



NATIONAL CERTIFICATE IV
**SEWERAGE SYSTEM
OPERATION &
MAINTENANCE**

Student
Learning
Materials

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1. WRITE 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.)

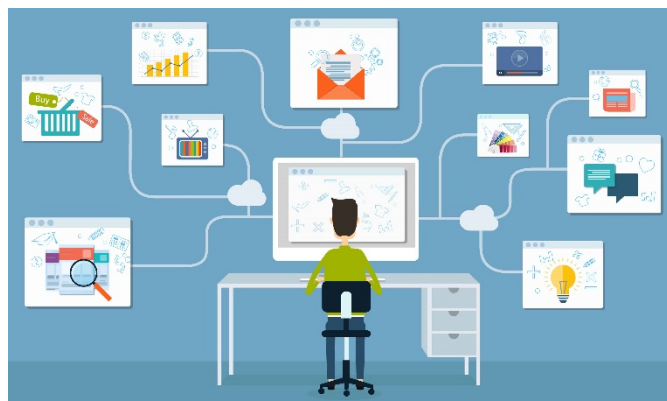
Where the research question appears in the proposal is something each writer must decide. It could appear in the introduction; it could follow the introduction or the background or the literature review or it could appear within any of the above sections. Just don't leave it until the reference section!

4. Method (HOW? WHO? WHERE?)

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

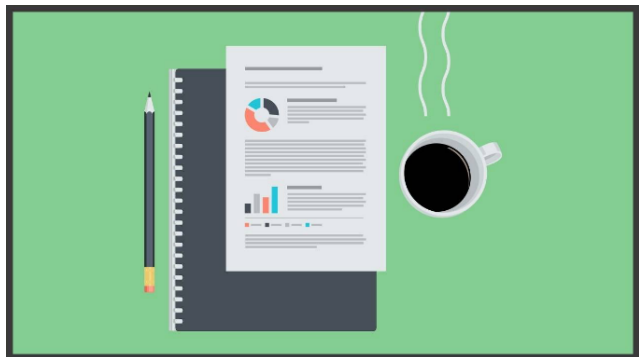
- ✓ Task 3 Field Visits
- ✓ Task 4 Preparation of First Draft
- ✓ Task 5 Preparation of Second Draft
- ✓ Task 6 Preparation of Final Draft

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:

$$\begin{aligned} & \text{Task 1} + 25\% \text{ of sub-tasks 2a, 2b, and 2c} \\ & = 10\% + 0.25 \times (16\% + 16\% + 16\%) \\ & = 22\% \end{aligned}$$

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".

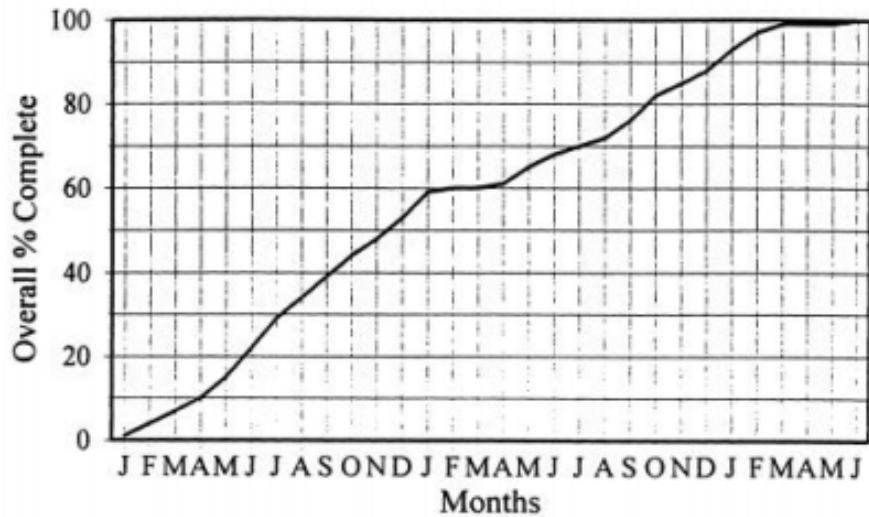


Figure B-7: Planned Progress

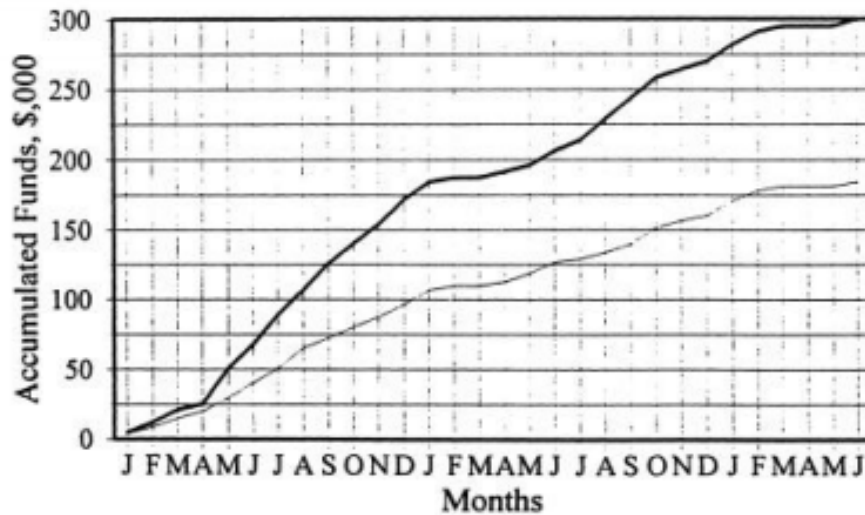


Figure B-8: Anticipated Expenses

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

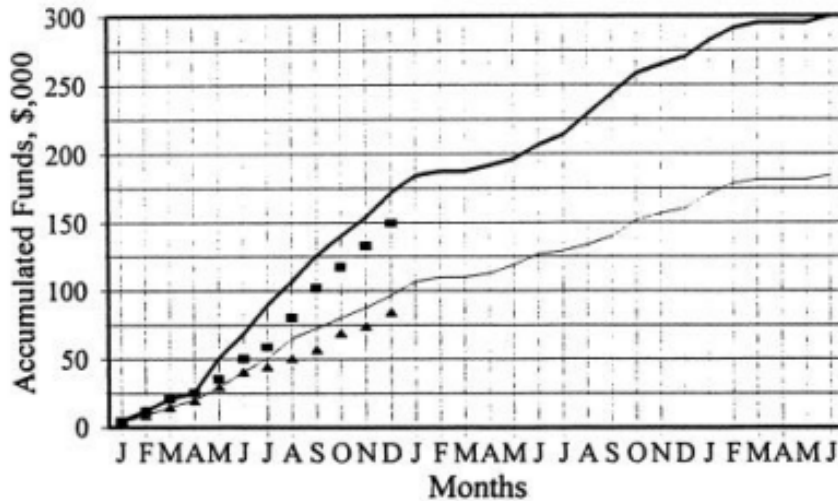


Figure B-11: Expenditures to December, 1996

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 behaviour, 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:

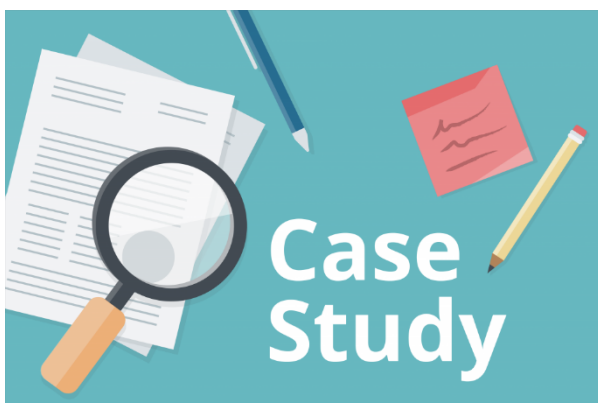
$$NPV = \sum_{i=1}^N \frac{(Bi - Ci)}{(1+r)^i}$$

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.

<p>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.</p>	<p>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.</p>
<p>Conclusions</p>	<p>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.</p>
<p>Recommendations (note: not all reports give recommendations)</p>	<p>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.</p>
<p>References (Not part of the word count)</p>	<p>A list of the sources that are used in and referred to in the report. Use APA referencing style.</p>
<p>Bibliography (Not always required)</p>	<p>Lists any sources that were read for the research but were not cited in the report. (Bibliography is not included in the word count).</p>
<p>Appendices (Not always required)</p>	<p>Additional relevant information. May include interview questions, surveys, glossary etc. (Appendices are not included in the word count).</p>

2. APPLY AND MAINTAIN OCCUPATIONAL HEALTH AND SAFETY

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.

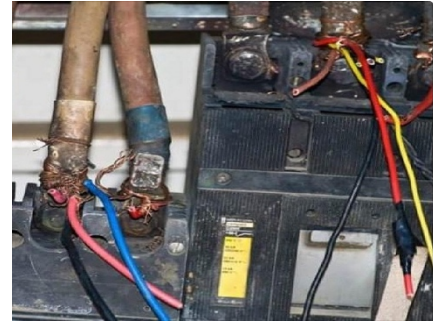
Anyone known to be under the influence of drugs or intoxicating substances which impair the employee's ability to safely perform the assigned duties shall not be allowed on the job while in that condition. If you are taking medication prescribed by a physician or taking over-the-counter medication, be 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.

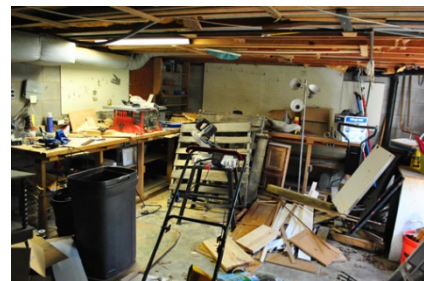


If you are injured on the job, report the injury immediately. Don't wait. Report the injury when it occurs, even if you believe that medical treatment is not necessary. If medical treatment is required, it will be provided.

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.



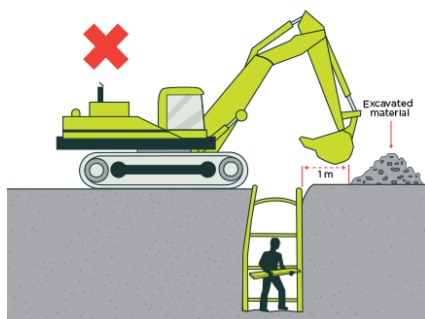
Vices must be equipped with handles and not used to punch or pry. A screwdriver should not be used as a chisel. Portable electric tools shall not be lifted or loaded by means of a power cord. Use ropes, not the power cord for lifting or lowering electrical tools. Before electrical tools are used, they 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, minimizing 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

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.

How to find hazards

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, and 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 shift work). 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.

RISK ASSESSMENT

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.

Work Out How Hazards 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?

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

Table 1: Risk matrix

High	Yellow	Orange	Red
Med.	Light Yellow	Orange	Orange
Low	White	Light Yellow	Yellow
	Low	Med.	High

Probability

Severity

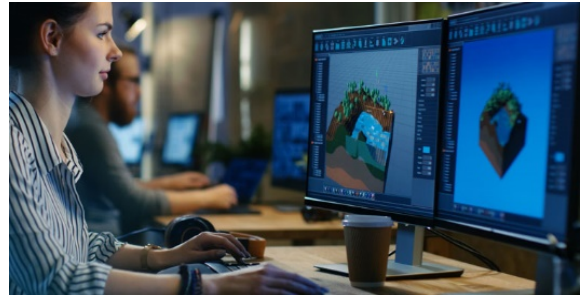
The level of risk will increase as the likelihood of harm and its severity increases.

3. CARRY OUT DATA ENTRY AND RETRIEVAL PROCEDURES

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.

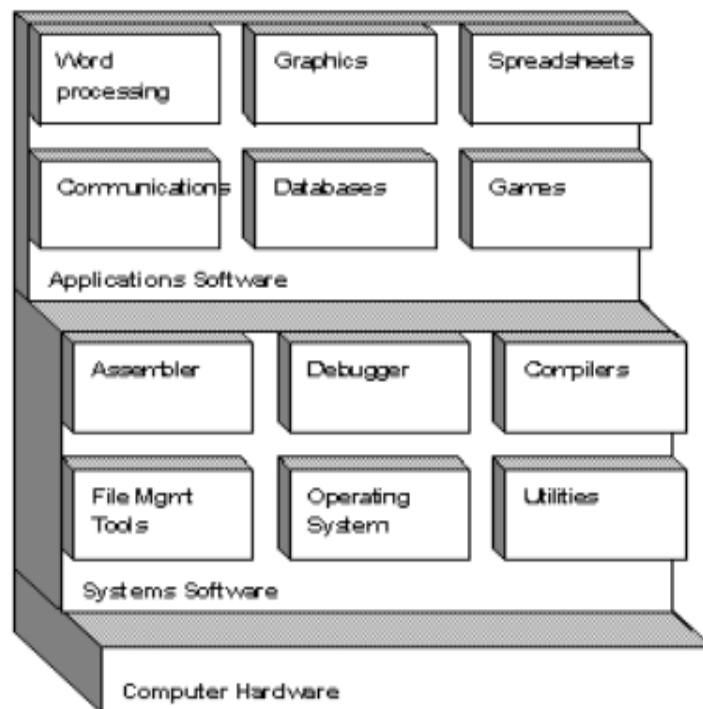


Although computers are used to schedule airlines, predict the weather, play music, control space stations and keep the wheels of the world economy turning; essentially computers do only four things:

- ✓ 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

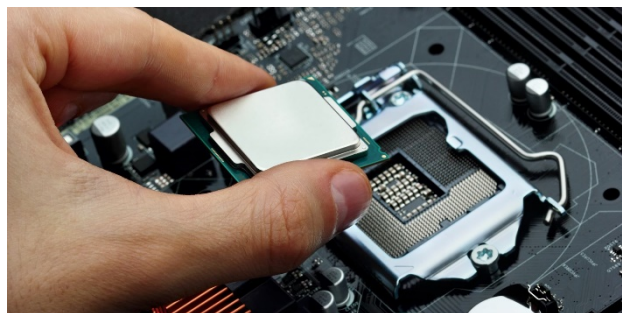
Every computer system contains hardware components that specialise in each of these four functions:

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.

Customise 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:

Are you married?

Yes

No

What languages do you speak?

Englisch

French

German

Spanish

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:

What Is Your Educational Background?

- 1 - Elementary
- 2 - High School
- 3 - Undegraduate
- 4 - Graduate

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:

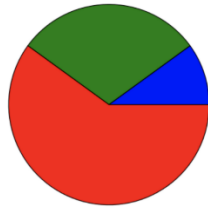
Frequencies: The Frequency is the rate at which something occurs over a period of time or within a dataset.

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)

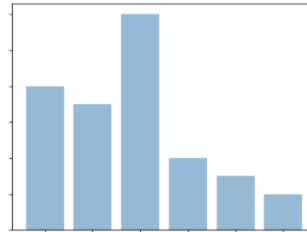
Percentage.

Visualisation Methods: To visualise nominal data you can use a pie chart or a bar chart.

Pie Chart



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.

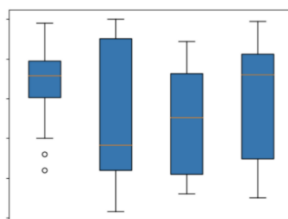
Continuous Data

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.

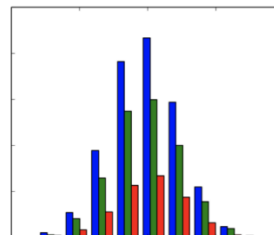
Visualisation Methods:

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.

Boxplot



Histogram



RETRIEVE 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 assigned 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 lead 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 deal 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.

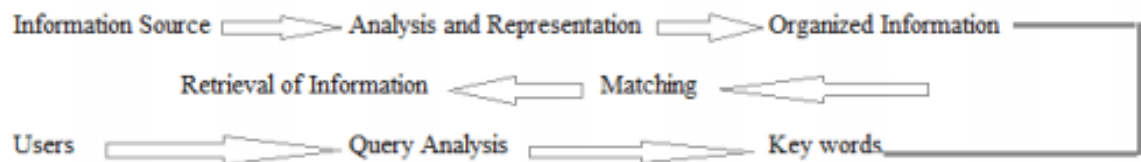
- ✓ Retrieve the information that is relevant.
- ✓ Necessary adjustments in system based on feedback from the user.

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:

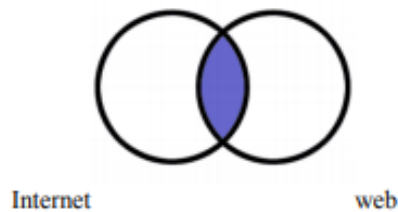
1. Offline Search: In offline search, users can get the required information with or without the help of computer and internet for example: libraries, CD-ROM etc.
- ✓ Online Search: means the search of a remotely located database through interactive communications with the help of computer and communication channel. Online databases can be access through vendor or directly. For example: OPAC, Databases, Internet etc.

Retrieval Techniques:

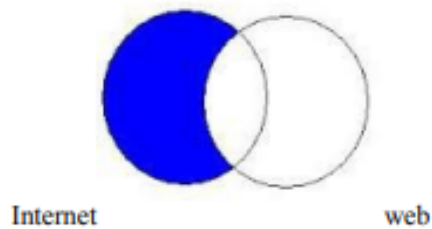
Retrieval techniques are designed to help users to locate the information they need effectively and efficiently. These techniques help users to find out the required information easily. There are two types of retrieval techniques.

1. Basic Retrieval Techniques:

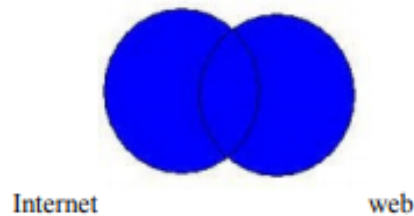
- a. Boolean Searching George Boole (1815-1864) developed AND, OR, NOT Boolean operators. By using these techniques user can narrow down their search to get the required information.
 - i. AND: It includes addition of two different concepts for narrowing down the search. It retrieves all those items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

Greater than or equal to (\geq)

Less than or equal to (\leq)

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 terms 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:

3. 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 SERVICES

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

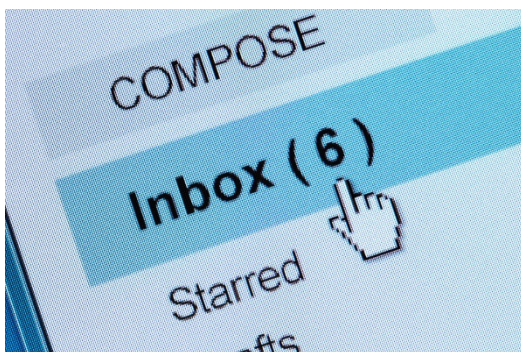
E-commerce or Electronic-Commerce means online transactions of business. In this, the vendor and customer conduct a transaction sitting at different geographical locations, connected through the Internet. The customer need not strain himself by visiting a number of shops outside in scorching heat or 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.

E-MAIL ACCOUNTS

RECEIVE MAILES



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.

