected – e.g. displays around the plant, mobile devices, etc.
- ✓ Relevant focused shift and safety information should be easily shared.
- ✓ The handover process should always be aligned to the short and medium-term production goals and targets and these need to be visible.
- ✓ Coordination and linking of all the other relevant processes underway – such as any open permits, isolations and so on. The information should ideally be in a common system or database.
- ✓ Face to face communication between role-players.
- ✓ Catering for regular handover and / or production meetings that result in tasks being assigned, followed up and shared in a management system.
- ✓ Support for continuous training and audit of the processes.

Where to start?

During a review or implementation of a new shift handover process it is suggested that you first analyse the existing procedures to see what steps can be improved, and not necessarily just transcribe "what has always been done" into a new computer-based system. These procedures might include:

- ✓ Permit to work
- ✓ Isolation management
- ✓ Shift handover
- ✓ Production meetings
- ✓ Maintenance
- ✓ Routine and non-routine operations that take place over shifts
- ✓ Shift roster management
- ✓ And so on…

In this early phase of the project you would work closely with the supplier of the software to understand the capabilities of the system and help you map your existing processes to the new system. This process mapping exercise will often identify gaps and opportunities which will greatly enhance operational effectiveness and safety.

Machinery, plant and equipment

This section covers the different safety aspects of using machinery and maintaining plant and equipment in the workplace. Employers should consider how their workers use machinery, and have adequate maintenance arrangements in place to ensure it remains safe to use.

There is also specific advice on lifting equipment and carrying out vehicle repairs.

Case study

A company were prosecuted after a worker was killed when he was crushed in the rollers of a rubber and cloth inspection machine.

Other workers heard him cry out and he was found with his left arm, shoulder, head and torso trapped between the rubberised blanket and the roller. He was pronounced dead at the scene.

What caused the accident?

The company had not assessed the risks associated with using the machine. They had not checked that it was safe to use following modifications when the nip guards were removed and an unguarded roller was inserted.

Why is machinery safety important?

Moving machinery can cause injuries in many ways:

- ✓ People can be struck and injured by moving parts of machinery or ejected material. Parts of the body can also be drawn in or trapped between rollers, belts and pulley drives.
- ✓ Sharp edges can cause cuts and severing injuries, sharp-pointed parts can cause stabbing or puncture the skin, and rough surface parts can cause friction or abrasion.
- ✓ People can be crushed, both between parts moving together or towards a fixed part of the machine, wall or other object, and two parts moving past one another can cause shearing.
- ✓ Parts of the machine, materials and emissions (such as steam or water) can be hot or cold enough to cause burns or scalds, and electricity can cause electrical shock and burns.
- ✓ Injuries can also occur due to machinery becoming unreliable and developing faults or when machines are used improperly through inexperience or lack of training.

What should employers do?

Before they start

Before they start using any machine they need to think about what risks may occur and how these can be managed. They should therefore do the following:

- ✓ Check that the machine is complete, with all safeguards fitted, and free from defects. The term 'safeguarding' includes guards, interlocks, two-hand controls, light guards, pressure-sensitive mats etc. National legislation often requires the supplier to provide the right safeguards and inform buyers of any risks ('residual risks') that users need to be aware of and manage because they could not be designed out.
- ✓ Produce a safe system of work for using and maintaining the machine. Maintenance may require the inspection of critical features where deterioration would cause a risk. They should also look at the residual risks identified by the manufacturer in the information/instructions provided with the machine and make sure they are included in the safe system of work.
- ✓ Ensure every static machine has been installed properly and is stable (usually fixed down).
- ✓ Choose the right machine for the job and do not put machines where customers or visitors may be exposed to risk.

Make sure the machine is:

- ✓ Safe for any work that has to be done when setting up, during normal use, when clearing blockages, when carrying out repairs for breakdowns, and during planned maintenance;
- ✓ Properly switched off, isolated or locked off before taking any action to remove blockages, clean or adjust the machine;

Also, make sure they identify and deal with the risks from:

- ✓ Electrical, hydraulic or pneumatic power supplies;
- ✓ Badly designed safeguards. These may be inconvenient to use or easily overridden, which could encourage their workers to risk injury and break the law. If this is happening employers should find out why workers are doing it and take appropriate action to deal with the reasons/causes.

Preventing access to dangerous parts

Employers should think about how they can make a machine safe. The measures they use to prevent access to dangerous parts should be in the following order. In some cases it may be necessary to use a combination of these measures:

- ✓ Use fixed guards (e.g. secured with screws or nuts and bolts) to enclose the dangerous parts, whenever practical. Use the best material for these guards – plastic may be easy to see through but may easily be damaged. Where you use wire mesh or similar materials, make sure the holes are not large enough to allow access to moving parts.
- ✓ If fixed guards are not practical, they should use other methods, e.g. interlock the guard so that the machine cannot start before the guard is closed and cannot be opened while the machine is still moving. In some cases, trip systems such as photoelectric devices, pressure-sensitive mats or automatic guards may be used if other guards are not practical.
- ✓ Where guards cannot give full protection, use jigs, holders, push sticks etc. if it is practical to do so.
- ✓ Employers should control any remaining risk by providing the worker/operator with the necessary information, instruction, training, supervision and appropriate safety equipment.

Other things employers should also consider

- ✓ If machines are controlled by programmable electronic systems, changes to any programmes should be carried out by a competent person (someone who has the necessary skills, knowledge and experience to carry out the work safely). It is good practice if employers' keep a record of such changes and check to ensure they have been made properly.
- ✓ Ensure control switches are clearly marked to show what they do.
- ✓ Have emergency stop controls where necessary, e.g. mushroom-head push buttons within easy reach.
- ✓ Make sure operating controls are designed and placed to avoid accidental operation and injury, use two-hand controls where necessary and shroud start buttons and pedals.
- ✓ Don't let unauthorized, unqualified or untrained people use machinery – never allow children to operate or help at machines. Some workers, e.g. new starters, young people or those with disabilities, may be particularly at risk and need instruction, training and supervision.
- ✓ Adequate training should ensure that those who use the machine are competent to use it safely. This includes ensuring they have the correct skills, knowledge and experience – sometimes formal qualifications may be needed.

- ✓ Supervisors must also be properly trained and competent to be effective. They may need extra specific training and there are recognized courses for supervisors.
- ✓ Ensure the work area around the machine is kept clean and tidy, free from obstructions or slips and trips hazards, and well lit.

Dos and don’ts of machinery safety for workers

Do...

- ✓ check the machine is well maintained and fit to be used, i.e. appropriate for the job and working properly and that all the safety measures are in place – guards, isolators, locking mechanisms, emergency off switches etc.;
- ✓ use the machine properly and in accordance with the manufacturer’s instructions;
- ✓ make sure operators are wearing the appropriate protective clothing and equipment required for that machine, such as safety glasses, hearing protection and safety shoes.

Don’t...

- ✓ use a machine or appliance that has a danger sign or tag attached to it. Danger signs should only be removed by an authorised person who is
- ✓ satisfied that the machine or process is now safe;
- ✓ wear dangling chains, loose clothing, rings or have loose, long hair that could get caught up in moving parts;
- ✓ distract people who are using machines;
- ✓ remove any safeguards, even if their presence seems to make the job more difficult.

Case study

A company were prosecuted after a worker received horrific injuries, almost severing his left arm when using a cross-cut saw.

What the employer did

The nose guard had not been set correctly because training was inadequate. The worker had no previous experience and had only five minutes’ training on the saw. This did not include any instruction about the saw guards and how to adjust them properly. In addition, the saw was unsuitable for training purposes.

Plant and equipment maintenance

Maintenance on plant and equipment is carried out to prevent problems arising, to put faults right, and to ensure equipment is working effectively.

Maintenance may be part of a planned programme or may have to be carried out at short notice after a breakdown. It always involves non-routine activities and can expose those involved (and others) to a range of risks.

Why is maintenance of plant and equipment important?

An effective maintenance programme will make plant and equipment more reliable. Fewer breakdowns will mean less dangerous contact with machinery is required, as well as having the cost benefits of better productivity and efficiency.

Additional hazards can occur when machinery becomes unreliable and develops faults. Maintenance allows these faults to be diagnosed early to manage any risks. However, maintenance needs to be correctly planned and carried out. Unsafe maintenance has caused many fatalities and serious injuries, either during the maintenance or to those using the badly maintained or wrongly maintained/repaired equipment.

What should employers do?

Employers who provide equipment for use, from hand tools and ladders to electrical power tools and larger plant, need to ensure that, so far as is reasonably practicable that the machinery and equipment under their control is safe and without risk to health. One way to achieve this is for employers to have arrangements in place to make sure machinery and equipment is maintained in a safe condition.

They should think about what hazards can occur if:

- ✓ tools break during use;
- ✓ machinery starts up unexpectedly;
- ✓ there is contact with materials that are normally enclosed within the machine, i.e. caused by leaks/breakage/ejection etc.

Failing to correctly plan and communicate clear instructions and information before starting maintenance can lead to confusion and can cause accidents. This can be a particular problem if maintenance is during normal production work or where there are contractors who are unfamiliar with the site.

Case study

A worker received crush injuries to his head and neck while he was undertaking maintenance work, when the hoist he was working on started up.

What caused the accident?

The power supply to the hoist had not been isolated before work started. This was because workers had not been given adequate training or instruction on safe isolation procedures. It was also found that isolation by the interlocked gates could be bypassed.

Extra care is also required if maintenance involves:

- ✓ working at height or when doing work that requires access to unusual parts of the building;

- ✓ when entering vessels or confined spaces where there may be toxic materials or a lack of air.

How can employers do it?

Establishing a planned maintenance programme is a useful step towards reducing risk, as well as having a reporting procedure for workers who may notice problems while working on machinery.

Some items of plant and equipment may have safety-critical features where deterioration would cause a risk. Employers must have arrangements in place to make sure the necessary inspections take place.

But there are other steps to consider:

Before employers instruct workers to start maintenance

- ✓ Decide if the work should be done by specialist contractors. Never take on work for which workers are not prepared or competent.
- ✓ Plan the work carefully before it starts, ideally using the manufacturer's maintenance instructions, and produce a safe system of work. This will avoid unforeseen delays and reduce the risks.
- ✓ Make sure maintenance staff are competent and have appropriate clothing and equipment.
- ✓ Try and use downtime for maintenance. This can avoid the difficulties in co-ordinating maintenance and production work if maintenance work is performed before start-up or during shutdown periods.

Safe working areas

- ✓ Employers must provide safe access and a safe place of work.
- ✓ They must not just focus on the safety of maintenance workers – they must take the necessary precautions to ensure the safety of others who may be affected by the maintenance work, e.g. other workers or contractors working nearby.
- ✓ Employers and the maintenance personnel should set up signs and barriers and position people at key points if they are needed to keep other people out.

Case study

Maintenance staff removed a section of grating to gain access to plant located below a walkway. A worker fell through a gap in the walkway, seriously injuring his shoulder.

What caused the accident?

The fall happened because there was nothing to make workers aware of the dangers caused by machinery maintenance. Barriers, guards and signs should have been used to indicate that maintenance was taking place.

Safe plant and equipment

Employers should ensure plant and equipment is made safe before maintenance starts, through:

Safe isolation

- ✓ Ensuring moving plant has stopped and isolate electrical and other power supplies. Most maintenance should be carried out with the power off. If the work is near uninsulated, overhead electrical conductors, e.g. close to overhead travelling cranes, cut the power off first.
- ✓ Locking off machines if there is a chance the power could be accidentally switched back on.
- ✓ Isolating plant and pipelines containing pressured fluid, gas, steam or hazardous material. Locking off isolating valves.

Other factors needing to be considered

- ✓ Releasing any stored energy, such as compressed air or hydraulic pressure that could cause the machine to move or cycle.
- ✓ Supporting parts of plant that could fall, e.g. support the blades of down-stroking bale cutters and guillotines with blocks.
- ✓ Allowing components that operate at high temperatures time to cool.
- ✓ Place mobile plant in neutral gear, apply the brake and chock the wheels.
- ✓ Safely cleaning out vessels containing flammable solids, liquids, gases or dusts, and check them before hot work is carried out to prevent explosions. Specialist help and advice may be needed to do this safely.
- ✓ Avoiding entering tanks and vessels where possible. This can be very high-risk work. If required, get specialist help to ensure adequate precautions are taken.
- ✓ Cleaning and checking vessels containing toxic materials before work starts.

Dos and don’ts of plant and equipment maintenance

Do…

- ✓ ensure maintenance is carried out by a competent person (someone who has the necessary skills, knowledge and experience to do the work safely);
- ✓ maintain plant and equipment regularly – use the manufacturer’s maintenance instructions as a guide, particularly if there are safety-critical features;
- ✓ have a procedure that allows workers to report damaged or faulty equipment;
- ✓ provide the proper tools for the maintenance person;
- ✓ schedule maintenance to minimise the risk to other workers and the maintenance person wherever possible;

- ✓ make sure maintenance is done safely, that machines and moving parts are isolated or locked and that flammable/explosive/toxic materials are dealt with properly.

Don't...

- ✓ ignore maintenance;
- ✓ ignore reports of damaged or unsafe equipment;
- ✓ use faulty or damaged equipment.

Safe lifting by machine

If the employer provides lifting equipment for use at work, or if they have control of the use of lifting equipment, they must make sure it is safe.
Employers should think about what risks there may be and how they can be managed, for example:

- ✓ damage or deterioration of the equipment caused by wet, abrasive or corrosive environments;
- ✓ trying to move weights that are too heavy and exceed the load limit of the machine;
- ✓ equipment failure;
- ✓ untrained workers planning the lift or using the equipment;
- ✓ people being struck by moving parts of the machinery or by things falling.

Safe lifting needs to be properly planned by a competent person, appropriately supervised and carried out safely. Any equipment used must have been properly designed, manufactured and tested. Not forgetting the need to maintain it properly.

Factors that should be considered

- ✓ What is being lifted?
- ✓ How heavy is it?
- ✓ Where is its centre of gravity?
  - ✓ How will it be attached to the lifting machinery?
  - ✓ Who is in control of the lift?
  - ✓ What are the safe limits of the equipment?
  - ✓ Could the lift be rehearsed if necessary?

Dos and don'ts when using lifting machinery

Do...

- ✓ use only certified lifting equipment, marked with its safe working load, which has been regularly examined to ensure it is fit for purpose;
- ✓ keep the reports of any examinations as well as any declarations of conformity or test certificates;
- ✓ make sure the load is properly attached to the lifting equipment. If necessary, securely bind the load to prevent it slipping or falling off;
- ✓ before lifting an unbalanced load, find out its centre of gravity. Raise it a few inches off the ground and pause – there should be little harm if it drops;

- ✓ use packaging to prevent sharp edges of the load from damaging slings and do not allow tackle to be damaged by being dropped, dragged from under loads or subjected to sudden loads;
- ✓ when using jib cranes, make sure any indicators for safe loads are working properly and set correctly for the job and the way the machine is configured;
- ✓ use outriggers where necessary;
- ✓ when using multi-slings, make sure the sling angle is taken into account;
- ✓ have a responsible slinger or banksman and use a recognized signalling system.

Don't...

- ✓ use unsuitable equipment, e.g. makeshift, damaged, badly worn chains shortened with knots, kinked or twisted wire ropes, frayed or rotted fibre ropes;
- ✓ exceed the safe working load of machinery or accessories like chains, slings and grabs. Remember that the load in the legs of a sling increases as the angle between the legs increases;
- ✓ lift a load if you doubt its weight or the adequacy of the equipment.

DISPOSE OF WASTE AND RETURN PLANT TO OPERATION CONDITION

It's not uncommon to see signs in workplaces reminding employees to clean up after themselves. If doing so is important in office kitchens, it's doubly important on construction sites. Keeping sites orderly and removing waste can help avert accidents, prevent damage and even boost morale among workers.

The strategies below are a good starting point for keeping a jobsite clean.

Establish a housekeeping program

Set up a housekeeping system that involves everyone on the team. Focus on the importance of cleaning and removing debris after it has been created, and assign specific tasks to specific people to create accountability.

To keep the site tidy, use the 5S system, a method of workplace organization invented in Japan that includes making sure everything has a designated place and removing items not in use. To encourage compliance, use toolbox talks to remind everyone of the benefits of a clean, organized jobsite, such as improved safety and efficiency.

Separate the scraps

Construction companies may be required to recycle materials like metal, wood and sometimes, concrete. In addition to federal regulations, you may need to follow state or regional recycling rules. And the contract might stipulate which materials or debris should be diverted from landfills, along with target diversion rates for non-hazardous solid waste.

Observe the rules and designate piles, bins and containers for leftover materials. Do this ahead of time so nothing that should be kept or recycled is accidentally thrown away. In general, while recycling containers should be easy to access, the fewer containers for each type of material the better in terms of keeping transportation costs low and minimizing jobsite obstructions. Consider hiring a company that does waste and recycling management for construction firms.

Eliminate waste at the source

The less waste that arrives or is created at the site, the less disposal and cleanup is necessary. Choose products with minimal packaging. Measure carefully so you order only the materials you need, in the optimal sizes. Buy quality materials so you throw out fewer warped studs, for instance. Embrace the use of prefabricated elements when possible.

Keep waste properly contained

Keeping a lid on waste, literally, is important, especially when the waste could spill, evaporate or smell. Containers and product drums should be sealed tightly. Use the right container for the type of hazardous waste. Mark the container to indicate its contents, and make sure the container is in good condition. Containers of used oil should be free of leaks, structural defects and severe rusting, for example. Use a locked compound if you're storing one near water or a drain.

All workers must be trained in the management of hazardous waste as it relates to their job function. Make sure everyone knows where to discard flammable and combustible materials.

Oily rags aren't just tripping hazards; they're also flammable. In fact, they can spontaneously combust. That's why they should be stored in a metal container with a cover, preferably a self-closing lid. Schedule frequent removal of hazardous waste to keep areas clean and prevent fires and accidents.

To discourage dumpster divers and any unauthorized use of your dumpster, consider a lock for it.

Manage dust safely

Use engineering and work practice controls such as dust collection systems to limit dust in the air during certain tasks, such as sawing or grinding concrete, stone or mortar. Reduce the amount of dust created by installing water systems that steam or spray a cutting blade.

Controlling respirable crystalline silica is especially important since it can cause incurable lung disease if inhaled. Per OSHA's silica dust compliance guide for small entities, don't allow dry brushing or dry sweeping unless methods such as wet sweeping and HEPA-filtered vacuuming are not feasible. Workers should of course have access to appropriate respiratory protection.

The last sweep

Last impressions count. Performing a final cleaning during closeout will leave a good impression on the client and possibly help you win more projects in the future. Create a checklist of tasks, such sweeping, mopping, cleaning all surfaces, washing windows and removing any remaining stickers. And don't forget trash removal.

If you established a good housekeeping routine at the beginning of the job, cleanup should be a relatively easy final step.