SENDING E-MAILS

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:

4. Click on the 'Compose' option.
5. 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.
6. Write in the message in the text box as indicated in the figure
7. 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:

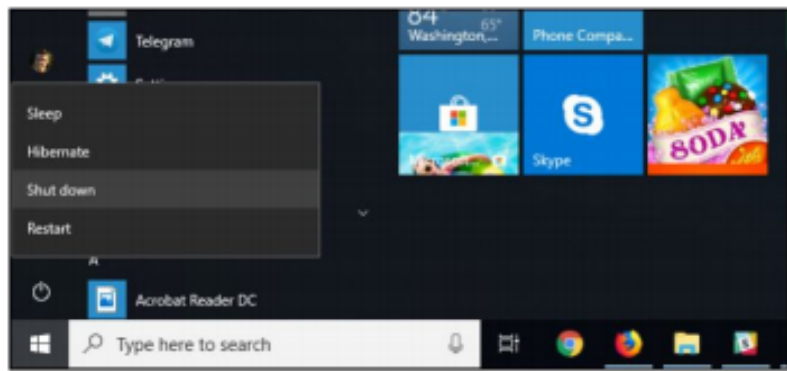
8. Click the Windows Icon at the lower left side of the screen.
9. Click the Shutdown button.

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:

10. Click the Windows Icon at the lower left side of the screen.
11. 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.
12. From the Windows desktop, press Alt+F4 to get the Shut down Windows screen and select Shut down.



4. APPLY MATHEMATICS FOR WATER OPERATIONS

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:

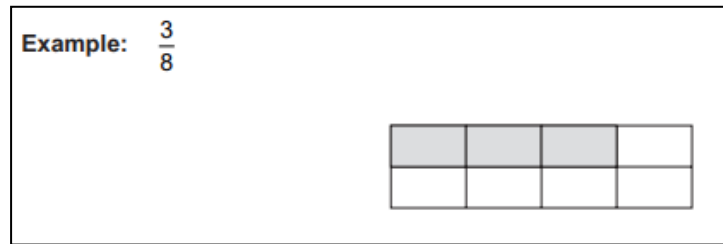
1. Common fractions (fractions)
Decimal fractions (decimals)

Common fraction examples are: $\frac{1}{2}$, $\frac{3}{4}$, $\frac{5}{8}$

Decimal fraction examples are: .50, .75, .625

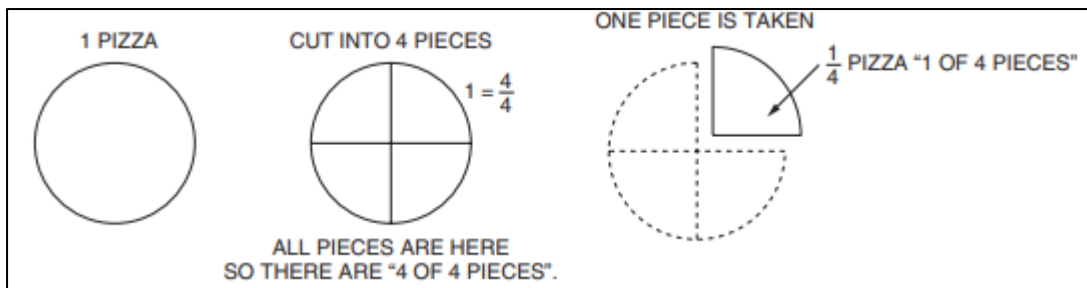
Basic principles

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.



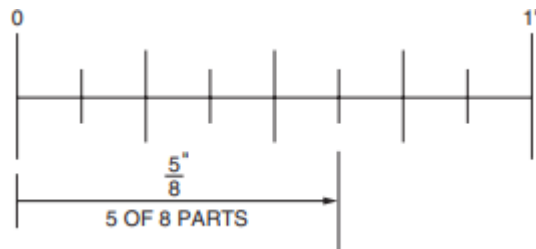
3 is the numerator, and 8 is the denominator. This fraction shows that an object has been divided into 8 equal pieces, and that 3 of those 8 pieces are shaded.

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 $\frac{1}{4}$, ("1 of 4 pieces").

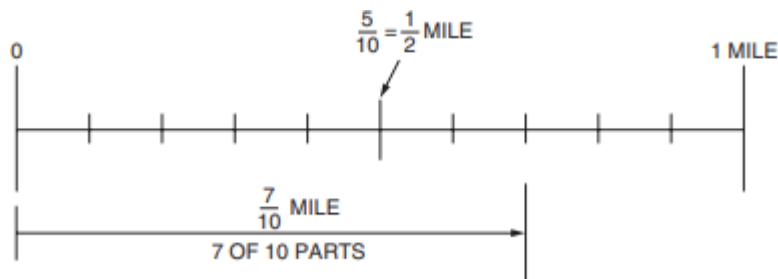


$\frac{3}{4}$ indicates that "3 of 4 pieces" are still available.

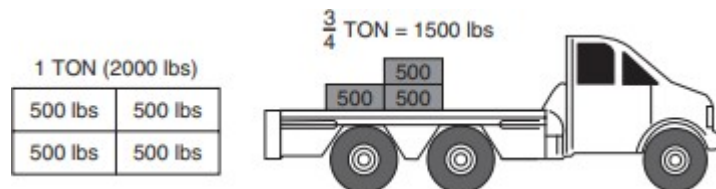
1. $\frac{5}{8}$ " (five-eighths inch) shows that an inch is divided into 8 parts and that 5 of those 8 parts have been measured.



2. $\frac{7}{10}$ of a mile (seven-tenths mile) shows that a mile is divided into 10 parts, and we've measured 7 of those 10 parts.



$\frac{3}{4}$ 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 $\frac{5}{8}$, $\frac{7}{10}$, and $\frac{3}{4}$ 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

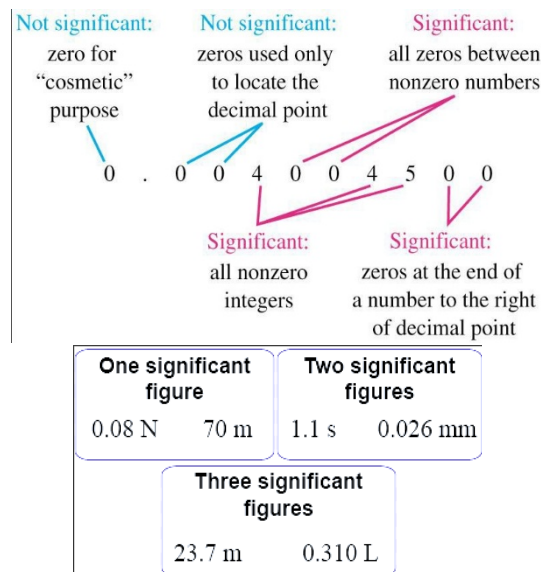
.50 = .500

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

$$9411 \rightarrow 9000$$

$$3849 \rightarrow 4000$$

$$9000 + 4000 = 13,000$$

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 center 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 × 10 ⁹ m
Mega	M	10 ⁶	1 megameter (Mm) = 1 × 10 ⁶ m
Kilo	k	10 ³	1 kilometer (km) = 1 × 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 × 10 ⁻⁶ m
Nano	n	10 ⁻⁹	1 nanometer (nm) = 1 × 10 ⁻⁹ m
Pico	p	10 ⁻¹²	1 picometer (pm) = 1 × 10 ⁻¹² m
Femto	f	10 ⁻¹⁵	1 femtometer (fm) = 1 × 10 ⁻¹⁵ m

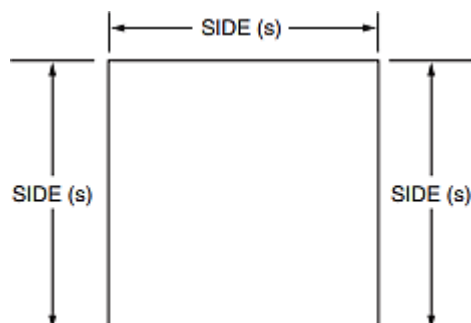
Table 1.2 Derived quantities and their units

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

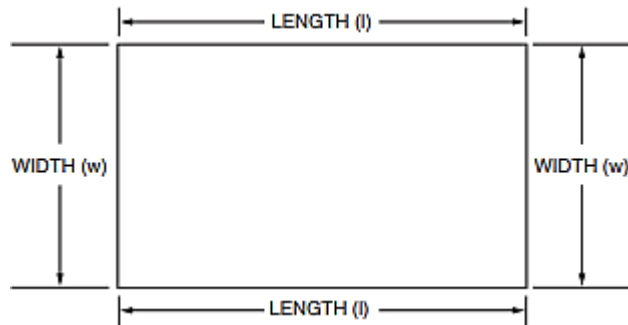
The distance around a figure is called the “perimeter.” Square

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° .

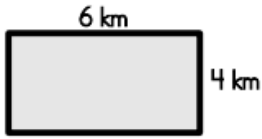


Area of Square

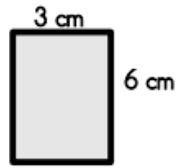
Formula: $A = \text{Side} \times \text{Side}$

Area of Rectangle Formula: $A = L \times H$

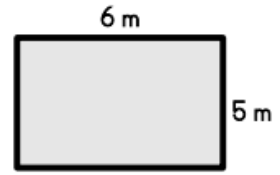
Find the area of each rectangle by multiplying.



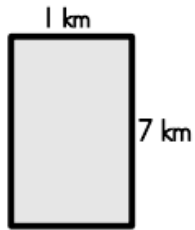
area = _____



area = _____



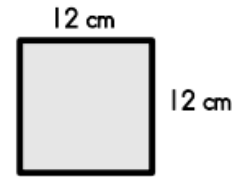
area = _____



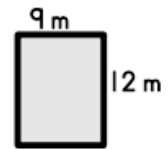
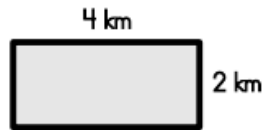
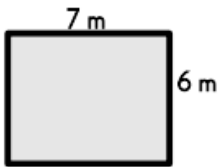
area = _____



area = _____



area = _____

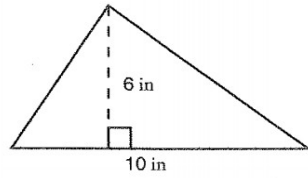


Area of triangle

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

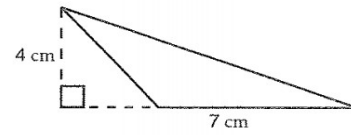
Examples: Find the area.

(a)



$$A = \frac{1}{2}bh$$
$$A = \frac{1}{2}(10)(6)$$
$$A = 30 \text{ in}^2$$

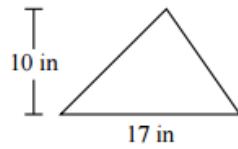
(b)



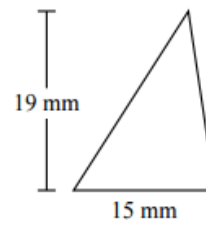
$$A = \frac{1}{2}bh$$
$$A = \frac{1}{2}(7)(4)$$
$$A = 14 \text{ cm}^2$$

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

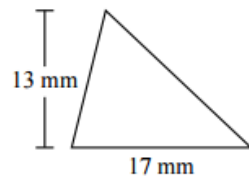
1)



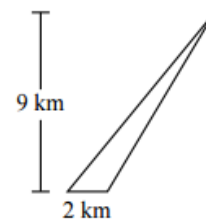
2)



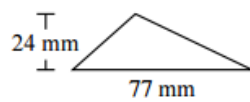
3)



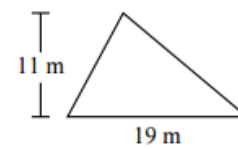
4)



5)

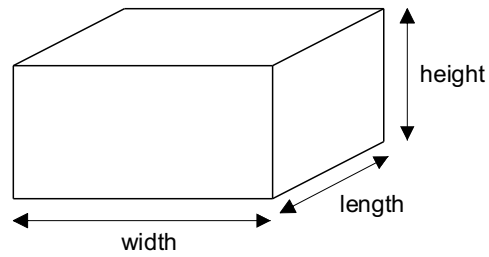


6)

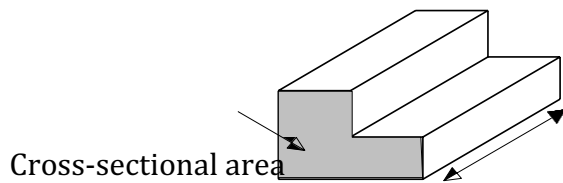


Volume and Surface Area

Volume of cuboid = length \times width \times height



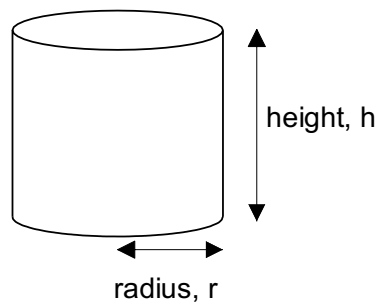
Volume of prism = cross-sectional area \times length



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:

$$\text{Volume} = 15 \times 12 \times 8 = 1440 \text{ cm}^3.$$

As 1 litre = 1000 cm³, the capacity of the cuboid = 1.44 litres.

Example: 2

A cylinder has a volume of 965 cm³. 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.

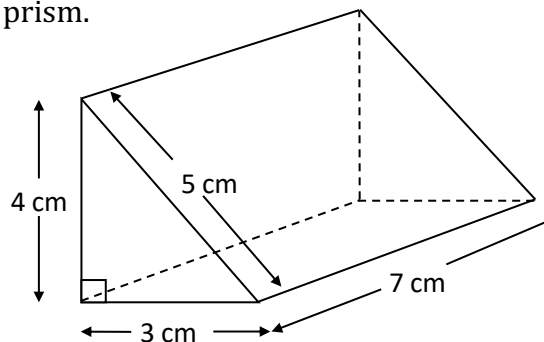
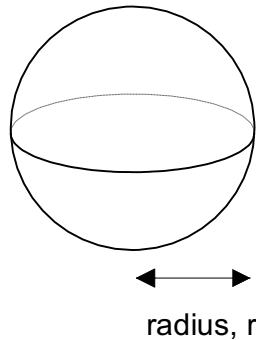


Diagram **NOT** accurately drawn

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:

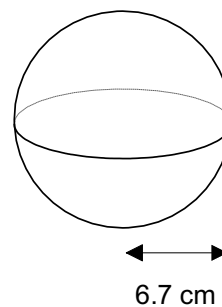
Substitute $r = 6.7 \text{ cm}$ into the formula

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

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

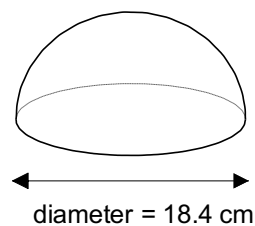
$$V = 1259.833 \text{ (remember to use the cube button on your calculator)}$$

$$V = 1260 \text{ cm}^3 \text{ (to 3 SF)}$$



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

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

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

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

$$= 1630 \text{ cm}^3 \quad (\text{to 3 SF})$$

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 $86.5 = 4.18879r^3$

i.e. $20.65035 = r^3$

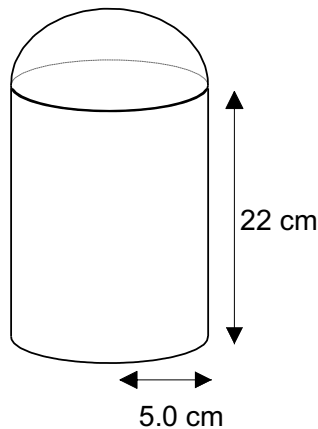
So $r = 2.74 \text{ cm}$ (to 3 SF) (cube rooting)

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:

$$\begin{aligned}\text{Volume of cylinder} &= \pi r^2 h \\ &= \pi \times 5^2 \times 22 \\ &= 1728 \text{ cm}^3 \text{ (to nearest whole number)}\end{aligned}$$

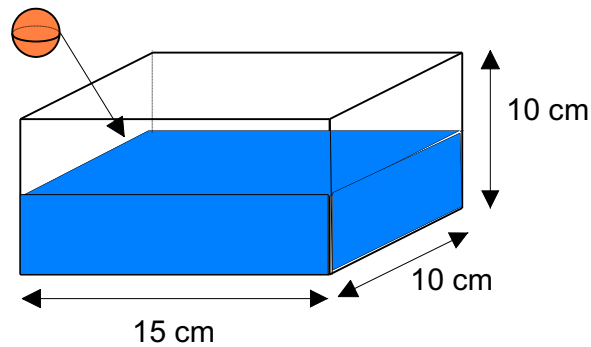
The hemisphere must also have radius 5 cm.

$$\begin{aligned}\text{Volume of the hemisphere} &= \frac{1}{2} \times \text{volume of sphere} \\ &= \frac{1}{2} \times \frac{4}{3} \pi r^3 \\ &= \frac{1}{2} \times \frac{4}{3} \times \pi \times 5^3 \\ &= 262 \text{ cm}^3\end{aligned}$$

Therefore total volume of the object = $1728 + 262 = 1990 \text{ cm}^3$.

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.

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

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.

$$\text{So } 15 \times 10 \times h = 33.51$$

$$\text{i.e. } h = 0.22 \text{ cm}$$

The water rises by 0.22 cm.

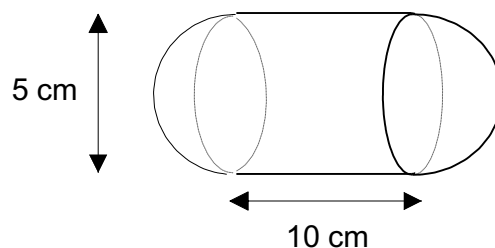
Examination question

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.

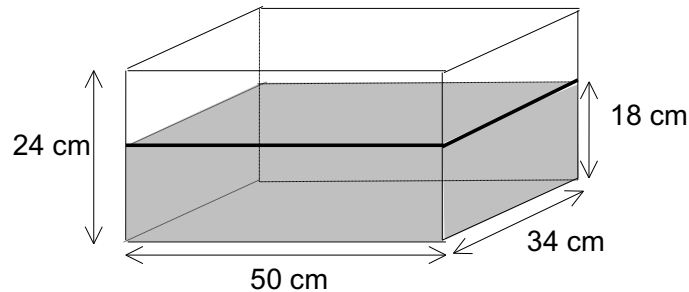
The length of the cylindrical part of the toy is 10 cm.

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



Examination question

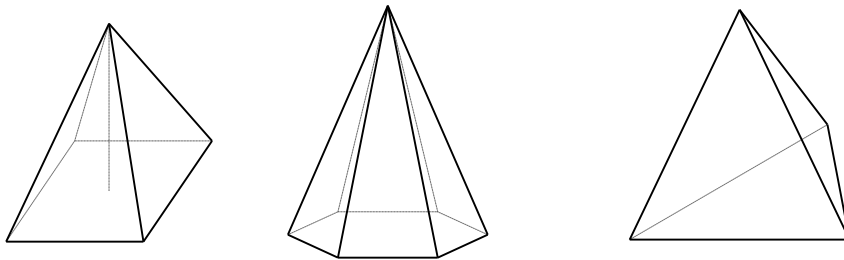
A water tank is 50 cm long, 34 cm wide and 24 cm high. It contains water to a depth of 18 cm.



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

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

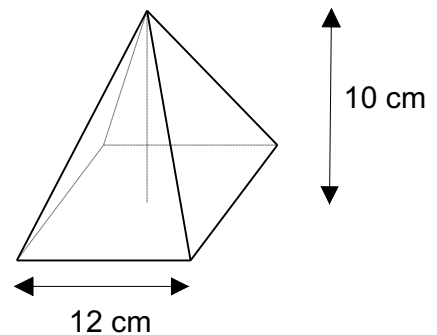
Example:

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 $12 \times 12 = 144 \text{ cm}^2$

So, the volume of the pyramid is:



$$\text{Volume} = \frac{1}{3} \times 144 \times 10$$

$$= 48 \times 10$$

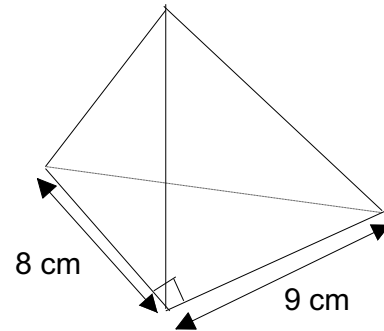
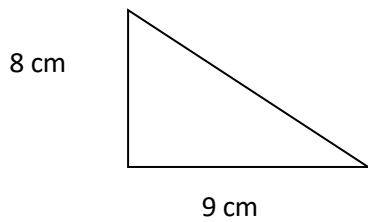
$$= 480 \text{ cm}^3.$$

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.

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

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

$$325 = 12 \times \text{height.}$$

So, height = $325 \div 12 = 27.08 \text{ cm}$ (to 4 SF).

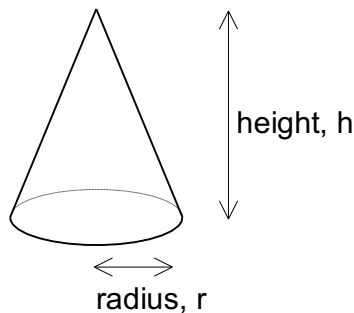
Volume of a cone

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:

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

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

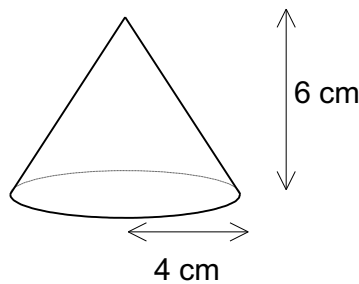
The base of a cone has a radius of 4 cm. The height of the cone is 6 cm.

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

$$\begin{aligned}\text{Volume of cone} &= \frac{1}{3}\pi r^2 h \\ &= \frac{1}{3} \times \pi \times 4^2 \times 6 \\ &= 2 \times \pi \times 16 \quad (\text{start by finding } 1/3 \text{ of } 6) \\ \text{volume} &= 32\pi \text{ cm}^3.\end{aligned}$$



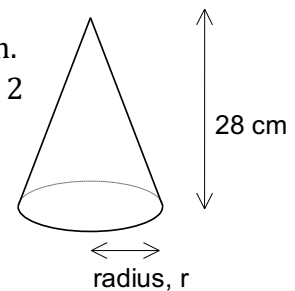
Example 2:

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:

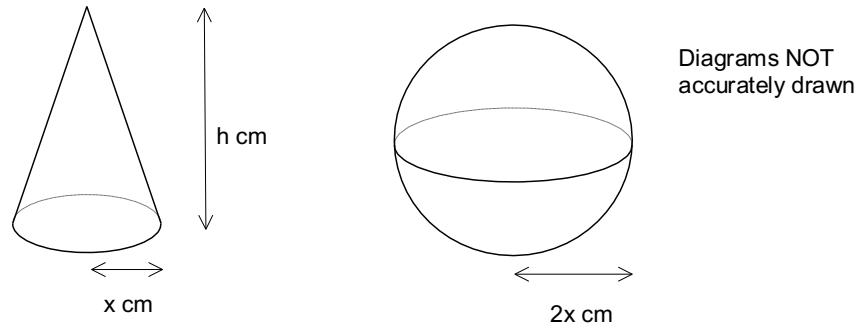
$$\begin{aligned}\text{Volume of cone} &= \frac{1}{3}\pi r^2 h \\ 1650 &= \frac{1}{3} \times \pi \times r^2 \times 28 \\ 1650 &= 29.32153r^2 \quad (\text{evaluating } \frac{1}{3} \times \pi \times 28) \\ r^2 &= 56.2726 \\ \text{i.e. } r &= 7.5 \text{ cm (to 2 SF)}\end{aligned}$$



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

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)

$$\begin{aligned} &= \frac{4}{3}\pi \times 8x^3 && \text{(cubing both 2 and } x\text{)} \\ &= \frac{32}{3}\pi x^3 \end{aligned}$$

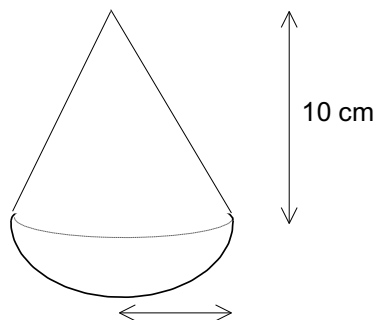
As the sphere and the cone have the same volume, we can form an equation:

$$\begin{aligned} \frac{1}{3}\pi x^2 h &= \frac{32}{3}\pi x^3 \\ \pi x^2 h &= 32\pi x^3 && \text{(Multiplying both sides by 3)} \\ x^2 h &= 32x^3 && \text{(Dividing both sides by } \pi\text{)} \\ h &= 32x && \text{(Dividing both sides by } x^2\text{)} \end{aligned}$$

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

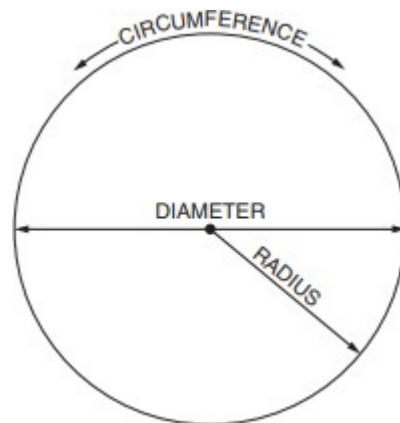
Geometry is essential to welding. Several welding projects require you to understand, calculate and measure welds at different angles accurately. Moderate knowledge of geometrical measurements will make it easier for you to connect metals together while advanced knowledge will make it possible to work 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).

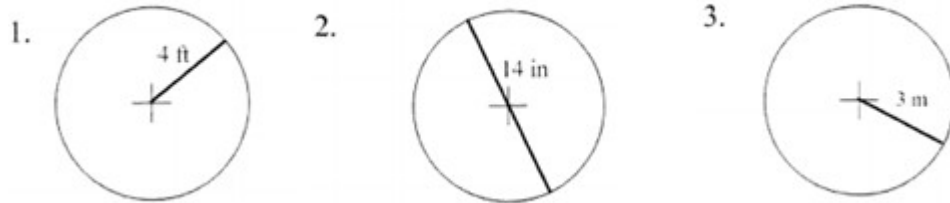
Diameter is designated on blueprints with the symbol \varnothing .

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.

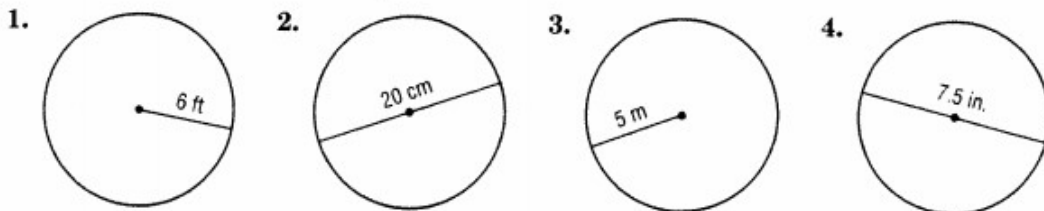
The formula for calculating the circumference of a circle is:

$$\text{Area} = \pi r^2$$

Examples: Find the area of the circle. Remember $\pi = 3.14$



Find the circumference of each circle. Use 3.14 or $\frac{22}{7}$ for π . Round to the nearest tenth if necessary.



5. diameter = 15 km

6. radius = 21 mi

7. radius = 50 m

8. diameter = 600 ft

9. radius = 62 mm

10. diameter = 7 km

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.

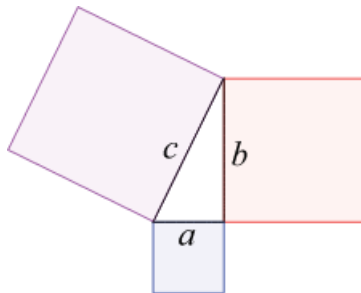
Trigonometry helps welders determine the strength of the weld and how joints should be made to ensure that they will not break with usage. The welder can test the strength of the joint without breaking it by applying module testing methods such as ultrasonic waves based on tangents, signs and cosigns.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

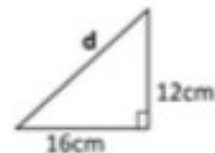
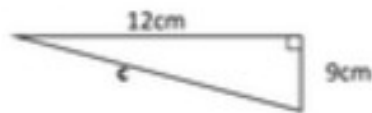
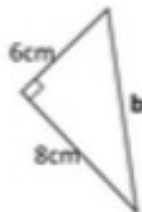
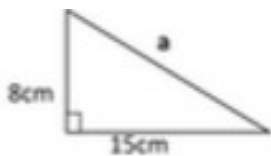
Pythagoras' Theorem

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.

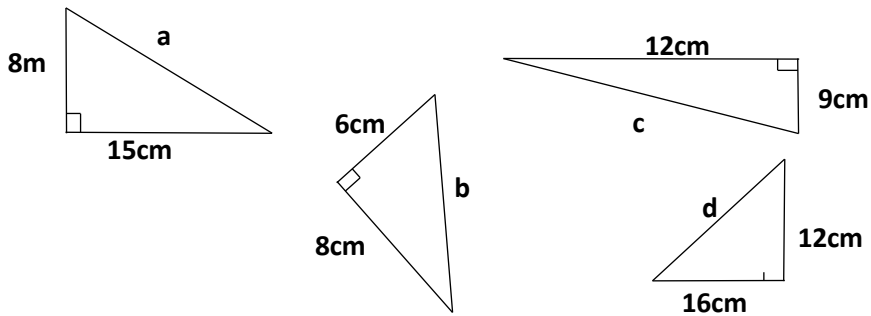
$$a^2 + b^2 = c^2$$



Find hypotenuse of following



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



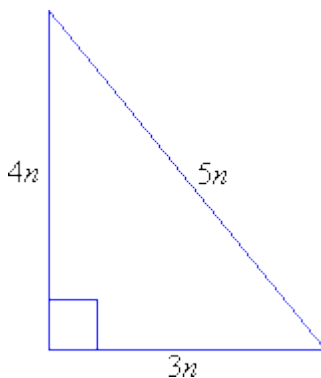
2.

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 = $3n : 4n : 5n$

3.



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. $6 : 8 : ? = 3(2) : 4(2) : ?$

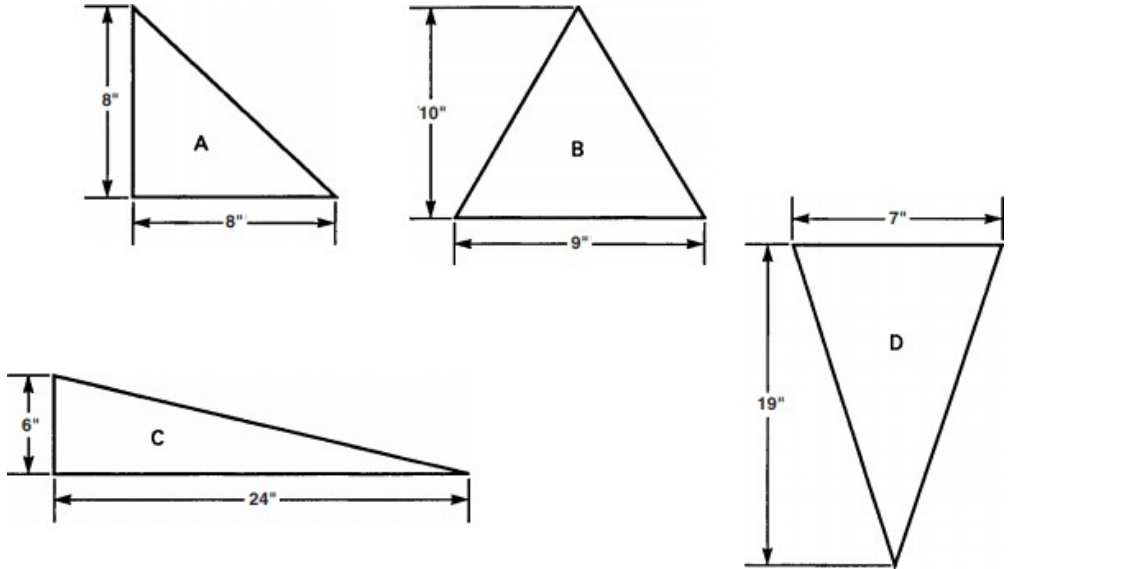
Step 2: Yes, it is a 3-4-5 triangle for $n = 2$.

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

Answer:

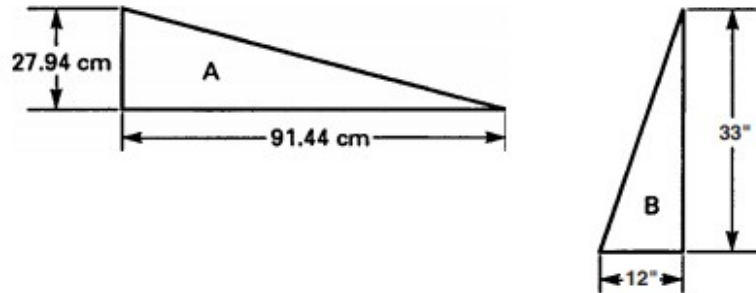
The length of the hypotenuse is 10 inches.

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:

$$\text{Decimal degrees} = \text{Degrees} + (\text{Minutes}/60) + (\text{Seconds}/3600)$$

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

1. First, convert minutes and seconds to their degree equivalents and add the results
2. $25'/60=0.4167^\circ$
3. $30"/3600=.0083^\circ$
4. and $0.4167^\circ + 0.0083^\circ = 0.425^\circ$
5. Then, add this number to the number of degrees. $39^\circ + 0.425^\circ = 39.425^\circ$
6. So, the final result is: $39^\circ 25' 30" = 39.425^\circ$

APPLY KNOWLEDGE OF MATHEMATICS IN WATER OPERATIONS

Prior to proceeding with the water measurement units, it is important to understand the commonly used units of measurements across the Maldives. Referred two types of measurements used widely across the Maldives.

a- Metric System of Measurement

It is an international decimal system of weights and measures, based on the metre for length and the kilogram for mass, that was adopted in France in 1795 and is now used officially in almost all countries. Referred system of measurement is also widely used in the

Category	Name of Unit	Measure	
Length	Inch	1/12 th	ft
	Foot	1	ft
	Yard	3	ft
	Mile	5280	ft
	Nautical mile	6080	ft
Area	Acre	43,560	sq ft
Volume	Fluid ounce	1/20 th	pint
	Pint	1	pint
	Quart	2	pint
	Gallon	8	pint
Weight	Ounce	1/16 th	lb
	Pound	1	lb
	Stone	14	lb
	Ton	2240	lb

Metric Unit of Measure	
Measures of Length	
1 meter (m)	= 1000 millimeters (mm)
1 meter (m)	= 100 centimeters (cm)
1 Kilometer (km)	= 1000 meters
1 decimeter (dm)	= 1/10 meter
Measure of Weight	
1 gram (g)	= 1000 milligrams (mg)
1 kilogram (kg)	= 1000 grams
Liquid Measures	
1 liter (L)	= 1000 milliliters (mL)
1 deciliter (dL)	= 1/10 liter

Maldives.

b- Imperial or English system of measurement

The English system is defined as the measurement system used in many

countries including the United States using feet, pounds and seconds.

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) weighs 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.

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

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

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/m^3 , you need to measure the volume in m^3 , and if you've measured the volume in ft^3 , you'll need the density in lb/ft^3 . The density of water in kg/m^3 is $1,000 \text{ kg}/\text{m}^3$, and in lb/ft^3 it is $62.4 \text{ lb}/\text{ft}^3$.

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

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

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 $g = 9.81 \text{ m}/\text{s}^2 = 32.17 \text{ ft}/\text{s}^2$, 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, we 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/s² to ensure the answer makes sense.

Wastewater Conversion Table

Take a moment to review the formulas given below and with the help of the lecturer, make sure you learn the ways how these formulas can be applied when undertaking different calculations related to water sanitation problems.

$$\text{Alkalinity, as mg CaCO}_3/\text{L} = \frac{(\text{Titrant Volume, mL})(\text{Acid Normality})(50,000)}{\text{Sample Volume, mL}}$$

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

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

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

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

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

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

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

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

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

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

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

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

Circumference of Circle = (π) (Diameter)

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

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

Degrees Celsius = (Degrees Fahrenheit - 32) $(\frac{5}{9})$ or $\frac{(F - 32)}{1.8}$

Degrees Fahrenheit = [(Degrees Celsius) $(\frac{9}{5}) + 32]$ or [(Degrees Celsius) (1.8) + 32]

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

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

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

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

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

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

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

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

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

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

Hardness, as mg CaCO_3/L = $\frac{(\text{Titrant Volume, mL})(1,000)}{\text{Sample Volume, mL}}$ Only when the titration factor is 1.00 of EDTA

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

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

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

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

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

$$\text{Mass, lbs} = (\text{Volume, MG})(\text{Concentration, mg/L})(8.34 \text{ lbs/gal})$$

$$\text{Mass Flux, lbs/day} = (\text{Flow, MGD})(\text{Concentration, mg/L})(8.34 \text{ lbs/gal})$$

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

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

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

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

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

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

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

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

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

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

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

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

$$\text{Reduction of Volatile Solids, \%} = \frac{(\text{In} - \text{Out})(100\%)}{\text{In} - (\text{In} \times \text{Out})}$$
 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 = $N_1 \times V_1 = N_2 \times V_2$, where N = concentration (normality), V = volume or flow

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

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

$$\text{Volume of Cone} = (1/3) (0.785) (\text{Diameter}^2) (\text{Height})$$

$$\text{Volume of Cylinder} = (0.785) (\text{Diameter}^2) (\text{Height})$$

$$\text{Volume of Rectangular Tank} = (\text{Length}) (\text{Width}) (\text{Height})$$

$$\text{Waste Milliequivalent} = (\text{mL}) (\text{Normality})$$

$$\text{Watts (DC circuit)} = (\text{Volts}) (\text{Amps})$$

$$\text{Watts (AC circuit)} = (\text{Volts}) (\text{Amps}) (\text{Power Factor})$$

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

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

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

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	$^{\circ} \text{F} = 9/5 (^{\circ} \text{C}) + 32$
Kelvin to Fahrenheit	$^{\circ} \text{F} = 9/5 (\text{K} - 273) + 32$
Fahrenheit to Celsius	$^{\circ} \text{C} = 5/9 (^{\circ} \text{F} - 32)$
Celsius to Kelvin	$\text{K} = ^{\circ} \text{C} + 273$
Kelvin to Celsius	$^{\circ} \text{C} = \text{K} - 273$
Fahrenheit to Kelvin	$\text{K} = 5/9 (^{\circ} \text{F} - 32) + 273$

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 °C. Because specific gravity is a ratio, it is a unitless quantity. For example, the specific gravity of water at 4°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: $V = L \times W \times D$

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:

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

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.

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.

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.

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.

Wait 30 – 60 minutes without using any water, if possible, to allow the water in the water main to settle.

Open the outside spigot/faucet again and check water clarity.

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.

After the water from the outside spigot/faucet appears clear, begin the general process of flushing the service connection's interior pipes and faucets.

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.

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.

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.

Individually open each remaining outside spigot/faucet and similarly flush as above.

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.

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.

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.