UNIT 19

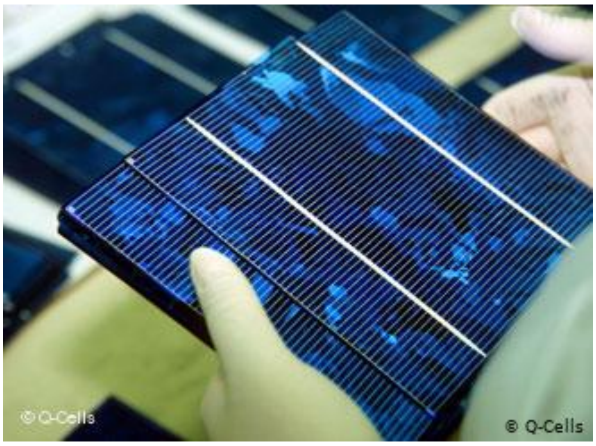
OPERATE AND MAINTAIN OF POWER GENERATION SYSTEM (RENEWABLE ENERGY)

This unit deals with the skills and knowledge for the co-ordination of the operations of a hybrid power plant

COORDINATE THE SOLAR POWER PLANT OPERATIONS

Plant operational procedures are implemented in consultation with others and reviewed as required

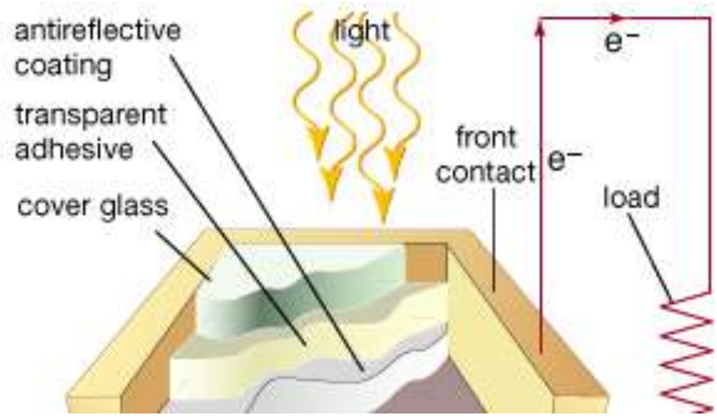
Solar radiation may be converted directly into electricity by solar cells (photovoltaic cells). In such cells, a small electric voltage is generated when light strikes the junction between a metal and a semiconductor (such as silicon) or the junction between two different semiconductors. The power generated by a single photovoltaic cell is typically only about two watts. By connecting large numbers of individual cells together, however, as in solar-panel arrays, hundreds or even thousands of kilowatts of electric power can be generated in a solar plant.



Photovoltaic cell

A photovoltaic cell, commonly called a solar cell or PV, is a technology used to convert solar energy directly into electricity. A photovoltaic cell is usually made from silicon alloys. Particles of solar energy, known as photons, strike the surface of a photovoltaic cell between two semiconductors. These semiconductors exhibit a property known as the photoelectric effect, which causes them to absorb the photons and release electrons. The electrons are captured in the form of an electric current

Four Seasons Resort Maldives at Landaa Giraavaru connected its first Roof Solar inverter, and in doing so turned on one of the Maldives' largest resort-based solar installations.



When sunlight strikes a solar cell, an electron is freed by the photoelectric effect. The two dissimilar semiconductors possess a natural difference in electric potential (voltage), which causes the electrons to flow through the external circuit, supplying power to the load. The flow of electricity results from the characteristics of the semiconductors and is powered entirely by light striking the cell.

Resources and supplies are coordinated to meet plant requirements

- Select low- or no-maintenance alternatives when available (for example plastic wire ties would require replacement whereas coated metal ones may not);
- Track the performance of fielded equipment and identify and specify the ones that have low failure rates, and which have the best OEM warranty service; standardize on preferred products to avoid mis-match of parts and expertise in a fleet;
- Make use of network-connected inverters for remote testing, software configurations and/or updates, and remote resets
- Provide required access to and clearance around equipment for maintenance
- Provide elevated pads to prevent flooding of ground-mounted equipment and provide permanent storm-water management system that is integrated with surrounding properties.
- Enable third-party inspection and commissioning of original EPC installations to spot operation problems before acceptance
- Conform to the evaluation and quality-assurance protocol detailed in the SAPC PV System Installation Best Practices Guide (Keating, Walker, and Ardani 2015).
- Build PV and storage systems to relevant standards, such as IEEE 937: Recommended Practice for Installation and Maintenance of Lead-Acid Batteries for Photovoltaic (PV) Systems (IEEE 2007).
- Apply IEC 62446: Grid Connected Photovoltaic Systems-Minimum Requirements for System Documentation, Commissioning Tests, and Inspections (IEC 2009), which requires documentation of the system, array testing, and whole-system performance test1 (applicable to commercial, industrial, and utility-scale systems). Commissioning is the link between the engineering, procurement, and construction (EPC) contractor and the operator. In addition to the above-mentioned safeguards, commissioning is now recommended to be a two-part process: The first part is done when the system starts operation, and the second is performed after one year of operation. Full acceptance of the system comes after the second step. Third-party verification of a plant can help ensure that best practices are applied throughout the life cycle of a plant. Such verification could include concept, site selection, design, equipment selections, installation, commissioning, final commissioning, PV system performance reporting,

annual certification, certification for transfer of ownership or for refinancing, O&M practices, and/or end-of-performance period.

Based on inspections of PV systems damaged in hurricanes, the following are prerequisites to address in the design and installation of a system in the areas vulnerable to hurricanes prior to O&M tenure:

- Through-bolting is preferred to self-tapping screws. Self-tapping screws are more likely to pull out, and due to the hardened threads and lack of galvanized coating on the threads, they get weaker over time due to corrosion.
- Through-bolting is preferred to clamps in rack hardware. Clamps may have the specified strength in the proper orientation when forces are applied in the proper direction, but relative movement, rotation, or vibration of rack parts in a storm can cause them to release. An entire row of modules can fail if one module is lost, and they are held by Tshaped clamps that hold two modules at one point.
- Stainless-steel boxes with thick rubber gaskets and multiple closure attachments stay intact and exclude moisture more effectively than those with only handle-actuated attachments (specify NEMA 6 rating).
- Mastheads can break off or leak in a storm and must be sealed with foam packing provided for that purpose to avoid water infiltration and keep insects out.
- Drainage from boxes and conduit runs must be provided in the case of water infiltration.

MONITOR SOLAR POWER PLANT OPERATIONS

Deviations from standard plant operations are identified and recorded

PV operations includes the following five areas:

Administration of operations: Ensures effective implementation and control of O&M services including curation of as-built drawings, equipment inventories, owners and operating manuals, and warranties. Curation involves not only keeping an archive but also selecting what to keep, pursuing missing documents, preserving documents, keeping them up to date, and, finally, archiving documents. Administration includes keeping records of performance and O&M measures, preparing scopes of work and selection criteria for service providers, contracting with suppliers and service providers, paying invoices, preparing budget, and securing funding and contingency plans for O&M services. Administration also includes compliance with regulations by the government or authorities having jurisdiction and mandatory guidelines issued by utilities.

Conducting operations: Ensures efficient, safe, and reliable process operations including making decisions about maintenance actions based on cost/benefit analysis. This includes serving as a point of contact for personnel regarding operation of the PV system; coordinating with others regarding system operation; preparing power and energy forecasts; scheduling maintenance operations; listing spare parts inventory (either in-stock onsite or in suppliers' consignment stocks); and inspecting work and approving invoices. Meanwhile, operations include any day-to-day operation of the system to maximize power delivery, assess performance and trends, operate the grid interface, manage curtailments, or adjust settings such as power factor or other ancillary services. Operations activities related to utility interaction or distribution-system integration/control are of increasing importance as individual plants get larger and the penetration of PV systems get more concentrated.

Directions for the performance of work: Specifies the rules and provisions to ensure that maintenance is performed safely and efficiently, including the formalization and enforcement of safety policy [including training for direct current (DC) and alternating

PV maintenance includes the following four types of maintenance procedures:

Administration of maintenance: This overlaps with "administration of operations" and ensures effective implementation, control, and documentation of maintenance services and results. Administration includes establishing budgets and securing funds for preventive maintenance; establishing reserves or lines of credit for corrective maintenance; planning services to avoid conflict with system operation or operations at the customer site; correspondence with customers; selection and contracting with service suppliers and equipment manufacturers; record keeping; enforcement of warranties; providing feedback to designers of new systems; and reporting on system performance and the efficacy of the O&M program.

Preventive maintenance: Scheduling and frequency of preventive maintenance is set by the operations function and is influenced by a number of factors, such as equipment type, environmental conditions at the site (e.g., marine, snow, pollen, humidity, dust, wildlife), and warranty terms. Scheduled maintenance is often carried out at intervals to conform to the manufacturers' recommendations, as required by the equipment warranties.

Corrective maintenance: Required to repair damage or replace failed components. It is possible to perform some corrective maintenance such as inverter resets or communications resets remotely. Also, less urgent corrective maintenance tasks can be combined with scheduled, preventive maintenance tasks.

Condition-based maintenance: Condition-based maintenance is the practice of using real-time information from data loggers to schedule preventive measures such as cleaning or to head off corrective maintenance problems by anticipating failures or catching them early. Because the measures triggered by condition are the same as preventive and corrective measures, they are not listed separately. Rather, condition-based maintenance affects when these measures occur, with the promise of lowering the frequency of preventive measures and reducing the impacts and costs of corrective measures.

End-of-performance period disposition: Specifying the options for the parties in an offtake contract (such as a PPA) at the end of the performance period or at the end of the projected life of a host-owned system, the alternatives are the following: to continue the performance contract for an extended term, including continued O&M; purchase of the system by the site or others (often at "fair market value") involving a new O&M provider; or removal of the system and restoration of the site.