Other items that utilize water such as coffee makers, pitcher type water filters, and dental cleaning appliances should be cleaned and their filters replaced.

If water from taps is not clear, repeat steps 2 through 16.

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:

$$\text{BOD, mg/L} = [(\text{Initial DO} - \text{Final DO}) \times 300] / \text{mL sample}$$

For example:

$$\text{Initial DO} = 8.2 \text{ mg/L}$$

$$\text{Final DO} = 4.4 \text{ mg/L}$$

$$\text{Sample size} = 5 \text{ mL}$$

$$\text{BOD mg/L} = [(8.2 - 4.4) \times 300] / 5 = (3.8 \times 300) / 5 = 1140 / 5 = 228 \text{ mg/L}$$

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.

5. PREPARE BASIC TECHNICAL DRAWING SKILLS

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).

IDENTIFY DRAWING REQUIREMENTS

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 behaviour 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. These 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 (they 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 rationale 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 be 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:

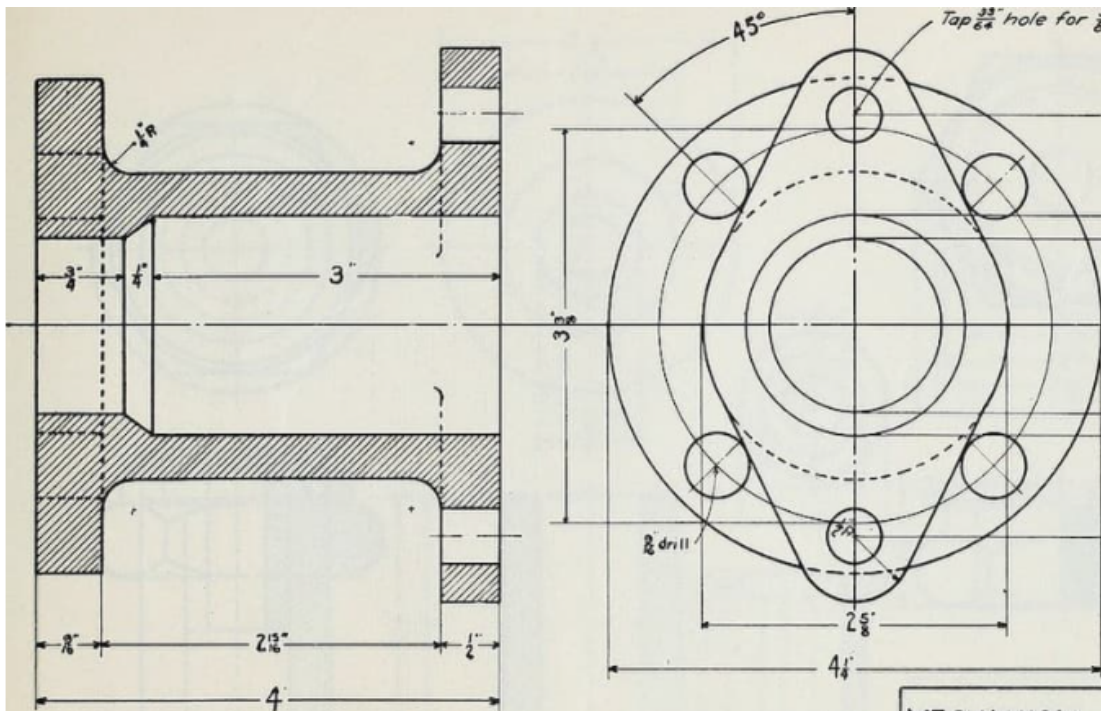
1. Sell it to your management to the customer. If you **don't** get buy-in **this will fail**, so make sure you put together a good sales presentation.
2. Train your core team on the techniques you'll be using (could be Process Modeling, Data Modeling, Prototyping, etc.)

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.



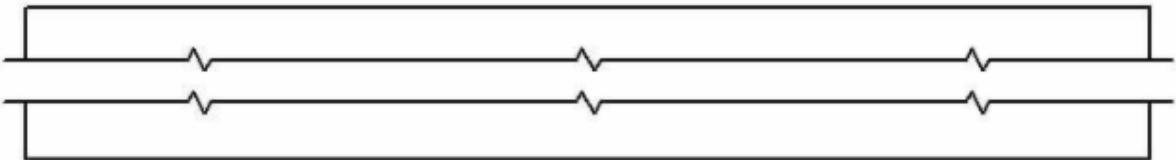
Hidden lines can show something that would not be otherwise visible on the drawings. For example, hidden lines may show the length of an internal step in a turned part without using a section or a cutout view (we explain both later).



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

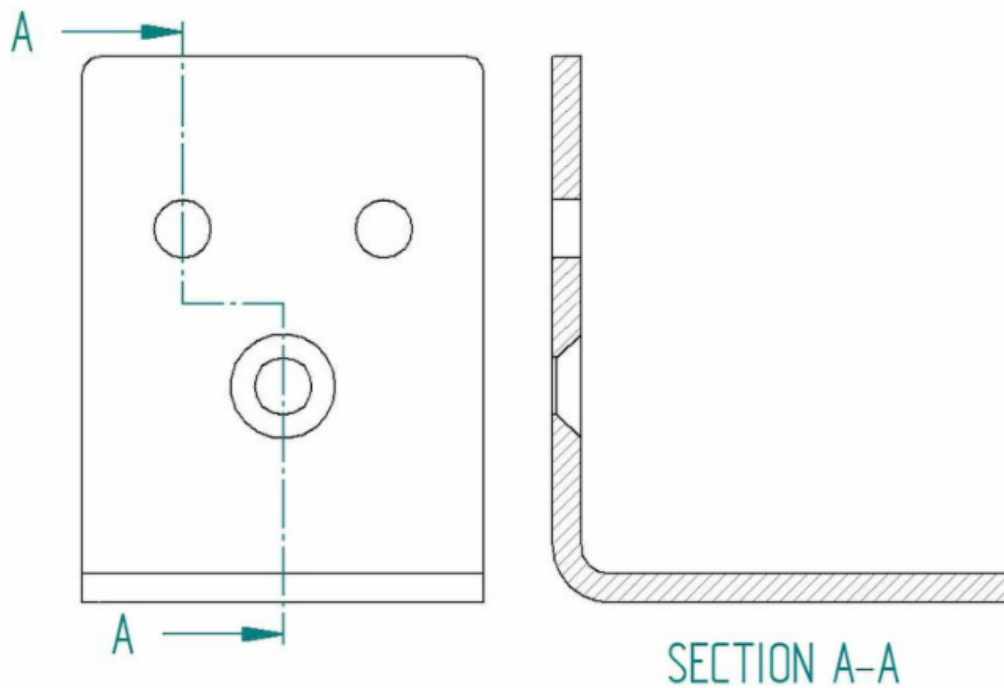


Extension lines annotate what is being measured. The dimension line has two arrowheads between the extension lines and the measurement on top (or inside, like in the image above) the line.



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

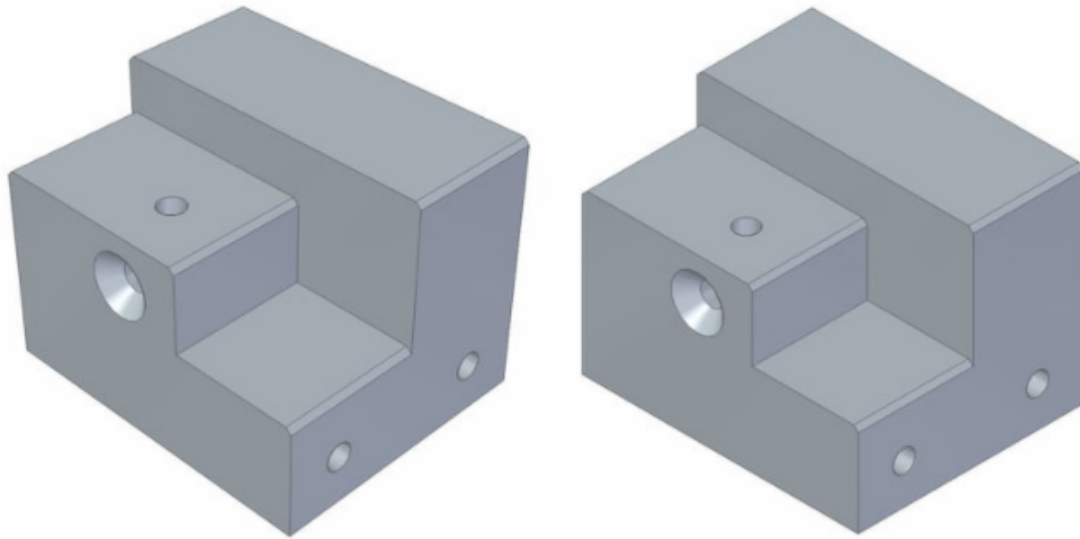
So let's take a closer look at the different types of views that are often present in a manufacturing drawing. Each serves a certain purpose. Bear in mind that adding views should follow the same logic as dimensioning – include as little as possible and as much as necessary.

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.

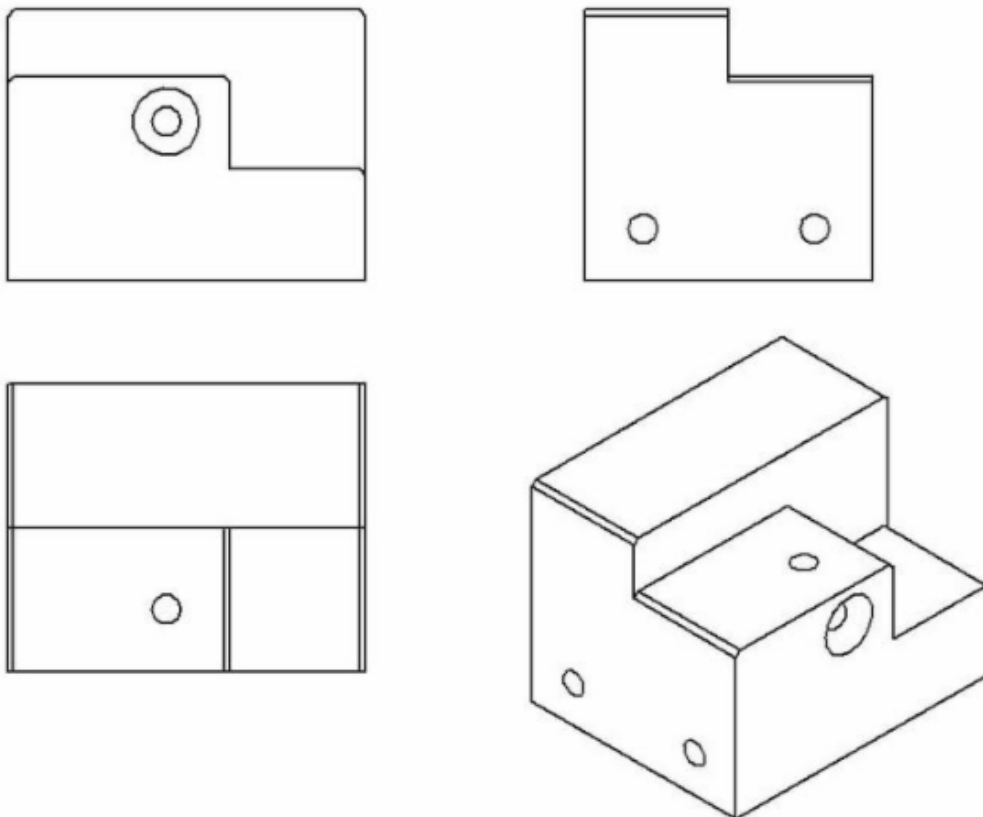
The lines that are vertical and parallel are in their true length. Which means you can use a ruler and the scaling of the drawing to easily measure the length straight from a paper drawing, for example. The same does not apply to angled lines.



Left – perspective; right – isometric

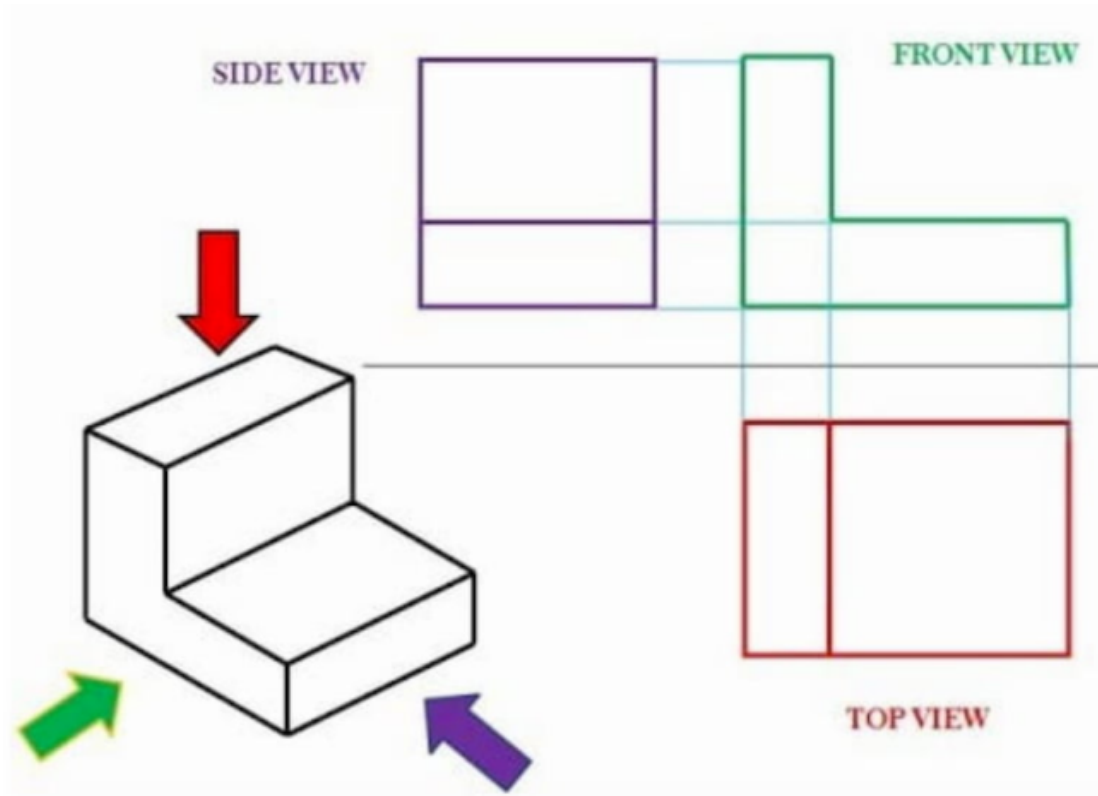
It is important to distinguish the isometric view from a perspective view. A perspective view is an artistic one that represents an object as it seems to the eye. Engineers stay true to the dimensions rather than optical illusions.

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.



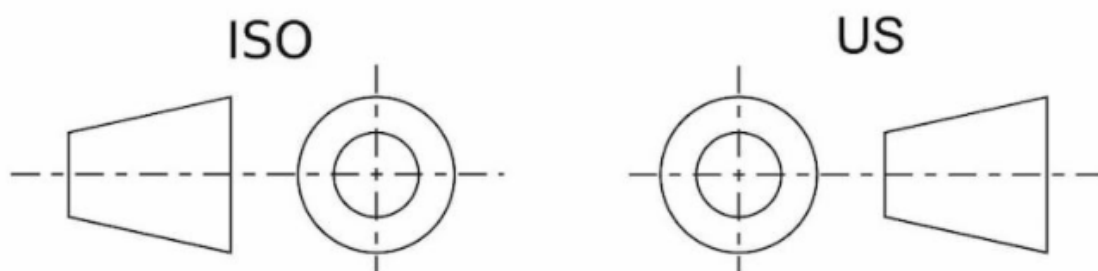
Orthographic projection (ISO standard)

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.

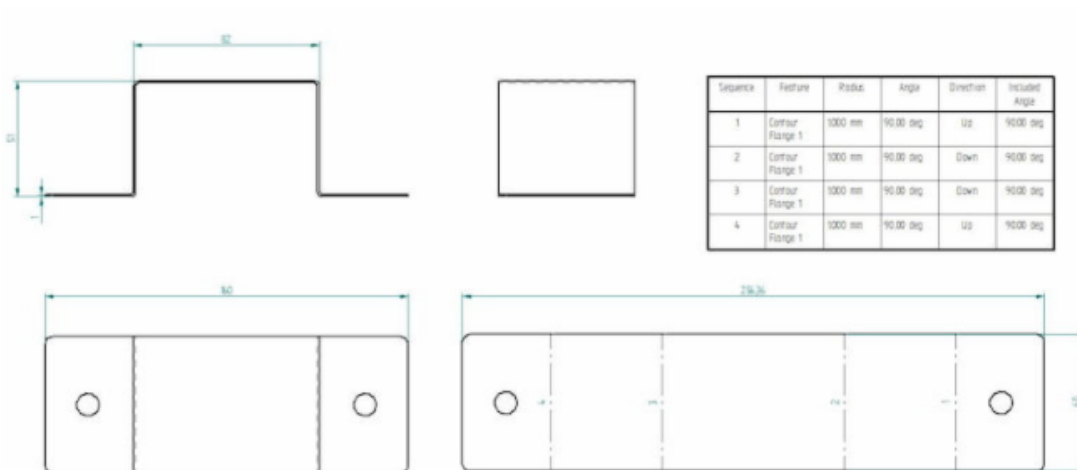
The positioning of the views differs a bit regionally. For example, look at the image below to compare the US and ISO layouts.



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.

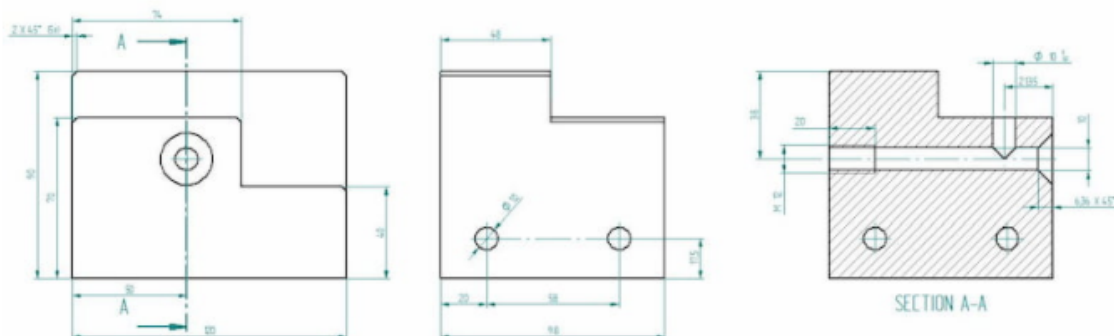
Flat Pattern



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.).

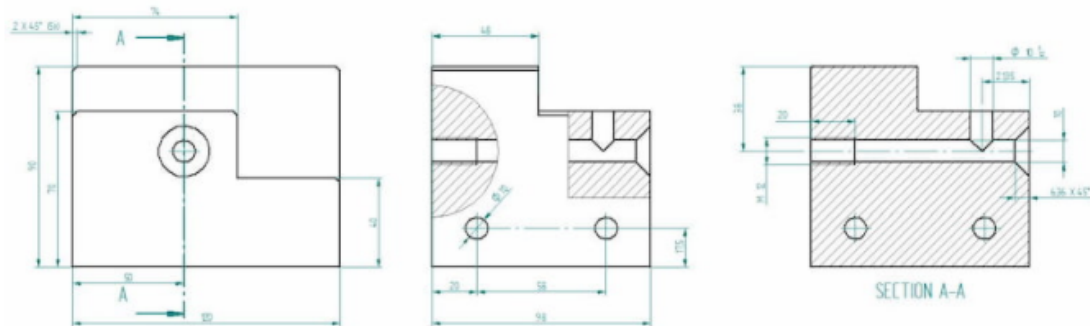
Section View



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 an indicator for cross sectional views.

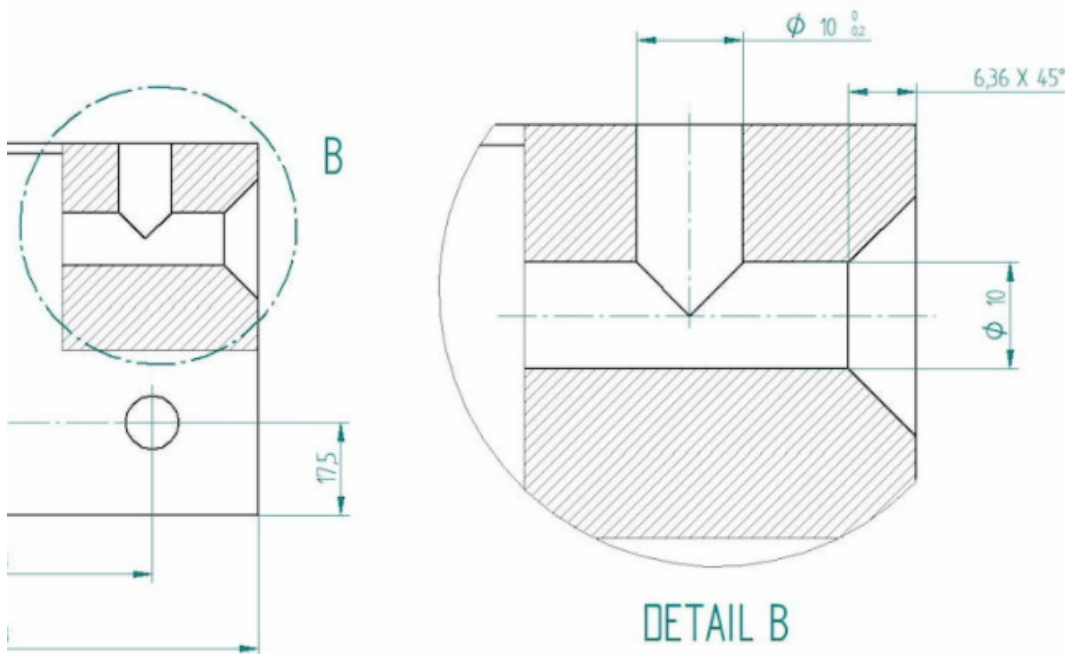
Cutout View



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.

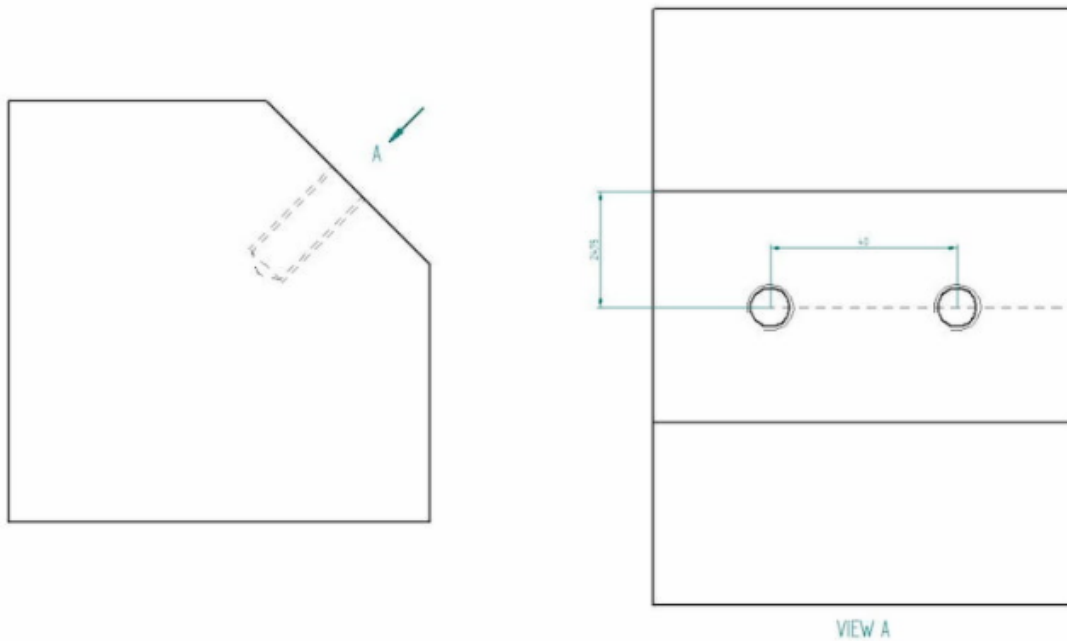
Thus, we could easily delete the section view and add all the necessary dimensions to cutouts.

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



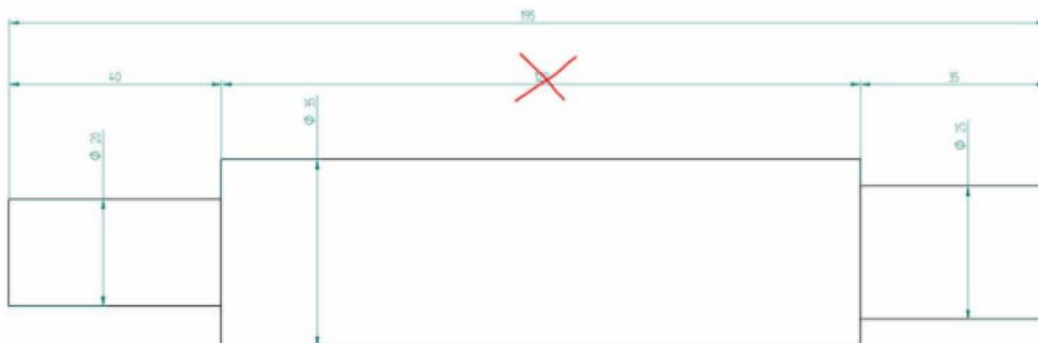
An orthographic view to represent planes that are not horizontal or vertical. It helps to show inclined surfaces without any distortion.

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.



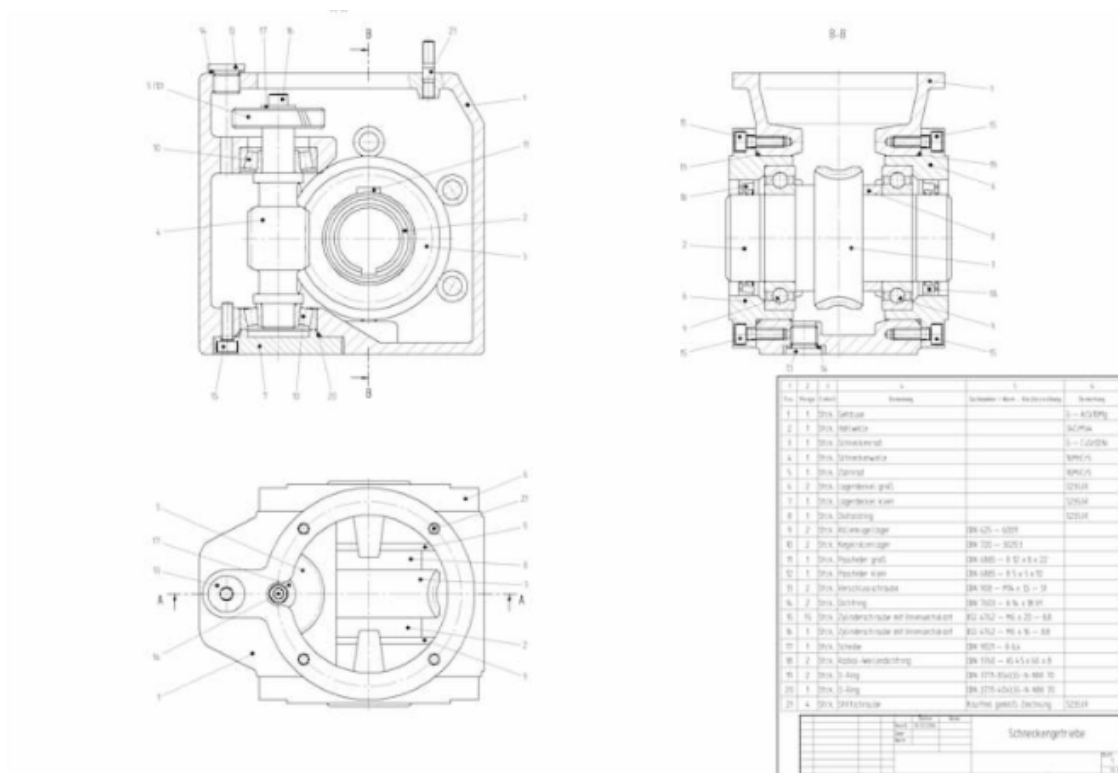
The image above shows a shaft with all the measurements. In reality, it creates a closed system whereby the manufacturer cannot guarantee all these dimensions 100%. Therefore, you have to determine the most important ones. In our case, we chose the end steps to be more important than the length of the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

6. APPLY SCIENCE FOR WATER OPERATIONS

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:

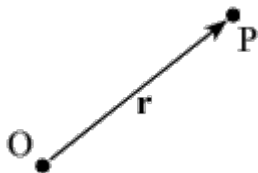
Scalar: Plain (or often italicized) letters: a , k , etc.

Vectors: Either bold letters: \mathbf{x} , \mathbf{v} (often used in books), or a small vector sign: \vec{x}

Magnitude of a vector: $A \equiv |A|$

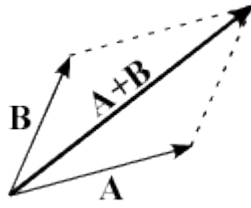
Unit vector in the direction of A (a vector which has a unit magnitude and the direction of A): \hat{A} . Clearly, one has that $|\hat{A}| = 1$ and $A = \hat{A}|A|$.

Position vector (aka radius vector or location vector): The vector \mathbf{r} is the vector connecting the origin (usually denoted as \mathbf{O}) to the location \mathbf{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: $A+B=B+A$.



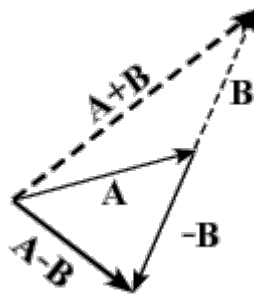
The negative of a vector:

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.



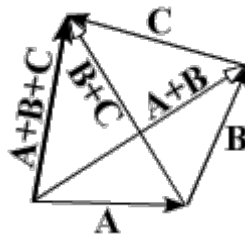
Vector subtraction:

Vector subtraction $A-B$ is defined as: $A+(-B)$, that is, adding the negative of the subtracted vector B , as is apparent in the figure.



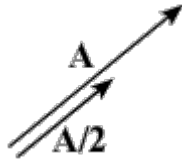
Vector distributivity:

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 scalar:

Multiplying a vector by a scalar gives a new vector with the same direction but with a magnitude which is multiplied by the scalar. A negative scalar would yield a vector in the opposite direction as the original vector. For example: $(-1)A=-A$.



Examples of Vectors:

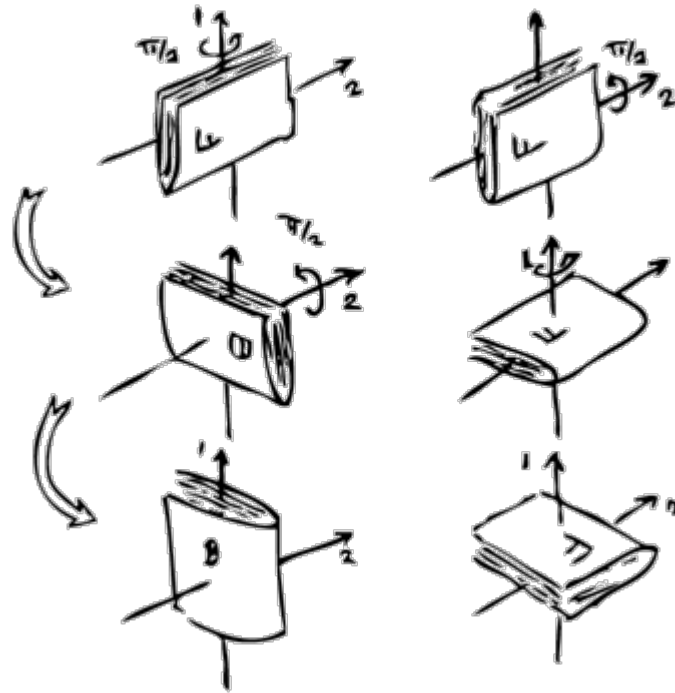
The following are examples of vectors, that is, entities which have both a magnitude and a direction, and which can be added following the parallelogram rule:

- ✓ 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 $2\sqrt{2}$ 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 $\pi/2$ (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

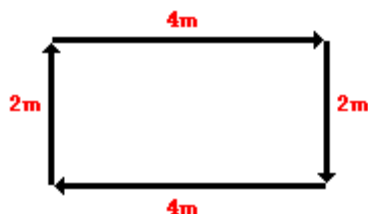
Distance and Displacement

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.

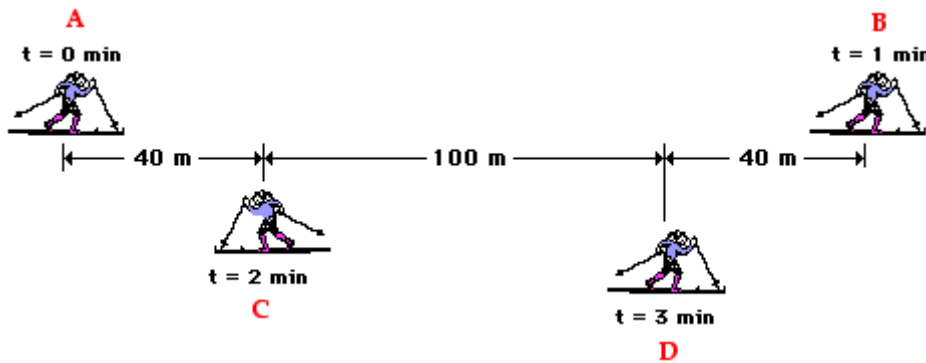


Even though the physics teacher has walked a total distance of 12 meters, her displacement is 0 meters. During the course of her motion, she has "covered 12 meters of ground" (distance = 12 m). Yet when she is finished walking, she is not "out of place" - i.e., there is no displacement for her motion (displacement = 0 m). Displacement, being a vector quantity, must give attention to direction. The 4 meters east *cancel*s the

4 meters west; and the 2 meters south *cancel*s 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.

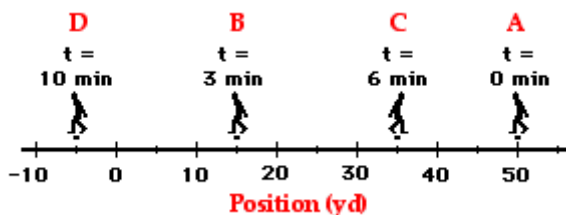
Now consider another example. The diagram below shows the position of a cross-country skier at various times. At each of the indicated times, the skier turns around and reverses the direction of travel. In other words, the skier moves from A to B to C to D.

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 speedometer 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

is  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

$$\text{Ave. acceleration} = \frac{\Delta \text{velocity}}{\text{time}} = \frac{v_f - v_i}{t}$$

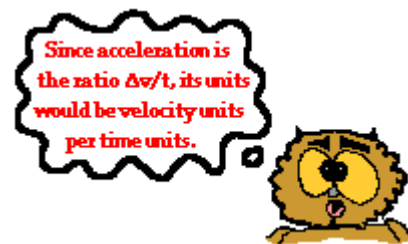
This equation can be used to calculate the acceleration of the object whose motion is depicted by the [velocity-time data table](#) above. The velocity-time data in the table shows that the object has an acceleration of 10 m/s/s. The calculation is shown below.

$$a = \frac{v_f - v_i}{t} = \frac{50 \text{ m/s} - 0 \text{ m/s}}{5 \text{ s}} = \frac{10 \text{ m/s}}{1 \text{ s}}$$

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/s².

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.

$$\text{Average Speed} = \frac{\text{distance}}{\text{time}} = \frac{\text{circumference}}{\text{time}}$$

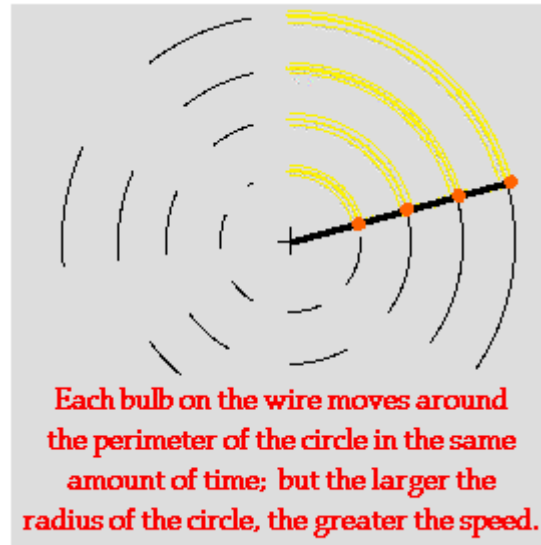
The circumference of any circle can be computed using from the radius according to the equation

$$\text{Circumference} = 2 \cdot \pi \cdot \text{Radius}$$

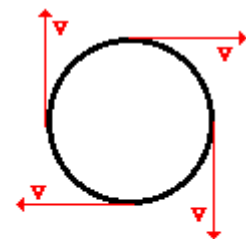
Combining these two equations above will lead to a new equation relating the speed of an object moving in uniform circular motion to the radius of the circle and the time to make one cycle around the circle (period).

$$\text{Average Speed} = \frac{2 \cdot \pi \cdot R}{T}$$

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 at every instant is in a direction tangent to the circle.

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.

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

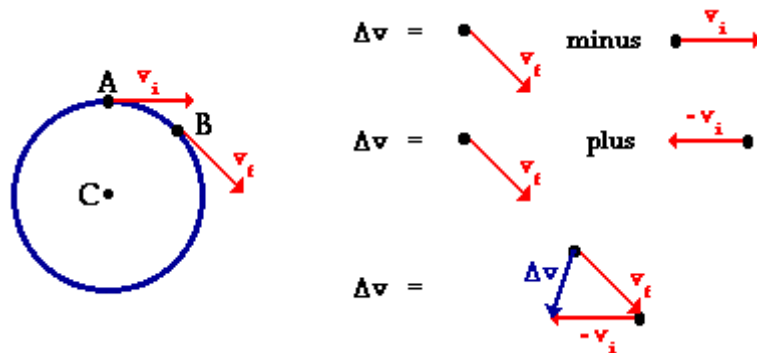
As mentioned earlier, an object moving in uniform circular motion is moving in a circle with a uniform or constant speed. The velocity vector is constant in magnitude but changing in direction. Because the speed is constant for such a motion, many students have the misconception that there is no acceleration. "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:

$$\text{Ave. acceleration} = \frac{\Delta \text{velocity}}{\text{time}} = \frac{v_f - v_i}{t}$$

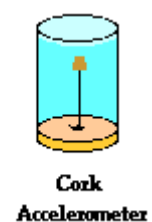
where \mathbf{v}_i represents the initial velocity and \mathbf{v}_f represents the final velocity after some time of t . The numerator of the equation is found by subtracting one vector (\mathbf{v}_i) from a second vector (\mathbf{v}_f). But the addition and subtraction of vectors from each other is 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 \mathbf{v}_i to \mathbf{v}_f . The process of subtracting \mathbf{v}_i from \mathbf{v}_f is shown in the vector diagram; this process yields the change in velocity.