Plant operation and/or condition is monitored against statutory and enterprise requirements taking into account constraints, budget requirements and performance indicators

As a solar plant is installed, engineers prepare a schedule for preventive maintenance. This includes, but is not limited to, adjustments, cleaning, lubrication, repairs, replacements, and the extension of equipment life. At least twice a year, O&M personnel conduct a general inspection of the installation-site.

During this inspection, technicians:

- ✓ Ensure roof drainage is adequate, roof drains are not clogged and confirm that there are no signs of water pooling near the array
- ✓ Ensure roof penetrations (if any) are watertight
- ✓ Check for ground erosion near the footings of a ground mount system
- ✓ Confirm electrical enclosures are only accessible to authorized personnel
- ✓ Check for corrosion on the outside of enclosures and the racking system
- ✓ Check for cleanliness throughout the site to ensure that there is no debris in the inverter pad area or elsewhere
- ✓ Check for loose hanging wires in the array
- ✓ Check for signs of animal infestation under the array

Frequency of cleaning: In normal conditions, where there isn't too much dust or dirt, cleaning is carried out on a fortnightly basis. However, in dusty areas such, the cleaning frequency is increased to once a week.

Water Quality: The cleaning of the modules is done keeping in mind the TDS (total dissolved solids) levels, water specifications and certain wiping details. In India, the TDS level of the water needs to be at least below 250 parts per million (ppm). The chlorine (less than 250 ppm) and calcium (less than 250 ppm) level of the water, as well as the electrical conductivity, is kept in mind while carrying out the cleaning. Water quality is tested after every six months to ensure that set standards are maintained.

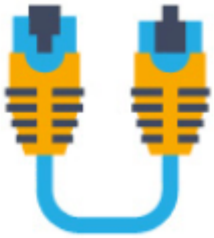
***Quality of cleaning equipment*:** Brushes without hard bristles (say fibre brushes) should be used for cleaning. A low-quality brush, like one with metal bristles, could negatively impact the glass surface of the modules. In some cases where hard substances like bird droppings have gotten stuck on the module, engineers use detergent to clean the surface. However, the detergent is not highly concentrated and has very high-water content.

***Innovation in Cleaning*:** Technicians are currently in the process of developing automated cleaning systems. In the sprinkle-type cleaning system, nozzles will be placed on the module itself, and it will automatically start the system using remote monitoring, pressurize the water, and pour it over modules. It would be particularly useful when it is hard to install a water source at the site. However, this would be a costlier way to clean when compared to deploying someone at the site.

***Post wash care*:** Post extensive cleaning, modules are wiped off properly to ensure no stain is left to avoid affecting the generation capacity. Since Clean Max takes up the responsibility of maintaining the plant, our engineers make arrangements for Ultra Poly Vinyl Chloride (UPVC) conduit pipes to ensure water supply. After the system returns to steady-state temperature (i.e. there is no remaining impact from the cooling effect of wash water), the current produced is noted along with weather conditions including temperature, irradiance etc. This maintenance work is recorded in the log book, and the production of the clean system to the previous

production values is compared.

- ✓ ***Inverter*:** Most German-make inverter manufacturers recommend servicing it on a quarterly basis. However, CleanMax carries out servicing on a monthly basis as there is a lot more dust in India compared to other countries. The ventilation is provided via a filter, and this filter needs to be frequently cleaned. Therefore, usage of high-quality filters is advantageous. As part of preventive activities, our engineers check the voltage of the string inverter and record it in the periodic log book. This gives an understanding of voltage fluctuations if any.



- ✓ ***MC4 Cabling Connector*:** Under preventive measures, we ensure that there is no gap between the male and female connector pipes. Any gap, irrespective of the size, could cause a fire and damage the modules. Separately, off-takers can install a "check" meter of equal or higher accuracy with reference to the main meter to cross-check the production level on a monthly basis. All readings have to be, more or less equal, with a 2-3% correction allowance.

- ✓ ***Transformer*:** For transformers at the site with installed capacity in megawatts, parameters such as the operating temperature, OTI (oil temperature), WTI (winding temperature), and oil level are monitored daily. If there is any internal disturbance in the transformer, it reflects in these parameters which are monitored at least three times in a day (at 11 AM, 02 PM and 04 PM as solar power is generated at its peak during these slots). The transformer has to be cleaned thoroughly once in six months. conduct IR test and cable yearly to check the transformer performance.

- ✓ ***Protection from external elements*:** To ensure that the plant is working smoothly (i.e. without any shutdown), the same has to be sealed properly. Else, rats and other rodents can enter, and get electrocuted. This, in turn, can cause a short circuit, and affect the entire plant. Many people are not aware that even high-pressure water can damage the modules. If the water stream is too strong, our team will place the outlet at a farther distance.

- ✓ ***Remote monitoring*:** A solar power plant constantly needs to be monitored to detect breakdowns and optimise its operation. The same function could be performed either on-site or remotely wherein we retrieve all the data either from the inverter or from communicating equipment (probes, meters etc.).

New requirements that may impact on operations are considered

- Wires, plastic wire ties, or grommets/bushings are exposed to sunlight. Even products listed for direct ultraviolet (UV) exposure will show degradation over the long life of a PV system and require eventual replacement.
- Movement or rubbing against modules, rack parts, or other wires due to wind or thermal expansion/contraction are allowed. This will require more frequent inspection, testing, and replacement. Movement of ballasted rack systems on a roof can cause damage to conduit or wires, and even ground -mounted parts can experience movement over a long period of time. A design that accommodates such movement and thermal expansion/contraction will require less corrective maintenance.
- Wire ties pinch wires too tightly. This will eventually deform the insulation. Faults may occur anywhere that wires are held tightly between metal parts.
- Wires are pulled too tight or do not have strain relief. This will require more frequent maintenance. Wires exposed where there is weight from accumulated ice, or where module leads do not come in the right length for the installation, will require frequent testing and repair.
- Exposure to animals, such as squirrels, requires measures to deny the animals access to the wiring and to repair any sections where the insulation has been chewed.
- Large bundles of wires do not allow wires at the center of the bundle to cool as they would in open air, leading to early degradation of the insulation and potential fault.

Maintenance of wire management systems depend on plastic wire ties and grommets, which can break or pinch wires (left); exposure to sunlight; wind and weight of ice (center); and access by chewing rodents (right).

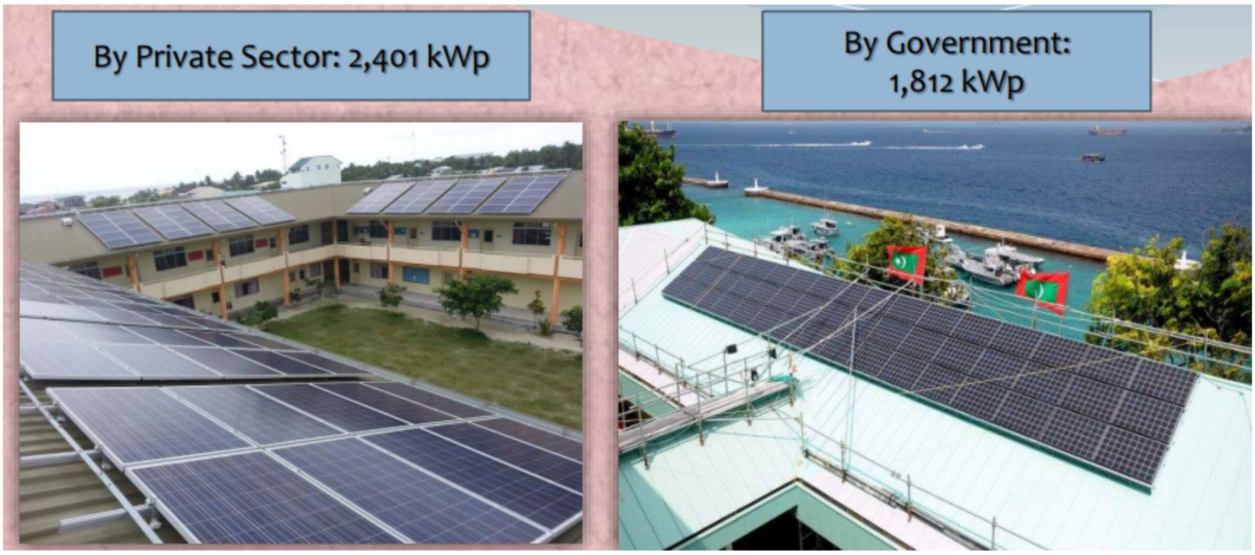
GSU transformers are common in utility-scale PV plants, and the failure risk has been low historically. In the past, transformers were overbuilt and have a reputation for being very reliable. However, as design engineers now have access to computer-aided design (CAD) tools, they are able to meet requirements without overdesigning. If the GSU fails, it can idle the plant for months. GSUs are very expensive and have a very long lead time. Also, they are large and heavy, and the logistics associated with delivery are complicated. Delivery of GSUs may include a crane and require special permits for transport on roads and interstates.

The risk of GSU transformer failure may be mitigated during the design phase by dividing the plant into multiple arrays, each with its own GSU transformer. It is critical to follow the manufacturer's recommendations for a preventive maintenance program. It may also be possible to work with local utilities to pool resources for better access to replacement units. At the minimum, the responsible party should have a fully formed reaction plan in place. Some operators keep a spare GSU on-site to reduce down-time associated with this critical component.

Operations are monitored for suitability/approval with statutory, industry and enterprise/ site requirements

Legal and Regulatory Framework of the Energy Sector of the Maldives

- All public utility companies (FENAKA and STELCO) are owned by the government but adheres to the regulations implemented by MEA.
- All power systems and electrical installations must comply with the regulations of Maldives Energy Authority.
- Only MEA licensed engineers and consultants are allowed to carry out works related to power. This includes design, installation and commissioning of power systems.