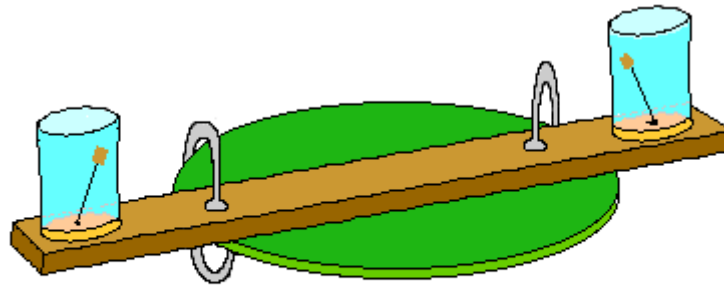
Direction of the Acceleration Vector

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.



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.

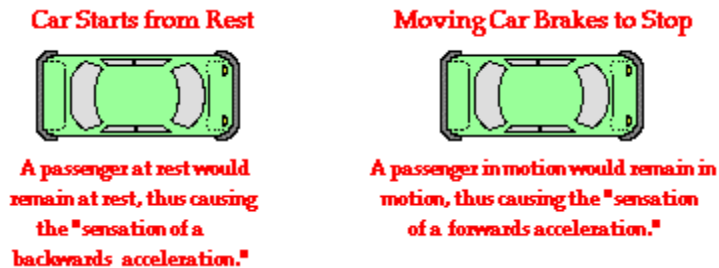
Inertia, Force and Acceleration for an Automobile Passenger

The idea expressed by Newton's law of inertia should not be surprising to us. We experience this phenomenon of inertia nearly every day 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

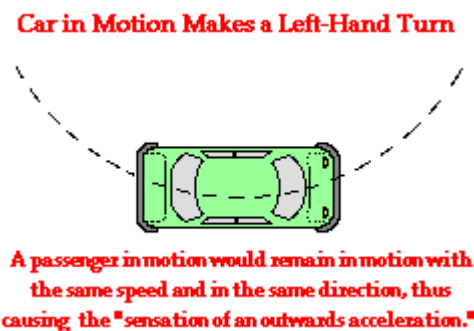
with the same speed and in the same direction... ." The unbalanced force acting upon the car causes the car to slow down while your body continues in its forward motion. You are once more left with the false feeling of being pushed in a direction which is opposite your acceleration.

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

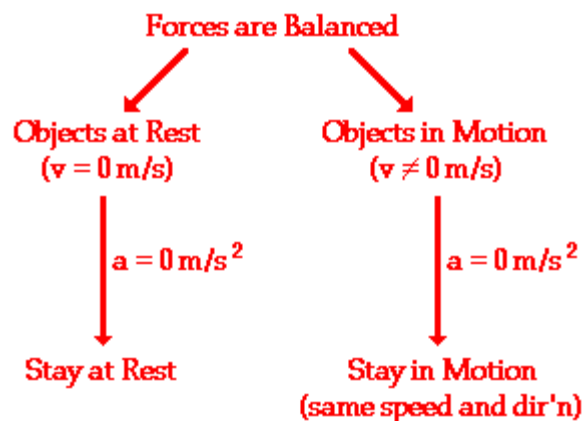
Newton's First Law

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 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

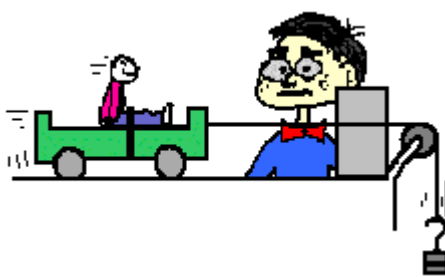
- The container was in motion and you attempted to stop it
- The container was moving in one direction and you attempted to change its direction.



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

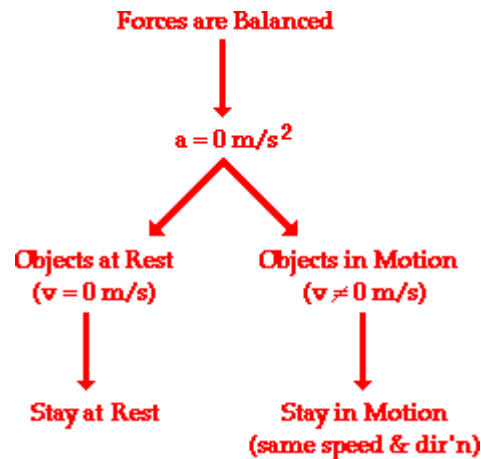
There are many applications of Newton's first law of motion. Consider some of your experiences in an automobile. Have you ever observed the behavior of coffee in a coffee cup filled to the rim while starting a car from rest or while bringing a car to rest from a state of motion? Coffee "keeps on doing 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.



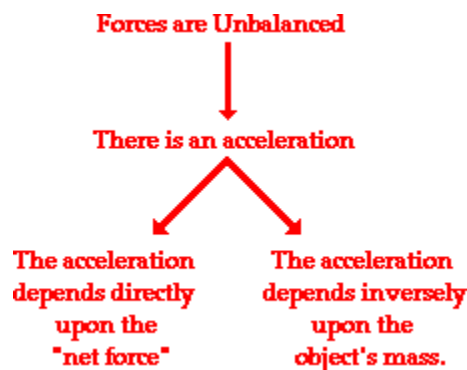
Have you ever experienced inertia (resisting changes in your state of motion) in an automobile while it is braking to a stop? The force of the road on the locked wheels provides the unbalanced force to change the car's state of motion, yet there is no unbalanced force to change your own state of motion. 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^2 . 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:

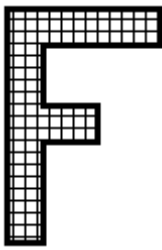
The acceleration of an object as produced by a net force is directly proportional to the magnitude of the net force, in the same direction as the net force, and inversely proportional to the mass of the object.

This verbal statement can be expressed in equation form as follows:

$$\mathbf{a} = \mathbf{F}_{\text{net}} / m$$

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.

$$F_{\text{net}} = m \cdot a$$



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.

$$1 \text{ Newton} = 1 \text{ kg} \cdot \text{m/s}^2$$

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 result 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

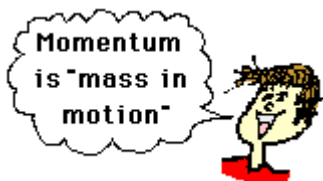
As humans we use a lot of energy to drive our cars, heat and cool our houses, watch TV, and more. This energy comes from a variety of places and in a number of forms. Conservationists classify the energy we use into two types: renewable and nonrenewable. Nonrenewable energy uses up resources that we 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.

$$\text{Momentum} = \text{mass} \bullet \text{velocity}$$

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 $\text{kg}\bullet\text{m}/\text{s}$. While the $\text{kg}\bullet\text{m}/\text{s}$ 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 $\text{kg}\bullet\text{mi}/\text{hr}$, $\text{kg}\bullet\text{km}/\text{hr}$, and $\text{g}\bullet\text{cm}/\text{s}$. 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 ($F_{\text{net}} = m \bullet a$) 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 ($a = \text{change in velocity} / \text{time}$), 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 \bullet time is known as **impulse**. And since the quantity $m\bullet v$ is the momentum, the quantity $m\bullet\Delta v$ must be the **change in momentum**. The equation really says that the

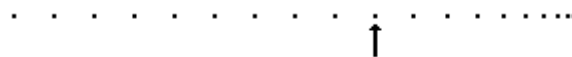
$$\text{Impulse} = \text{Change in momentum}$$

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, $F \cdot t = m \cdot \Delta v$.

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.

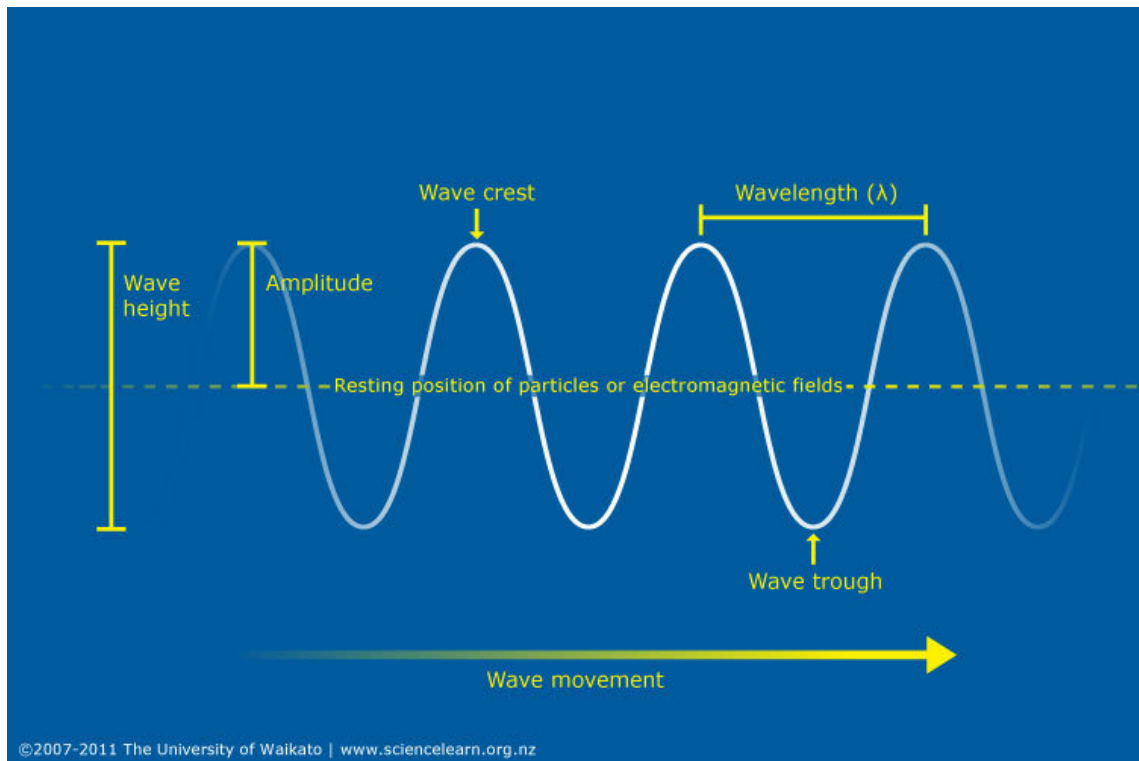
Different waves, same properties

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.

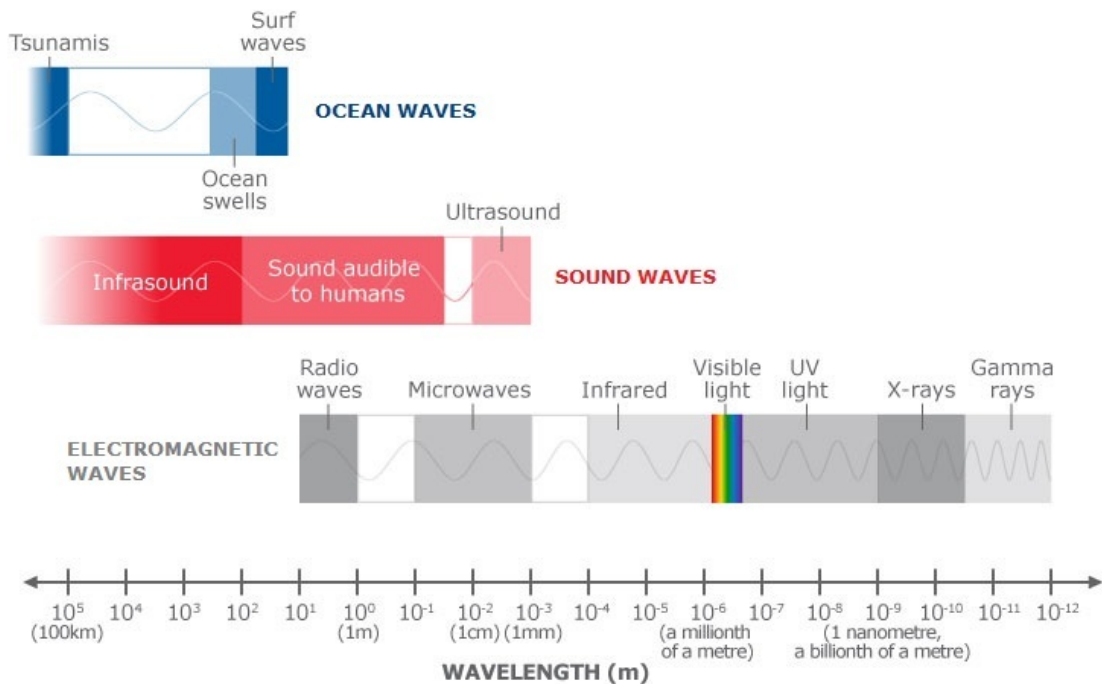
Electromagnetic waves (such as light waves, UV radiation, microwaves and others) are formed through oscillating electric and magnetic fields.



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).



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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 meters 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

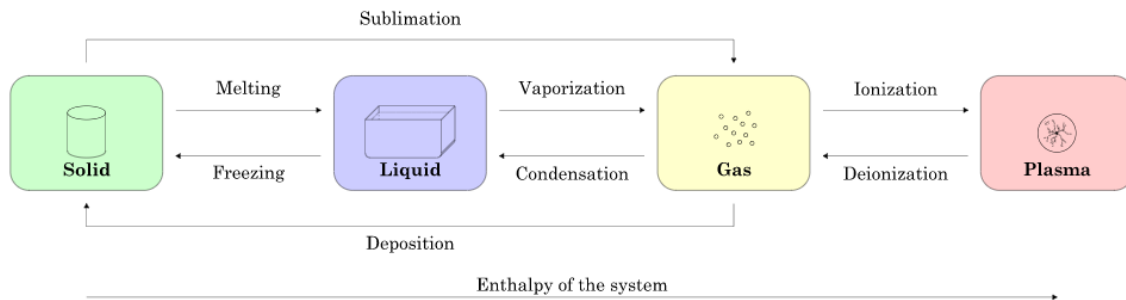
- ✓ Matter can exist in one of three main states: solid, liquid, or gas.
- ✓ Solid matter is composed of tightly packed particles. A solid will retain its shape; the particles are not free to move around.
- ✓ Liquid matter is made of more loosely packed particles. It will take the shape of its container. 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

- ✓ Solid: a substance that retains its size and shape without a container; a substance whose molecules cannot move freely except to vibrate.
- ✓ Gas: a 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.
- ✓ Liquid: a 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 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 H₂O → H₂ and O₂), 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 unseptium, 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 (eg. taking dissolved sugar from water is impossible with a sifter or another mechanical method).

Solution is stable

A solution is stable in given conditions. Eg. 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 wole of it is either gasous, liqiud 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 litre 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.

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.

7. PLAN TO UNDERTAKE A ROUTINE TASK

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.

Calculate the average monthly use.

Add the planned growth rate for the product line.

Check parts catalogs or call the source for best buy rates.

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.

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.
- Run product through heat-shrink.
Place product in package.
Glue ends of package together.
Place label on front of package.
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:
 - move cursor to middle of word
 - double-click mouse button
- ✓ IF text is a section of words or letters THEN:
 - move cursor to beginning of text
 - press mouse button down
 - move cursor to end of text
 - 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:

- Give lots of clear instructions (training) because the task is new.
- 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
- ✓ 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):
 - 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 with several examples to provide context
 - Practice the task
- ✓ Identify the critical decision points (what do experts ask themselves when deciding on what learning technique to use):
 - What is the experience level of the learners?
 - 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):
 - Ask learners for their experience level to gain a background.
 - Ask questions that provide clues.
 - Observe how they react to new and difficult information.
- ✓ Prioritize the decision points:

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

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:
 - Program in html (hypertext markup language).
 - Design and build on-screen layout and messages using company templates.
 - Use Dreamweaver or similar remote publishing tool.
 - Works with others (teamwork) by interacting with the merchandising department group.
 - Constructs pictures using digital cameras and photo editing software.
 - 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 that is 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.

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!

8. PERFORM ELECTRICAL SERVICE AND MAINTENANCE

DEVELOP FUNDAMENTALS OF ELECTRICITY

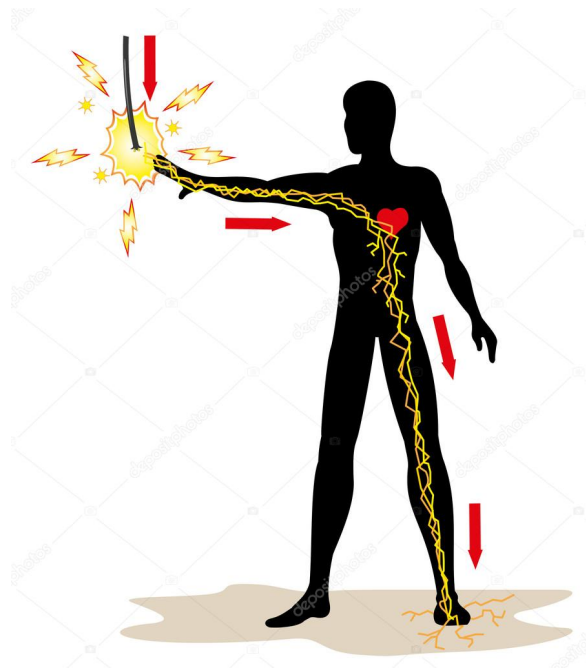
Electrical Safety

We rely on electricity, but sometimes underestimate its capability of causing injury. Even household current (120 volts) can stop your heart. UW personnel need to be aware of the hazards electricity poses, such as shock, fire and explosion, and either eliminate or control those hazards.

Shock

Electrical shock happens when current passes through the body. Electricity travels through closed circuits, and people, sometimes tragically, can become part of the circuit. When a person receives a shock, electricity flows between parts of the body or through the body to a ground. This can happen if someone touches both wires of an energized circuit, touches one wire of the circuit while standing unprotected or touches a metal part that has become energized.

Electrocution refers to the injury or lethal dose of electrical energy. Electricity can also cause forceful muscle contraction or falls. The severity of injury depends on the amount of current flowing through the body, the current's path through the body, the length of time the body remains in the circuit and the current's frequency.



Fire/Explosion

Electrical fires may be caused by excessive resistance that generates heat from any of the following:

- ✓ Too much current running through wiring where overcurrent protection fails or does not exist
- ✓ Faulty electrical outlets resulting in poor contact or arcing
- ✓ Poor wiring connections and old wiring that is damaged and cannot support the load

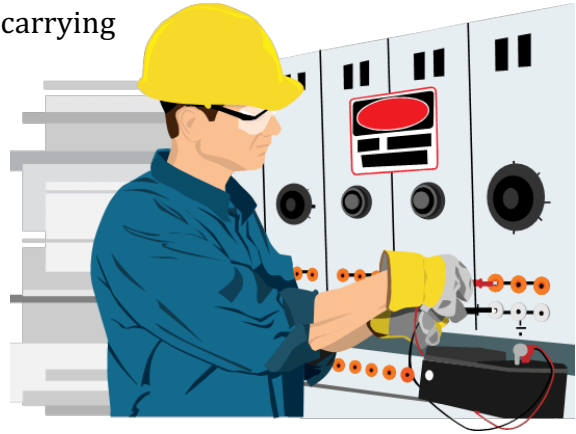


An explosion can occur when electricity ignites a flammable gas or combustible dust mixture in the air. Ignition from a short circuit or static charge is possible.