Installed Capacity of PV System

Generation, Distribution and Supply Licensing Regulation

- Details the rules and requirements for licensing operators who deal with electricity production or transmission or distribution (or any combination of these).
- Licensing Operators are categorized in to
- Service provider License
- Independent power producer License
- Transmission License

- All renewable power producers are also required to obtain operator's license under this regulation
- IPPs can distribute electricity to the registered Service Provider through a Power Purchasing Agreement

Net Metering Regulation

- This regulation with address the following aspects;
- Applicable to Consumers who are a buyer of energy/electricity from the service providers allocated in that island
- Allows connectivity on first come first serve basis, subject to operational constraints
- The capacity of the RE System that is installed to any premises is determined based on;
- The feasibility of the interconnection with the grid
- The sanction load of the consumer

TEST SOLAR POWER PLANT OPERATION

Tests are performed in accordance with defined procedures applicable to the operational test

The objective of monitoring is to provide enough information to accomplish an "energy balance" accounting for the amount of solar resource available and the losses in each energy conversion process up to delivery at the point of interconnection. Advanced operation of a PV plant such as modulating output or power factor can confound the drawing of conclusions from monitored data. A monitoring system should account for clipping of output due to high DC-to-AC ratio, interconnect limits, and called-for curtailment or any other reason.

PV Array Inspection

The two main methodologies used for these inspections are manual electrical testing and aerial thermal-imaging inspections.

Manual Electrical Testing

Manual electrical testing such as open-circuit voltage, operating current, or field I-V curve tracing is used as a method to detect faults in the DC system that the monitoring system is not able to detect. The accuracy of testing equipment is limited by the combined accuracy of irradiance, temperature, and electrical sensors, and in the case of I-V

tracing, it is limited to around 5% for standard field units.

Cracked or peeling back sheet leads to water infiltration and ribbon corrosion

This testing reveals only defects that are currently causing significant module failure, and it will not detect hot-spot defects that are not currently causing significant electrical degradation of the module. However, these signatures can be important for understanding underlying module-quality issues, in addition to allowing early detection of possible fire risks. Figure 18 shows a module that shows physical damage and compromised electrical insulation even though the module continues to perform electrically..

Manual testing is performed over several days or weeks to test a large array, and the meteorological conditions will vary over this time, making it difficult to spot relative differences in the array and requiring significant documentation to ensure that measurements are comparable. Because this testing must be performed inside the isolated combiner while the system is operational, arc-flash PPE is required for all testing—which can limit the speed of effective inspections and can pose a potential safety risk to operators. It should be noted that for some combiner topologies, the arc-flash hazard may be too high according to NFPA 70E, and electrical testing on live circuits in the combiner box may not be possible or may require portions of the array to be de-energized prior to measurement.

Manual inspection and testing requires that inverter wiring enclosures, re-combiner boxes, combiner boxes, and eventually module junction boxes be opened to access the circuits; it is important to note that these must be properly re-sealed (gasket, screw-torque) to maintain the original NEMA rating for the type of enclosure

Manual inspection and testing requires opening NEMA-rated enclosures. The integrity of any enclosure seal must be restored after opening to avoid moisture damage as in this module junction box.

Aerial Thermal Imaging

Aerial thermal imaging inspections refer to the collection and processing of image data collected by aerial sensors with the goal of detecting string, module, and sub-module faults in the array. By detecting thermal variations between modules, any critical defect that is causing a reduction in module efficiency can be detected, in addition to the proactive detection of hot spots and potential fire risks. These inspections can be performed instead of manual electrical testing as part of annual preventative maintenance and can also be used for system commissioning, end-of-warranty inspections, and infrared inspection of AC substation.

Aerial thermal imaging can be performed using manned survey aircraft or unmanned aerial vehicles (UAVs). The quality of the assessment depends largely on the imaging and post-processing systems that are used. These systems should have the following characteristics.

- Thermal detector sensitivity of <0.02°C and frame integration time of <2 ms
- Thermal wavelength imager ground resolution of 19 cm/pixel or better; visible wavelength imager ground resolution of 3 cm/pixel or better
- Irradiance at a minimum of 600 W/m2 with an irradiance deviation of <100 W/m2 and a temperature deviation of <5°C during inspections

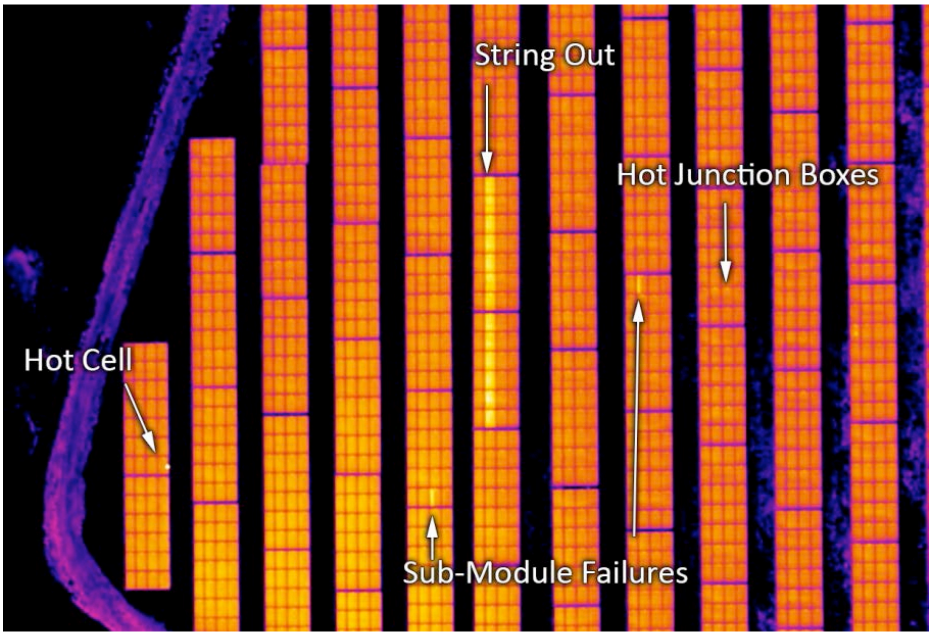
The resulting imagery should be processed by a validated processing routine to correctly identify module defects and their specific location in the field. These defects should be identified to the module level, and labelling should be provided to allow field technicians to quickly identify and remediate module-level issues. When properly applied, remote imaging inspections can proactively detect the following classes of array faults:

- *Module faults*: Hot spots, diode failures, full module failures, junction-box heating, cracked modules, ethylene vinyl acetate (EVA) fogging, yellowing, antireflective coating degradation, acute soiling (bird droppings, debris, vegetation), and other module-level defects
- *String and system faults:* Fuse failures, inverter failures, module-connector failures, reverse-polarity wiring, major maximum power-point tracking (MPPT) faults
- *Racking and balance of system*: Major racking shifts, systemic shading, major erosion.

The use of proper post-processing tools is critical to accurately detect and classify module faults. Post-processing tools should be validated against ground data, allowing a properly validated tool to identify the exact location and probable cause of all thermal faults in an array.

For inspections without validated post-processing routines, it is important to note that many of the problems described above cannot be diagnosed with aerial inspections. The inspection simply points out symptoms and the rough location of the problem. Further troubleshooting on the ground is required.

Alternatively, if the system is metered at the string level, and robust data analytics or data review is in place, then module faults that are affecting string output can be identified with a robust remote monitoring system. However, cell-level hot spots generally will not significantly affect module performance and cannot be detected by data analytics alone.



High-resolution infrared aerial imaging can identify failed strings, modules, and cells within modules

Battery Qualification Tests

Physical tests: Dimensional accuracy, static and dynamic mechanical stresses, and puncture resistance.

- ✓ *Environmental tests*: Extreme environmental conditions are likely to be encountered by the battery over its lifetime, most notably temperature. The manufacturers' published temperature limits on batteries are often exceeded by climate conditions in actual applications.
- ✓ *Cycle life*: Number of charge/discharge cycles a battery completes before its capacity falls below 80% of its initial rated capacity. These tests are expensive because they take a long time to run, ruin the battery under test, and require a statistically significant number of cells be tested. Thus, the only test data most practitioners have access to are performed by the manufacturers and published in the product literature. Temperature,

Test Conditions

Test conditions must be specified so that estimates of capacity (kWh) and cycle life are repeatable and can be compared to the manufacturers' specifications or to other batteries. Conditions to specify include:

- ✓ Definition of cycle life and range of test (e.g., to 80% of initial rated capacity)
- ✓ DOD (e.g., to 40% of capacity with each cycle)
- ✓ Rate of discharge: current in amps or percent of capacity per hour; rates are sometimes expressed as capacity divided by a number of hours; a discharge rate of C/10 for a 1,000 amp-hour battery would be (1,000 amp-hours/10 hours) = 100 amps
- ✓ Rate of charging: current in amps or percent of capacity per hour
- ✓ Temperature: battery performance is heavily dependent upon temperature; even small deviations from reference conditions (77°F) have significant effects on capacity, efficiency, and lifetime.

Non-Invasive Testing

State-of-charge testing required discharging the battery. Other tests might require that a battery be disconnected from its circuit. Some parameters of interest such as state-of-charge do not have any direct way of measuring (to cite an aging example: density of electrolyte is a proxy for state-of-charge in flooded lead-acid batteries). For these reasons, such tests are often not conducted and non-invasive approaches to ascertain battery status and health are needed, such as impedance and voltage.

Internal Resistance/Impedance

Comparing measured value of cell resistance to initial value provides an indication of any deterioration in battery performance. Impedance is calculated by measuring the current that results from a small AC voltage of known frequency applied across the terminals of the cell and can be carried out while the battery is under load to continuously monitor battery performance. Cell impedance is the applied voltage divided by the resulting current. This test detects other cell defects in the internal circuitry such as short or open circuits.

Voltage Measurements

Voltage measurements are available without interrupting battery operation, but in order to be meaningful, voltage measurements must be mathematically adjusted for voltage level, temperature, discharge rate, and the age of the cell.

Both impedance and voltage measurements depend not only on measurement conditions but also on the history of the batteries. Still, for an arrangement of batteries all at the same condition, differences in voltage over time or over position within the arrangement are important indicators of battery performance and the need for maintenance or replacement. Good record keeping is needed to track trends over time.

Infrared Imaging of Battery Systems

Similar to the use of infrared imaging in spotting problems in PV arrays, combiner boxes, and switchgear, infrared imaging can expose the location and effects of problems in battery systems. Individual battery cells with high internal resistance appear hotter than neighboring cells, battery post connections that are loose or corroded appear hotter, and imbalance of current between strings can be seen by a temperature difference. Batteries not passing current at all would appear cooler.

Infrared imaging exposes an imbalance of current through three parallel strings of batteries (the string on top is cooler) and exposes the cause of the problem, which is a battery terminal connection that is badly corroded.

Plant is observed for correct operational response

Safety is everyone's responsibility on site. All employees are to be trained and should know how to prevent and respond to a fire emergency. All employees must:

- ✓ Complete an on-site training program identifying the fire risks for the project site
- ✓ Know the protocol and follow emergency procedures should an event occur
- ✓ Review and report potential fire hazards to the Onsite O&M Primary Contact

Understanding Conditions Associated with Photovoltaic Solar Arrays

Photovoltaic (PV) solar arrays present a unique challenge for fire fighters. Unlike a typical electrical or gas utility, a PV array does not have a single point of disconnect. Whereas there are disconnects that will de-energize select parts of the system, as long as the PV panels are illuminated, the individual strings of PV panels are energized and capable of producing up to 1,000 volts. This is not just limited to PV panels being illuminated by the sun; illumination by artificial light sources, such as fire department lights, or the light for the fire itself are capable of producing electrical power sufficient to cause a lock-on hazard.
Below is a summary of the hazards associated with firefighting activities in photovoltaic solar arrays:

- ✓ Shock hazard due to the presence of water and PV power during suppression activities
- ✓ Outdoor rated electrical enclosures may not resist water intrusion from the high

- ✓ pressure stream of a fire hose.
- ✓ PV panels damaged in the fire may not resist water intrusion.
- ✓ Damaged conductors may not resist water intrusion
- ✓ Shock hazard due to direct contact with energized components
- ✓ No means of complete electrical disconnect.

Due to the dangers presented above, it is not typical to practice fire suppression by means of water inundation within solar PV arrays.

Small Stage Fires

Small stage fires are small fires that are in the beginning stage and can be controlled with a fire extinguisher. An example would be a small trash can fire. In the event of a small stage fire at the project:

- The person discovering the fire should immediately dispatch someone to activate the Incident Command Team.
- All non-essential personnel should be removed from the hazard area.
- All onsite vehicles are required to carry fire extinguishers. Fire extinguishment with a fire extinguisher or other means should be attempted if the person has been trained in the use of fire extinguishers and can do so without placing themselves in danger.
- The Onsite O&M Primary Contact will respond to the scene and determine if external resources or an evacuation are necessary. In the event of an evacuation, they will recruit/dispatch employees to assist with the evacuation and issue the following statement over the radio: "Attention, there is a fire emergency at (location name). Please evacuate (the affected area) and report to (designated meeting area).
- At this point, all employees in the affected area will stop work immediately, take steps to safely shut down equipment, exit the evacuation area, and report to the designated meeting area.
- The Onsite O&M Primary Contact will then take steps to ensure that no employee reenters the evacuated area until the Fire Department arrives and assumes command.
- The Onsite O&M Primary Contact will issue an "All Clear" only when the Fire Department informs them that it is safe to do so.

Large Stage Fires

In the event of a large stage fire at the project:

- The person discovering the fire should immediately contact the Onsite O&M Primary Contact. If the fire cannot be readily extinguished, they will call 911 to report the fire.
- All personnel should be removed from the immediate danger area in anticipation of an evacuation.
- The Onsite O&M Primary Contact will respond to the scene and ensure that the fire department has been dispatched. They will then determine evacuation needs, recruit/dispatch employees to assist with the evacuation and issue the following statement over the radio: "Attention, there is a fire emergency at (location name). Please evacuate (the affected area) and report to (designated meeting area).

- At this point, all employees in the affected area will stop work immediately, take steps to safely shut down equipment, exit the evacuation area, and report to the designated meeting area.
- In this scenario, fire extinguishers are to be used for escape purposes only.
- The Onsite O&M Primary Contact will take the necessary steps to ensure that no employee re-enters the evacuated area until the Fire Department arrives and assumes command.
- No employee is required or permitted to place themselves in harm's way in order to facilitate extinguishment, evacuation, or rescue. All rescue operations will be performed by trained professionals upon their arrival.
- The Onsite O&M Primary Contact will issue an "All Clear" only when the Fire Department informs them that it is safe to do so.

Vegetation Fire and Procedures

The site will be largely free of combustible vegetation with only a ground cover of maintained vegetation adjacent and beneath the solar tracker. (Figure 1) Flying embers from off-site fire may inundate the Project area during fire events. The modified fuel areas and project features will resist ignition from ember showers. Ignition of the ground cover could result in a fast moving, but lower intensity fire that burn in a patchy manner on the site beneath the modules. The vegetation on the Gen-tie line right-of-way will be cleared around poles and access roads, where not prohibited by environmental constraints. This type of fire would be relatively short-duration as vegetative fuels are consumed rapidly. There would not be a sustained source of heat and or flame as there would be with surrounding wild fires.

Typical Ground Cover under Solar Arrays

In the event of a vegetation fire under or near the modules or inverters:

- DO NOT attempt to extinguish the flames with water or other chemicals as an electric shock or arc could occur.
- If possible, safely attempt to shut down power at the inverter using the DC disconnect
- Let the fire burn vegetation and self-extinguish
- If flames continue away from modules or inverters, attempt to extinguish flames.

Correct action is taken when response is not in accordance with documentation, plant integrity or personnel safety requirements

Job site fire rules are to be posted on project the bulletin board along with OSHA compliance postings and first aid and site-specific project information (bulletin board to be located at the O&M office and accessible to all employees).

Personnel shall be trained in the practices of the fire safety plan relevant to their duties. Construction and maintenance personnel shall be trained and equipped to extinguish small fires to prevent them from growing into more serious threats. Confirm all employees understand the function and elements of the fire safety plan, including types of potential emergencies, reporting procedures, evacuation plans, and shutdown procedures. Review any special hazards that might occur at the North Star site, such as flammable materials, fuel storage, toxic chemicals, and water reactive substances.

Fire safety training will occur during the site safety training. Every employee must take this training before starting work. Training to include:

- ✓ Employee roles and responsibilities
- ✓ Recognition of potential fire hazards
- ✓ Alarm system and evacuation routes
- ✓ Location and operation of manually operated equipment (fire extinguishers)
- ✓ Emergency response procedures
- ✓ Emergency shutdown procedures
- ✓ Information regarding specific materials to which employees may be exposed
- ✓ Review OSHA requirements contained in Emergency Action Plans
- ✓ Review OSHA requirements contained in Fire Prevention Plans
- ✓ The location of the company FPP and how it can be accessed
- ✓ Good fire-prevention housekeeping practices and equipment maintenance

Written documentation of the training received by each employee must be maintained.

Use of Portable Fire Extinguishers

- ✓ A minimum of one portable fire extinguisher should be provided within 200 feet of anywhere in the work area during construction or heavy maintenance
- ✓ Fire extinguishers should be inspected monthly
- ✓ Fire extinguishers should not be obstructed and should be in conspicuous locations

Site Maintenance & Housekeeping

- ✓ Combustible material should not be stored in mechanical rooms, electrical equipment rooms or the SCADA buildings
- ✓ Outside dumpsters should be kept at least 5 feet away from combustible materials and the lid should be kept closed
- ✓ Storage is not allowed in electrical equipment rooms, or near electrical panels
- ✓ Electrical panel openings must be covered
- ✓ Power strips must be plugged directly into an outlet and NOT daisy-chained and should be for temporary use only
- ✓ Extension cords and flexible cords should not be substituted for permanent

Equipment Fire Safety

- ✓ All internal combustion engines, both stationary and mobile, shall be equipped with spark arresters. Spark arresters shall be in good working order
- ✓ Light trucks and cars with factory-installed (type) mufflers shall be used only on roads where the roadway is cleared of vegetation. These vehicle types shall maintain their factory-installed (type) mufflers in good condition
- ✓ Equipment parking areas and small stationary engine sites shall be cleared of all extraneous flammable materials
- ✓ The project proponent shall make an effort to restrict the use of chainsaws, chippers, vegetation masticators, grinders, drill rigs, tractors, torches, and explosives to periods outside of the official fire season. When the above tools are used, water tanks equipped with hoses, fire rakes, and axes shall be easily accessible to personnel.

Emergency Response

Project personnel will meet with local emergency response groups to review the Fire Safety Plan, discuss the type of work taking place, duration of project schedule and emergency procedures.

Emergency Procedure

The following course of action should be taken if an emergency situation develops:

- ✓ Evacuation procedures and assembly are contained in the Evacuation plan, which will be posted in all office trailers. Maintain site security and control.
- ✓ Notify proper emergency services for assistance. Dial 911 or direct-dial emergency contact numbers if possible. Emergency numbers shall be posted at each office trailer.
- ✓ Notify Onsite O&M Primary Contact and all affected personnel at the site through use of site radio or other communication devices.
- ✓ Once emergency personnel have been notified, an employee will then be designated to meet the emergency personnel at the construction trailer area and then guide them to incident location.