What we need to know

Electrical Safety Basics

- ✓ Don't work with exposed conductors carrying 50 volts or more.
- ✓ Make sure electrical equipment is properly connected, grounded and in good working order.
- ✓ Extension cords may not be used as permanent wiring and should be removed after temporary use for an activity or event.
- ✓ Surge suppressors with built-in circuit breakers may be used long-term and are available with three, six and 15 foot-long cords.
- ✓ High amperage equipment such as space heaters, portable air conditioners and other equipment must be plugged directly into permanent wall receptacles.
- ✓ Do not access, use or alter any building's electrical service, including circuit breaker panels, unless you are specifically qualified and authorized to do so.
- ✓ Wet environments can increase the risk of an electrical shock.



Housekeeping and Maintenance

- ✓ Maintain at least 30 inches of clearance in front of electrical panels to ensure a safe environment for facilities workers.
- ✓ Make sure that all junction boxes are covered.

What you can do to stay safe

Avoid Activities That Requires Training

- ✓ Working with exposed conductors carrying 50 volts or more
- ✓ Making repairs or alterations to any electrical equipment
- ✓ Opening up the case, or removing barrier guards, of any equipment that utilizes electricity
- ✓ Using any tools or a meter to measure for the presence of electricity
- ✓ Resetting a tripped circuit breaker, or replace a blown fuse

Ask a qualified person to perform these tasks.

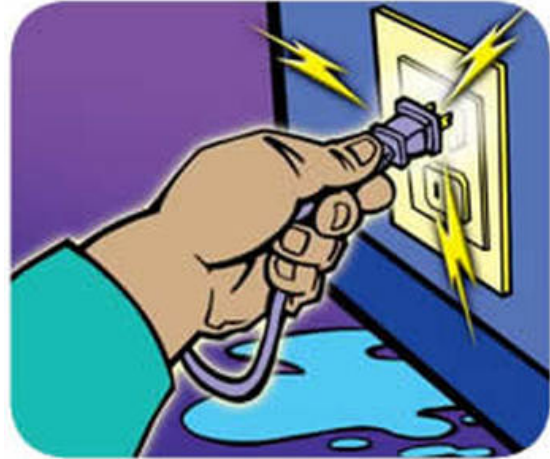


Grounding

To prevent electrical hazards, always make sure equipment is properly grounded. Electrical grounding provides an alternate path for electricity to follow, rather than going through a person. Equipment with a grounding prong must be plugged into an extension cord with a ground; the grounding plug should not be removed from the equipment.

Wet Locations

When using electricity in a wet or damp location, including outdoor locations, a Ground Fault Circuit Interrupter (GFCI) must be used. The GFCI ensures that any electrical shock is brief. Although painful, it wouldn't be fatal because the GFCI creates a ground fault or leak in the current. Additional information about GFCI devices can be found in the Ground Fault Circuit Interrupter Focus Sheet.



Lockout/Tagout

When servicing and maintenance tasks involve electricity and electrical equipment, you must prevent the unexpected startup of equipment



What is Electricity and How Electricity is Generated and Used

There are some inventions that changed human civilization. The first invention was the **wheel**, the second invention was **electricity**, the third invention was **telecommunications**, and the fourth invention was the **computer**. We will discuss the basic **introduction of electricity**. Each substance in this universe is made of plenty of atoms and each atom has the same number of negative electrons and positive protons.

As a result, we can say that each neutral substance has the same number of electrons and protons in it. The protons are immovable and strongly attached to the nucleus of the atoms. Electrons are also bounded to atoms and orbiting around the nucleus at different distinct levels. But some of the electrons can move freely or can come out from their orbit due to external influences. These free and as well as loosely bonded electrons cause **electricity**.

In neutral condition, the number of electrons and protons is the same in any piece of substance. But if somehow the number of electrons in a substance becomes more than the number of protons, the substance becomes negatively charged as the net charge of each electron is negative. If the number of electrons in a substance becomes less than the number of protons, the substance becomes positively charged.

The concentration of free electrons always tries to be uniform. This is the only reason for electricity. Let us explain in detail. If two dissimilarly charged conductive bodies come in contact, the electrons from the body of higher electron concentration will move to the body of lower electron concentration to balance the electron

concentration of both bodies. This movement of charge (as electrons are charged particles) is electricity.

Related Terms in Electricity

Electric Charge

As we told earlier that the number of electrons and number of protons are equal in a neutral body. The amount of negative charge and positive charge is also equal in a neutral body since the electric charge of an electron and a proton is numerically equal but their polarity is opposite. But for any reason, the balance of the number of electrons and protons in a body gets distributed the body becomes electrically charged. If the number of electrons more than that of protons the body becomes negatively charged and the amount of charge depends on the number of excess electrons in the body. In the same manner, we can explain the positive charge of a body. Here the number of electrons becomes lesser than that of protons. The positivity of the body depends on the difference between protons and electrons in the body.

Electric Current

When charge flows from one point to another to make uniform charge distribution then the rate at which the charge is flowing called electric current. This rate mainly depends on the difference between the charged condition of two points and the conditions of the pathway through which the charge is flowing. The unit of electric current is Ampere and it is nothing but coulomb per second.

Electric Potential

The level of charged condition of a body is known as electric potential. When a body is charged it gets the ability to do some work. Electric potential is the measurement of the ability of a charged body to do work. The current flowing through a conductor is directly proportional to the difference of electric potential between at two ends of the conductor. The electric potential can be visualized as the difference of water level in two water tanks linked with a pipeline. The speed of water flowing from the higher headed tank to lower headed tank depends on the level difference or head difference of the water in the tanks not on the quantity of water stored in the tanks. In the same way, the electric current between two bodies depends on the potential difference between two bodies not on the

Electric Field

There is always a force between two nearly placed charged bodies. The force may be either attractive or repulsive depending on the nature of the charge of two bodies. When a charged body enters the nearby zone of another charged body the force is practically experienced. Space surrounds a charged body where another charged body can experience a force is called the electric field of the former body.

How is Electricity Generated

There are three basic ways by which we generally produce electricity

Electromechanical Process

When a conductor moves in a magnetic field and the conductor cuts the field flux lines electricity is produced in the conductor. Depending on this principle all electrical generators work such as DC generators, alternators, and all kinds of dynamos.

Electrochemical process

In all types of battery electricity is produced due to chemical reactions. Here chemical energy gets converted to electrical energy.

Solid State Electric Generation

This is the most modern process of electricity generation. Here, free electrons and holes are generated at a PN junction and distribution of charge carriers gets imbalanced across the PN junction when the junction is exposed in the light. These free electrons and holes and their imbalanced distribution across the junction cause electricity in an external circuit. On this principle, PV solar cells work.

Types of Electricity

- ✓ When electricity produced in the armature of a generator it is always alternating. That means polarity of electricity alters in a periodic interval. In DC generators the produced electricity in armature gets rectified through commutator. In alternators, the AC produced in the armature supplied to the external circuit through slip rings.
- ✓ When electricity does not change its direction it is called DC electricity. Batteries and solar cells produce DC electricity.

Generation and Transmission and Distribution of Electricity

After electricity gets generated in an electrical power plant it gets stepped up by step up transformer for transmitting purpose. The generation of electricity at a low voltage level is practical and economical. But low voltage transmission is not economical. But for electrical transmission, the generated electricity first gets stepped up, and then after transmission it is stepped down by step down transformers for electrical distribution purpose.

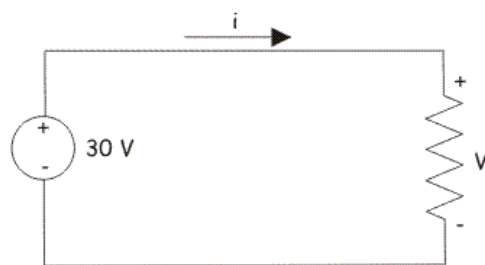
The generation of electricity, the transmission of electricity, and the distribution of electricity are normally with three-phase system. Very ultra-high voltage ac transmission is not economical always and that is why DC transmission is sometimes used. The supply system of domestic houses may be a single-phase AC but all commercial, industrial and bigger house supplies are of three phase system.

What is an Electric Circuit?

The interconnection of various active and passive components in a prescribed manner to form a closed path is called an electric circuit. The system in which electric current can flow from the source to the load and then back to the other terminal of the source is referred to as an electric circuit. The main parts of an ideal electric circuit are:

1. Electrical sources for delivering electricity to the circuit and these are mainly electric generators and batteries
- Controlling devices for controlling electricity and these are mainly switches, circuit breakers, MCBs, and potentiometer like devices etc.
- Protection devices for protecting the circuit from abnormal conditions and these are mainly electric fuses, MCBs, switchgear systems.
- Conducting path to carry electric current from one point to other in the circuit and these are mainly wires or conductors.
- Load.

Thus, voltage and current are the two basic features of an electric element. Various techniques by which voltage and current across any element in any electric circuit are determined is called electric circuit analysis. The figure shows a simple electric circuit containing a battery and resistor.



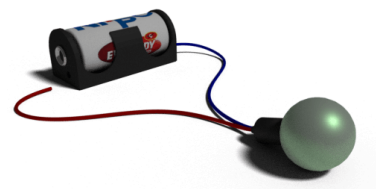
Basic Properties of Electric Circuits

- ✓ A circuit is always a closed path.
- ✓ A circuit always contains at least an energy source which acts as a source of electrons.
- ✓ The electric elements include uncontrolled and controlled source of energy, resistors, capacitors, inductors, etc.
- ✓ In an electric circuit flow of electrons takes place from negative terminal to positive terminal.
- ✓ Direction of flow of conventional current is from positive to negative terminal.
- ✓ Flow of current leads to potential drop across the various elements.

Types of Electric Circuits

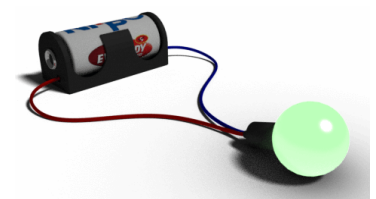
Open circuit

If due to disconnection of any part of an electric circuit if there is no flow of current through the circuit, is said to be an open circuited.



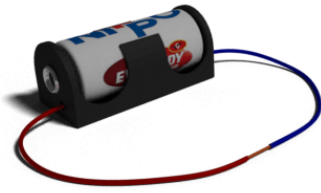
Closed circuit

If there is no discontinuity in the circuit and current can flow from one part to another part of the circuit, the circuit is said to be closed circuit.



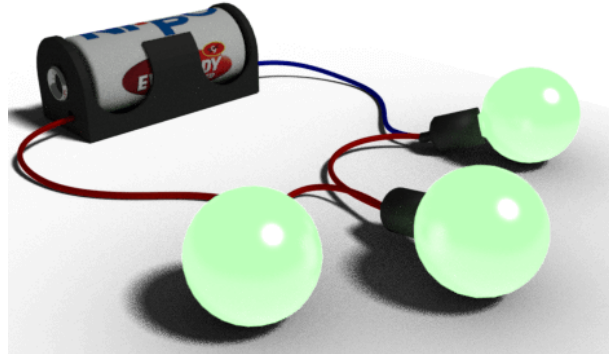
Short circuit

If two or more phases, one or more phases and earth or neutral of AC system or positive and negative wires or positive or negative wires and earth of DC system touch together directly or connected together by a zero impedance path then the circuit is said to be short circuited.



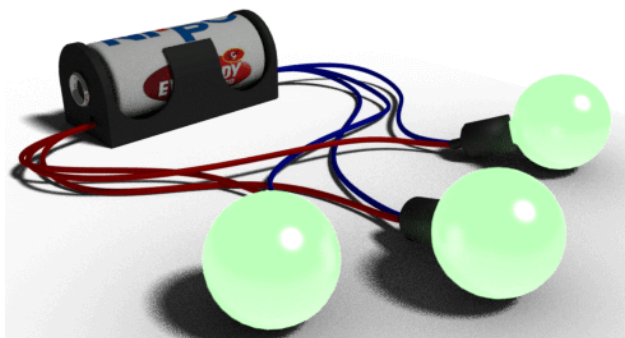
Series Circuits

When all elements of a circuit are connected one after another in tail to head fashion and due to which there will be only one path of flowing current then the circuit is called series circuit. The circuit elements then are said to be series connected. In the series electrical circuit, same current flows through all element connected in series.



Parallel Circuits

If components are connected in such a way that the voltage drop across each component is same then it is known as parallel circuit. In parallel circuit the voltage drop across each component is same but the currents flowing through each component may differ. The total current is the sum of currents flowing through each element.



An example of a parallel circuit is the wiring system of a house. If one of the electric lamp burns out, current can still flow through the rest of the lights and appliances. In a parallel circuit the voltage is the same for all elements.

- ✓ To find the total resistance of all components, add the reciprocals of the resistances of each component and take the reciprocal of the sum.
- ✓ Total inductance of non-coupled inductors in parallel is equal to the reciprocal of the sum of the reciprocals of their individual inductances.

The capacitors connected in parallel acts as series combination.

- ✓ The total capacitance of capacitors in parallel is equal to the sum of their individual capacitance.

Series Parallel Circuits.

An electrical circuit in which some of the elements are connected in series and some of the elements are connected in parallel is called a series parallel circuit. Most of the practical circuits are series parallel circuits. A very common example is the connection of conductors in the rotor of DC motor.

Electrical Tools

Pliers

Pliers are available in different types, shape, and sizes. They are also available in both insulated and uninsulated handles. An insulated handle should be used when working on or near hot wires. It is also used for cutting big and small wires.



Screw Drivers

A screwdriver comes in various sizes and with several tip shapes. Screwdrivers used by electricians should have insulated handles. Using a screwdriver for a particular job, the width of the screwdriver tip should match the width of the screw slot.



Drilling Equipment

Drilling equipment is needed to make holes in building structure passages of conduits and wires.



Sawing and Cutting Tools

Saws commonly used by electricians include the crosscut, keyhole, and hacksaw



Soldering Equipment

In doing electric wiring, splices and taps (connections made to wire) should be soldered, unless you use solderless connectors. Typical equipment available for soldering are shown below.



Hammers

Hammers are used with chisels and for nailing and fitting. Below are examples of carpenter's claw hammer, lineman's hammer, and machinist's ball-peen hammer.



Measuring Tools

To measure wire length and other items, the electrician finds considerable use for measuring tools such as the extension or zigzag rule, push-pull rule and a steel tape as shown below.

Voltmeter or Multimeter

A voltmeter is used to read voltage levels and verify that circuits are “live” or off. Unlike a circuit tester, this tool gives you reading on *how much* voltage is being carried. More sophisticated forms of the tool are known as multimeters, and they can not only read voltage levels but also amperage, resistance, and DC voltage and amperage. They do, however, require practice to learn how to use them properly.

This specialty tool is used mostly by advanced DIYers and professional electricians. Casual DIYers may not need to own this tool, but those who do a lot of electrical work on appliances and electronics may find it essential.



Electrical Measurements

Ammeter

Introduction to Ammeter

As we know a word “meter” is associated with the measurement system. Meter is an instrument which can measure a particular quantity. As we know, the unit of current is Ampere. Ammeter means Ampere-meter which measures ampere value. Ampere is the unit of current so an ammeter is a meter or an instrument which measures current.

Working Principle of Ammeter

The main principle of ammeter is that it must have a very low resistance and also inductive reactance. Now, why do we need this? Can't we connect an ammeter in parallel? The answer to this question is that it has very low impedance because it must have very low amount of voltage drop across it and must be connected in series connection because current is same in the series circuit.

Also due to very low impedance the power loss will be low and if it is connected in parallel it becomes almost a short circuited path and all the current will flow through ammeter as a result of high current the instrument may burn. So due to this reason it must be connected in series. For an ideal ammeter, it must have zero impedance so that it has zero voltage drop across it so the power loss in the instrument is zero. But the ideal is not achievable practically.



Voltmeter

What is a Voltmeter?

Voltmeter is a voltage meter. Which measures the voltage between the two nodes. We know the unit of potential difference is volts. So it is a measuring instrument which measures the potential difference between the two points.

Working Principle of Voltmeter

The main principle of voltmeter is that it must be connected in parallel in which we want to measure the voltage. Parallel connection is used because a voltmeter is constructed in such a way that it has a very high value of resistance. So if that high resistance is connected in series than the current flow will be almost zero which means the circuit has become open.

If it is connected in parallel, then the load impedance comes parallel with the high resistance of the voltmeter and hence the combination will give almost the same the impedance that the load had. Also in parallel circuit we know that the voltage is same

so the voltage between the voltmeter and the load is almost same and hence voltmeter measures the voltage.

For an ideal voltmeter, we have the resistance is to be infinity and hence the current drawn to be zero so there will be no power loss in the instrument. But this is not achievable practically as we cannot have a material which has infinite resistance.

Multimeter

Multimeter as the name suggest the meters that we use to measure multiple quantities with the same instrument. The most basic multimeter measures voltage, current, and resistance. Since we use it for measuring current (A), voltage (V) and resistance (Ohm), we call it as AVO meter. We can categorize the multimeters into two groups, namely analog multimeter and digital multimeter. We will discuss here in this article about analog multimeter.

Advantages of Analog Multimeter

- ✓ A sudden change in signal can detect by analog multimeter more swiftly than a digital multimeter.
- ✓ All measurements are possible by using one meter only.
- ✓ Increase or decrease in signal levels can be observed.

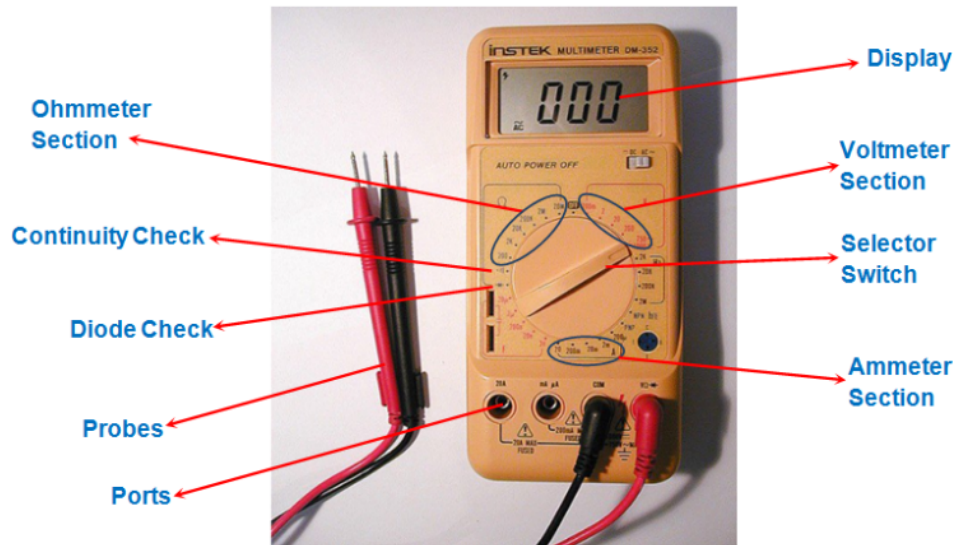
Disadvantage of Analog Multimeter

- ✓ Analog meters are bulky in size.
- ✓ They are bulky and costly.
- ✓ The pointer movement is slow, can't be used to measure voltages with frequencies higher than 50 HZ.
- ✓ Inaccurate due to the effect of earth magnetic field.
- ✓ They are vulnerable to shock and vibration.