- ✓ Only after emergency is declared over by the Onsite O&M Primary Contact can all other radio communication resume.
- ✓ Prepare a summary of the incident as soon as possible and no later than 24 hours after the incident.

Plant is returned to required operational status upon completion of test

After the completion of test, the faulty parts are either serviced or replaced and the plant is returned to the operational status with the optimal generation of required power.

REPORT OPERATIONS AGAINST STRATEGY REQUIREMENTS

Data is collected and processed for review against the established strategy

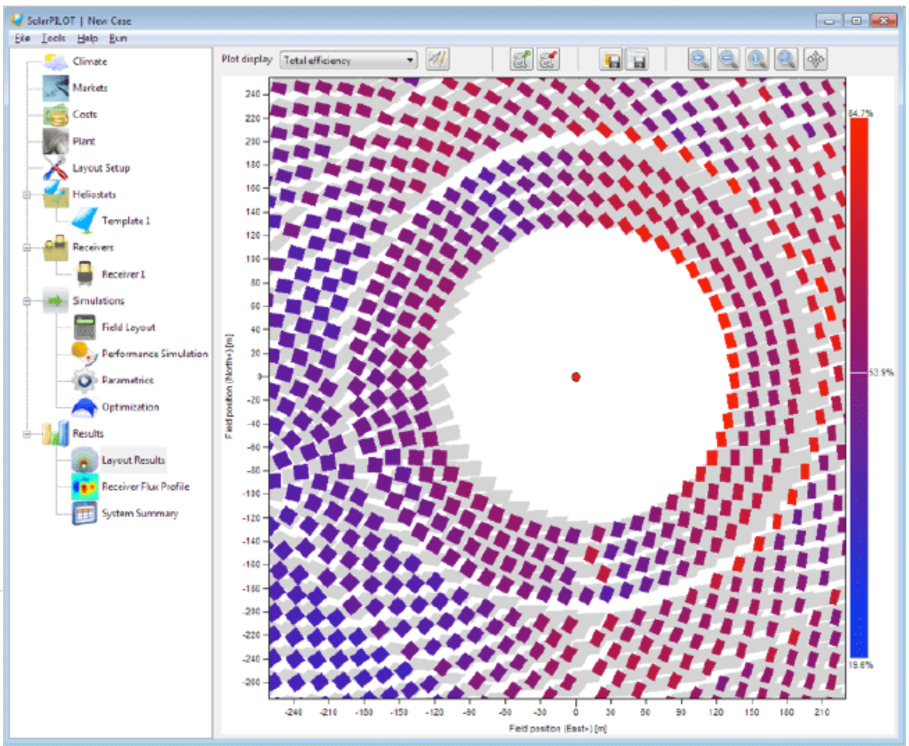
SolarPACES

Solar Power and Chemical Energy Systems (SolarPACES) worldwide database of CSP projects across 19 member countries. SolarPACES is a program of the International Energy Agency, and the database includes CSP plants that are operational, under construction, and under development. Technologies include parabolic trough, linear Fresnel reflector, power tower, and dish/engine systems. Individual project profiles include background information, project participants, and power plant configuration data.

The Solana Generating Station in Gila Bend, Arizona, is included in the SolarPACES database. Photo by Dennis Schroeder, NREL

Solar PILOT

The Solar Power tower Integrated Layout and Optimization

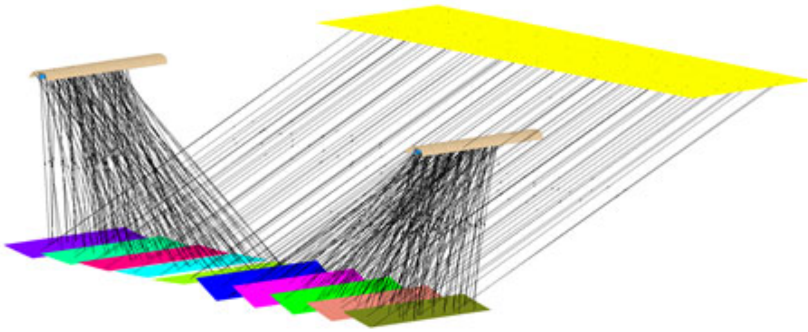


Tool (SolarPILOT™) is NREL-developed open-source software that generates and characterizes the performance and layout requirements for power tower systems. SolarPILOT is used by researchers, industry technology developers, and academics to evaluate technology performance, quantify the value of research findings, and provide third-party, independent validation for privately developed tools.

SolarPILOT allows engineers to design and optimize complex solar-field configurations for power tower systems.

SolTrace

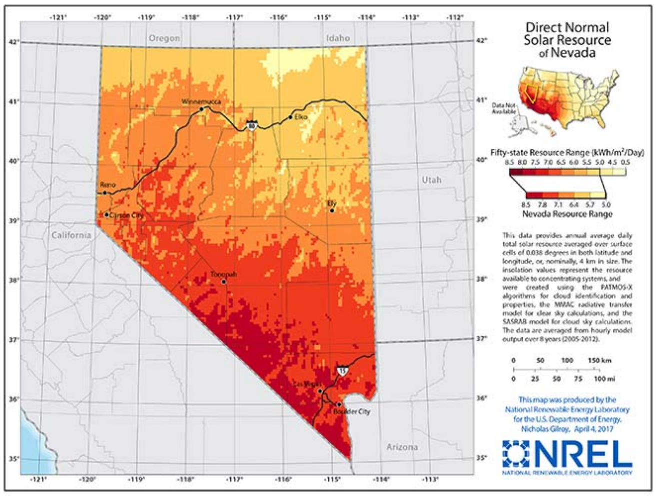
SolTrace is an NREL-developed open source software tool that models and analyzes optical performance of CSP systems. Although ideally suited for modeling complex optical systems within solar applications, the code can also be used to model and characterize many general optical systems.



SolTrace uses a Monte Carlo ray-trace method, shown here being applied to a linear Fresnel CSP configuration.

Solar Maps

NREL helps create and maintain solar maps of average daily total resource information, including direct-normal irradiance and global-horizontal irradiance maps of the 50 U.S. states. Additionally, the laboratory creates direct-normal solar radiation maps for the U.S. Southwest states that are filtered by solar resource (excluding areas below 6 kWh/m^2/day), land availability (excluding national parks and other areas off limits to development), and land slope (excluding land having slopes >1% or >3%). Filters help identify the most economically suitable lands available for deploying large-scale CSP plants.

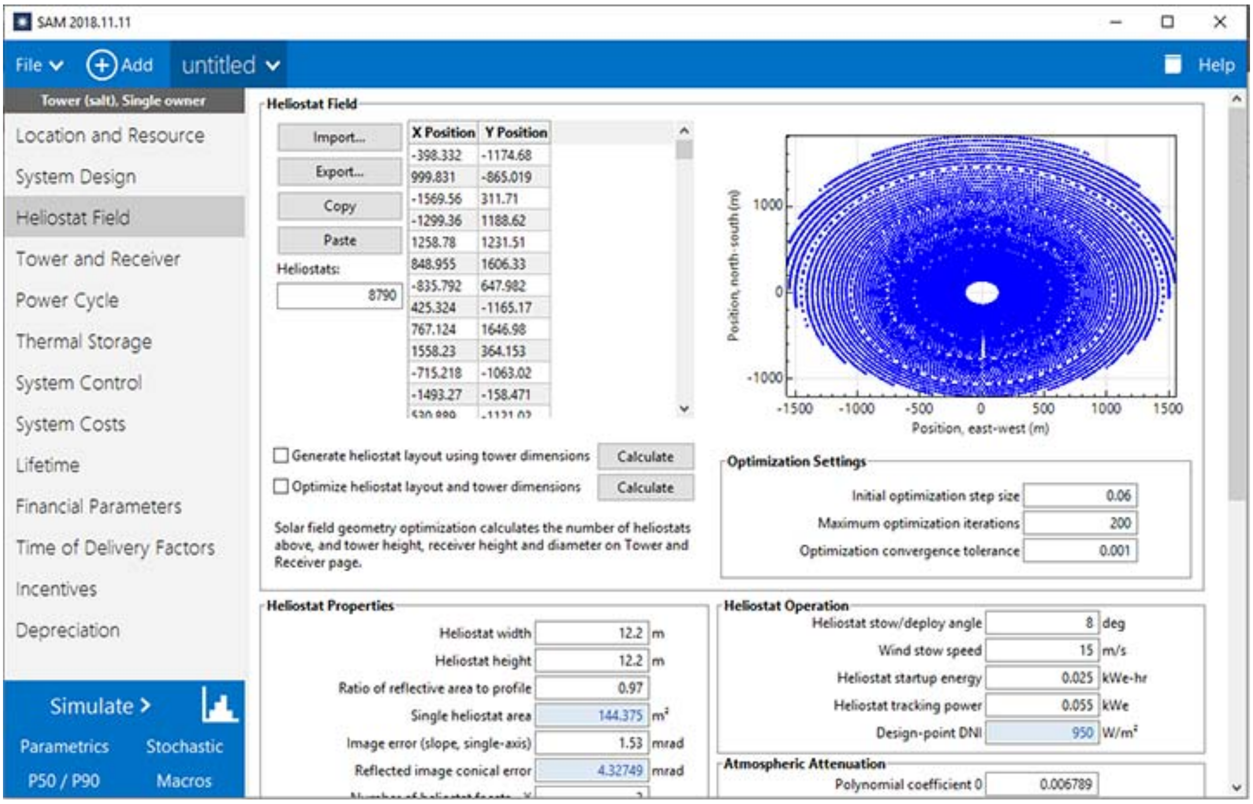


NREL also manages and updates the National Solar Radiation Database, a free and serially complete collection of meteorological and solar irradiance data sets for the United States and a growing list of international locations.

Direct normal irradiance map of Nevada.

System Advisor Model

The System Advisor Model (SAM) is a free techno-economic software modeling tool for predicting the performance and cost of grid-connected renewable energy projects at specific sites. SAM produces sub-hourly energy output and calculates detailed financial metrics based on installation and operating costs and system design parameters that the user inputs to the model.



SAM users can input a number of parameters to derive detailed project performance and cost analyses.

Plant operation and/or condition is reported against statutory and enterprise requirements taking into account constraints, budget requirements and performance indicators

A monitoring system is an essential part of a PV plant. Monitoring devices are crucial for the calculation of liquidated damages (LDs) and confirmation that the EPC contractor has fulfilled its obligations. Automatic data acquisition and monitoring technology is also essential during the operational phase in order to maintain a high level of performance, reduce downtime and ensure rapid fault detection.

A monitoring system allows the yield of the plant to be monitored and compared with theoretical calculations and raise warnings on a daily basis if there is a performance shortfall. Faults can therefore be detected and rectified before they have an appreciable effect on production. Without a reliable monitoring system it can take many months for a poorly performing plant to be identified. This can lead to unnecessary revenue loss.

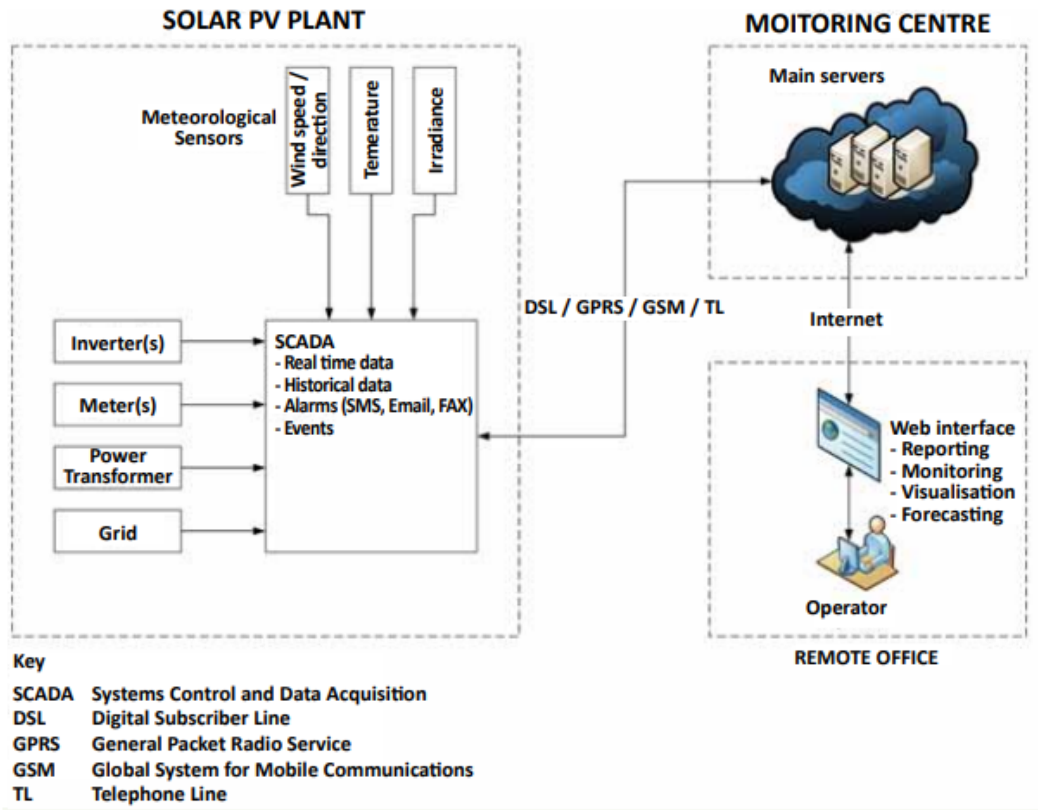
The key to a reliable monitoring and fault detection methodology is to have good simultaneous measurements of the solar irradiance, environmental conditions and plant power output. This is achieved by incorporating a weather station on site to measure the plane of array irradiance, module and ambient temperature, and preferably global horizontal irradiance, humidity and wind speed.

In large-scale solar PV power plants, voltage and current will typically be monitored at the inverter, combiner box or string level, each offering more granularity than the previous. Monitoring at the inverter level is the least complex system to install. However it only offers an overview of the plant's performance, while the other two options, although more expensive, provide more detailed information on the system components' performance and improved fault detection and identification.

Data from the weather station, inverters, combiner boxes, meters and transformers will be collected in data loggers and passed to a monitoring station, typically via Ethernet, CAT5/6, RS485 or RS232 cables. Communication protocols are varied, although the most commonly used worldwide are Modbus, TCP/IP and DNP3. If more than one communications protocol is considered for a monitoring system, protocol converters can be used.

Figure illustrates the architecture of an internet portalbased monitoring system, which may include functionality for:

- ✓ Operations management: The performance management (either onsite or remote) of the solar PV power plant to enable the monitoring of inverters or strings at the combiner box level.



PV System Monitoring Schematic

- ✓ Alarm management: Flagging any element of the power plant that falls outside pre-determined performance bands. Failure or error messages can be automatically generated and sent to the power plant service team via fax, email or text message.
- ✓ Reporting: The generation of yield reports detailing individual component performance, and benchmarking the reports against those of other components or locations.

QUALITY BENCHMARKS monitoring systems should be based on commercially available software/hardware that is supplied with user manuals and appropriate technical support. Depending on the size and type of the plant, minimum parameters to be measured include:

- Plane of array irradiance and horizontal plane irradiance: Measured using secondary standard pyranometers with a measurement tolerance within ±2 percent.46 Plane of array pyranometers are essential for contractually-binding performance ratio (PR) calculations, while horizontal plane pyranometers are useful in order to compare measured irradiation with global horizontal irradiation resource predictions. It is considered best practice to install irradiation sensors at a variety of locations within multi-megawatt plants, while avoiding locations that are susceptible to shading. Table 14 gives a rule of thumb for the number of pyranometers recommended according to the plant capacity.
- Ambient temperature: Measured in a location representative of site conditions with accuracy better than ±1°C. Ideally, temperature sensors should be placed next to the irradiation sensors, particularly if the PR at provisional acceptance is calculated using a temperature compensation factor (see Section 9: EPC Contracts).
- Module temperature: Measured with accuracy better than ±1°C, PT1000 sensors should be thermally

Plant DC Capacity (MWp)	< 1	1–5	5–10	10–20	> 20
Number of Plane of Array Pyranometers	0	2	2	3	4
Number of Horizontal Pyranometers	0	0	1	1	1

Recommended Number of Pyranometers Depending on Plant Capacity

Abnormal operating conditions are reported

Changes to the strategy are suggested in accordance with information received

The performance of a PV power plant may be optimized by a combination of several enabling factors: premium modules and inverters, a good system design with high quality and correctly-installed components and a good preventative maintenance and monitoring regime leading to low operational faults. The aim is to minimize losses. Measures to achieve this are described as follows. Reducing the total loss increases the annual energy yield and hence the revenue, though in some cases it may increase the cost of the plant. Interestingly, efforts to reduce one type of loss may be antagonistic to efforts to reduce losses of a different type. It is the skill of the plant designer to make suitable compromises that result in a plant with a high performance at a reasonable cost according to the local conditions. The ultimate aim of the designer is to create a plant that maximizes financial returns by minimizing the levelised cost of electricity (LCOE).

Shading

- Choose a location without shading obstacles.
- Ensure that the plant has sufficient space to reduce shading between modules.
- Have a robust O&M strategy that removes the risk of shading due to vegetation growth.

Incident angle

- Use anti-reflection coatings, textured glass, or tracking.

Low irradiance

- Use modules with good performance at low light levels.

Module temperature

- Choose modules with an improved temperature coefficient for power at high ambient temperature locations.

Soiling

- Choose modules less sensitive to shading.
- Ensure a suitable O&M contract that includes an appropriate cleaning regiment for the site conditions.

Module quality

- Choose modules with a low tolerance or positive tolerance.

Module mismatch

- Sort modules with similar characteristics into series strings where possible.
- Avoid partial shading of a string.
- Avoid variations in module tilt angle and orientation within the same string.

DC wiring resistance

- Use appropriately dimensioned cable.
- Reduce the length of DC cabling.

Inverter performance

- Choose correctly sized, highly efficient inverters.

AC losses

- Use correctly dimensioned cable.
- Reduce the length of AC cabling.
- Use high-efficiency transformers.

Plant downtime

- Use a robust monitoring system that can identify faults quickly.
- Choose an O&M contractor with good repair response time.
- Keep spares holdings.

Grid availability

- Install PV plant capacity in areas where the grid is strong and has the potential to absorb PV power.

Degradation

- Choose modules with a low degradation rate and a linear power guarantee.

MPP tracking

- Choose high-efficiency inverters with maximum power point tracking technology on multiple inputs.
- Avoid module mismatch.

Curtailment of tracking

- Ensure that tracking systems are suitable for the wind loads to which they will be subjected.

REPORT OPERATION AGAINST STRATEGY REQUIREMENTS

Power generation is constantly monitored and evaluated for performance against the developed strategy requirements.

Referred evaluation will be reported to the relevant stakeholder for continued monitoring and improvement. As the plant operation is monitored on regular basis, solar power generation system shall also be monitored and corrective actions will be taken on timely basis for enhanced and effective operation of the system.

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