How to use digital multimeter?

Digital Multimeter is a device which has two words in its name: Digital and Multimeter. Let's first try to analyze why do we have them there i.e. what do each of them actually convey which in turn helps us understand what does a multimeter do. The first word – digital – indicates that the meter has a digital or liquid crystal display while the next word – multimeter – indicates that this single device can be used for multipurpose i.e. to measure more than one parameter. A typical digital multimeter will be as shown by Figure 1 and comprises of selection switch, display, ports and probes as its major parts.

Here the probes are to be inserted into appropriate ports and are to be connected across the parameter which needs to be inspected. Meanwhile one should ensure that the selection switch is to be kept at the position which is appropriate for the measurement. When done so, the multimeter displays the value of the parameter which is being analyzed.



Generally digital multimeters are used to measure three important parameters viz., current, voltage and resistance. Apart from these, they can also be used to perform special functions like diode check, capacitance measurement, Transistor hFE or DC current gain, frequency measurement and continuity check. In this article, we present a brief note on the most frequently used applications of multimeter which are for current, voltage and resistance measurement along with diode and continuity checks.

Current Measurement by Digital Multimeter

Under this category, the digital multimeter mimics the behavior of an ammeter as it is used to measure current. To accomplish this, insert the red probe of the multimeter to one of the current measuring sockets: mA (to measure low level of current) or 20 A (to measure larger current). Connect the meter along the line through which the current is to be measured (nothing but series connection). Next set an approximate range around which we expect the current to be in the ammeter section of Figure 1. In this state, if we switch on the power supply, then the meter will read the current flowing through the circuit.

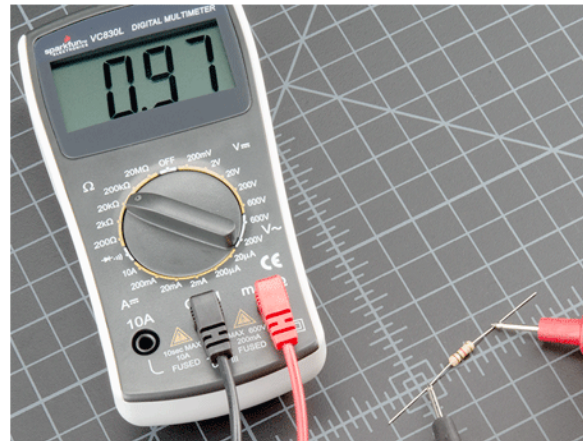
Voltage Measurement by Digital Multimeter

When set to measure the voltage, the multimeter acts like a voltmeter. To start with, one has to insert the red and the black probes of the multimeter to the sockets marked as 'V' and 'COM', respectively. Then we have to select the expected range in which our voltage would be. Simultaneously, even AC or DC should also be selected in the voltmeter section of Figure 1. On doing so, the meter reads the value of the voltage, provided one connects the leads across the component (in parallel fashion) or at the point at which the voltage needs to be measured.



Resistance Measurement by Digital Multimeter

In this case, we configure the multimeter to act like an ohmmeter. Here the red and the black probes of the multimeter are inserted into the sockets marked as 'V' and 'COM', respectively while the selection switch is set to an expected range in ohmmeter region (Figure 1). Now, the leads need to be connected across the component whose resistance is to be known. On doing so, we get a reading in the display part of the multimeter which reads the value of the resistance.



Diode Check by Using a Digital Multimeter

For this case, insert the probes into the sockets as that in the case of voltage measurement and set the selection switch to point towards diode check position shown in Figure 1. Now when the red lead of the multimeter is connected to positive terminal of the diode while its negative lead is connected to the negative terminal of the diode, then we have to get a low reading on the multimeter. On the other hand, if we connect the red lead to the negative terminal of the diode and the black to the positive terminal, then we have to get a high value. If the readings obtained are as per our expectation, then we say that the diode is working properly; else no. More information regarding this can be found in the article "Diode testing".

Continuity Check by Using a Digital Multimeter

Continuity check is used to know whether there exists any low resistance path via two points i.e. to check whether the points are short or not. To accomplish this task, the probes are inserted into the sockets as that in the case of voltage measurement and selector switch is made to point towards continuity check position (Figure 1). Then, the points to be tested are touched with the leads of the probes. Now, if the multimeter beeps out, then it means that the points are shorted or else the resistance between them can be read out from the display.

Megger

The device is being used since 1889, popularity raised during 1920s since the long back device is same in its uses and purpose of testing, few real improvements appeared in recent years with its design and quality of tester. Now high-quality options are available which are easy to use and quite safe.

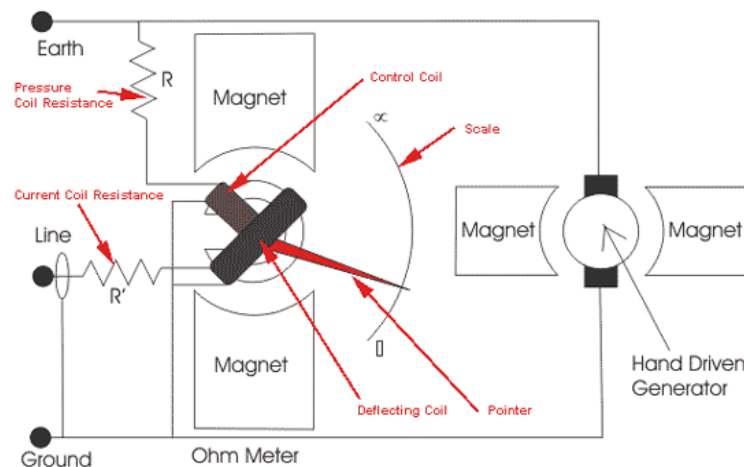
Insulation resistance IR quality of an electrical system degrades with time, environment condition, i.e., temperature, humidity, moisture and dust particles. It also gets impacted negatively due to the presence of electrical and mechanical stress, so it's become very necessary to check the IR (Insulation resistance) of equipment at a constant regular interval to avoid any measure fatal or electrical shock.



Types of Megger

- ✓ Electronic Megger (Battery operated)
- ✓ Manual Type (Hand Operated)

Construction of Megger



1. Deflecting and Control coil: Connected parallel to the generator, mounted at right angle to each other and maintain polarities in such a way to produced torque in opposite direction.

Permanent Magnets: Produce magnetic field to deflect pointer with North-South pole magnet.

Pointer: One end of the pointer connected with coil another end deflects on scale from infinity to zero.

Scale: A scale is provided in front-top of the megger from range 'zero' to 'infinity', enable us to read the value.

D.C generator or Battery connection: Testing voltage is produced by hand operated DC generator for manual operated Megger. Battery / electronic voltage charger is provided for automatic type Megger for same purpose.

Pressure Coil Resistance and Current Coil Resistance: Protect instrument from any damage because of low external electrical resistance under test.

Working Principle of Megger

- ✓ Voltage for testing produced by hand operated megger by rotation of crank in case of hand operated type, a battery is used for electronic tester.
- ✓ 500 Volt DC is sufficient for performing test on equipment range up to 440 Volts.
- ✓ 1000 V to 5000 V is used for testing for high voltage electrical systems.
- ✓ Deflecting coil or current coil connected in series and allows flowing the electric current taken by the circuit being tested.
- ✓ The control coil also known as pressure coil is connected across the circuit.
- ✓ Current limiting resistor (CCR and PCR) connected in series with control and deflecting coil to protect damage in case of very low resistance in external circuit.
- ✓ In hand operated megger electromagnetic induction effect is used to produce the test voltage i.e. armature arranges to move in permanent magnetic field or vice versa.
- ✓ Where as in electronic type megger battery are used to produce the testing voltage.
- ✓ As the voltage increases in external circuit the deflection of pointer increases and deflection of pointer decreases with a increases of current.
- ✓ Hence, resultant torque is directly proportional to voltage and inversely proportional to current.
- ✓ When electrical circuit being tested is open, torque due to voltage coil will be maximum and pointer shows 'infinity' means no shorting throughout the circuit and has maximum resistance within the circuit under test.
- ✓ If there is short circuit pointer shows 'zero', which means 'NO' resistance within circuit being tested.

Work philosophy based on ohm-meter or ratio-meter. The deflection torque is produced with megger tester due to the magnetic field produced by voltage and current, similarly like 'Ohm's Law'.

The torque of the megger varies in a ration with V/I , (Ohm's Law:- $V = IR$ or $R = V/I$). Electrical resistance to be measured is connected across the generator and in series with deflecting coil.

Produced torque shall be in opposite direction if current supplied to the coil.

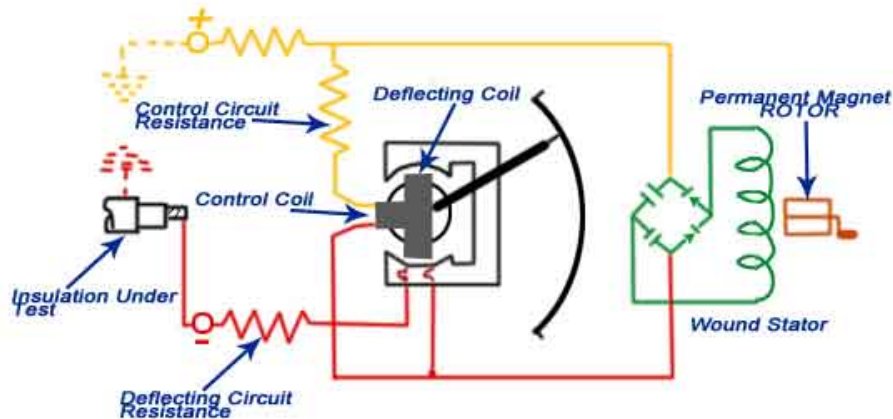
1. High Resistance = No Current: - No current shall flow through deflecting coil, if resistance is very high i.e. infinity position of pointer.

Small Resistance = High Current :- If circuit measures small resistance allows a high electric current to pass through deflecting coil, i.e. produced torque make the pointer to set at 'ZERO'.

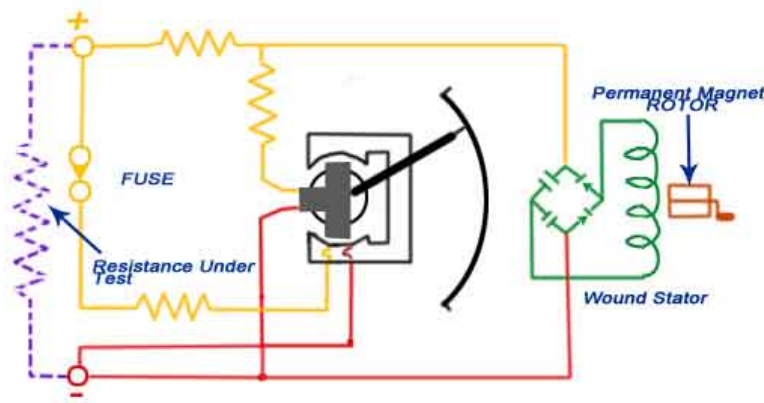
Intermediate Resistance = Varied Current: - If measured resistance is intermediate, produced torque align or set the pointer between the range of 'ZERO to INIFINITY'.

Connection Diagram of Megger for Testing

Instrument Arrangement for insulation test



Instrument Arrangement for continuity test



DIAGNOSE EQUIPMENT

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 provide 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!

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 especially 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.

Realizing 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.

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 have 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.

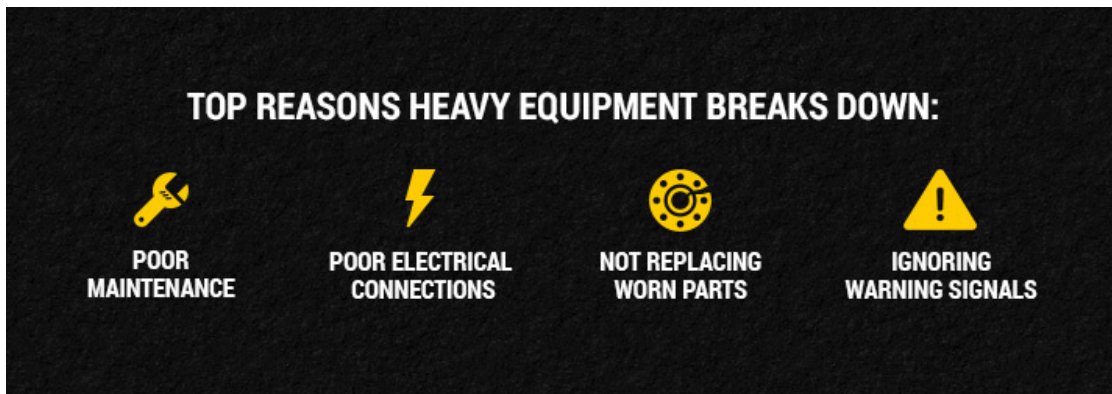
In general, equipment inspectors will check the following components using both diagnostic tools and an expert eye:

- ✓ 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.

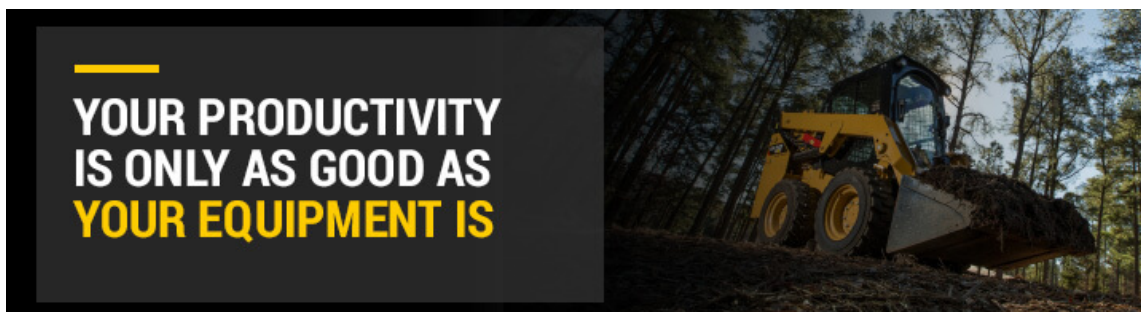
- ✓ **Poor maintenance:** Failing to replace belts or forgetting to check oil levels, for example.
- ✓ **Poor electrical connections:** An inspector can detect electrical issues early, before equipment breaks down and causes you to lose work.
- ✓ **Not replacing worn parts:** By fixing only one broken 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 check 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.

9. PERFORM INSTALL, COMMISSION AND REPAIR PUMPS

IDENTIFY SCOPE OF MACHINE INSTALLATION, COMMISSIONING OR MODIFICATION TASK

What is Project Scope?

PMBOK defines project scope as:

The work that needs to be achieved to successfully deliver a service, product, or result with a specified set of functionalities and features.

So, what is project scope? How would you define it?

Project scope, basically, outlines the goals that need to be achieved when delivering the final product or service. A few aspects that need to be identified in the project scope include:

- ✓ Project objectives
- ✓ Project goals
- ✓ Sub-phases
- ✓ Tasks
- ✓ Resources
- ✓ Budget
- ✓ Schedule

Now, let's cover the steps needed to identify the project scope.

How to Identify the Scope of a Project: The Four Steps

Step 1: Identify Project Needs

The first step in the project scope checklist is to identify project needs. For this, you need to:

- ✓ Establish a project timeline
- ✓ Understand project resource allocation needs
- ✓ Set project goals

It is essential to understand project requirements to know what exactly needs to be done when trying to reach the end goal. Everything needs to be identified right from defining the project goal to determining the subtasks that need to be accomplished for achieving the end goal. Further, the resources needed to get all the work done need to be identified as well.

Step 2: Identify Project Objectives

Project objectives are the different business goals that a company wishes to achieve through their product or service. A few examples of project objectives include introducing a new product, developing new software, or creating a new service in an



organization. *The best way to identify and determine project objectives is through the S.M.A.R.T guidelines.*

Specific – What are the project goals and objectives? Why and how will they be achieved?

Measurable – Can all of them be accounted for?

Achievable – Can it be accomplished with the available resources?

Realistic – Can it be easily delivered, irrespective of any complications?

Time-bound – Can everything be achieved in the set time frame?

Make sure you have answers to all these questions before you proceed to the third step.

Step 3: Identify Project Expectations

Quoting the Google Wave example again, the basic problem was not identifying and meeting the target audience's expectations - although the teams' expectations were met. Therefore, it is essential to identify project expectations for both the team working on the project and the target audience. So, for the team, the project expectations include the efficiency and effectiveness of the project's operational process.

For the target audience, the main expectation is customer delight; that is how happy the customers are when using your product or service. This usually is determined by the product or service:

- ✓ Price
- ✓ Quality
- ✓ Availability
- ✓ Policies

Make sure you have identified and defined all these aspects when defining the project scope.

Step 4: Identify Project Constraints

The last and most important step in the project scope checklist is identifying the project constraints. Being aware of a project's limitations is as equally important as identifying its goals. This can minimize problems or issues faced during project execution, thereby preventing any delay in deliverables.

A few things that can cause project constraints are:

- ✓ Internal and external conditions
- ✓ Dynamic environment
- ✓ Technical glitches
- ✓ Lack of resources

Along with knowing how to identify project scope, it is also important to understand the project scoping process.

Project Scoping Process: All You Need to Know

The project scoping process consists of three processes:

Planning



The first step in the project scoping process is to understand what needs to be done and plan projects accordingly.

- ✓ Understand the project as a whole
- ✓ Create subtasks that you will need to complete to deliver the project
- ✓ Set quality standards
- ✓ Define and delegate the work to respective teams

After you do this, you move on to the second step.

Controlling

This step is a part of project execution. Once you've defined and delegated everything, the project execution starts. During this phase it is essential that you control and monitor everything efficiently.

A few things you need to monitor during project execution include:

- ✓ Documents
- ✓ Project changes
- ✓ Work progress
- ✓ Quality checks

Closing

The third and last process is "*closing.*"

This includes:

- ✓ Auditing of all project deliverables
- ✓ Assessment of project outcomes
- ✓ Compare project outcome to estimated outcome

Project Scope Checklist: Wrap Up!

It is essential for you to always cover all the basics before understanding how to determine project scope. Always follow the four steps mentioned in this blog to make sure the project is implemented without any hassles.

The ideal way to make sure you avoid project scope is by using simple project management software. PM software, like ProProfs Project, not only helps you manage multiple projects easily but also gives you a platform to define project goals clearly and manage project creep efficiently.

ProProfs Project helps you to:

- ✓ Plan projects alongside your team using a shared calendar
- ✓ Create task dependencies so that teams move on to a new task only when previous tasks are finished
- ✓ Track work progress of all your projects on one dashboard
- ✓ Create insightful reports to monitor team and project performance

Other than these features, a robust project management software helps you pre-determine scope creep, manage it efficiently - therefore, avoid project failure.

Now that we know how to define project scope and identify it, let us cover a few FAQs on the same topic.

Q. What is included in project scope?

The project scope includes the major deliverables of a project, key milestones, and requirements. It also includes constraints, assumptions, and boundaries of a project.

Q. What are project deliverables in project scope?

Project deliverables in project scope include documents, services, or results that need to be completed during project execution.

Q. What is the difference between project scope and project deliverables?

Project scope can be defined as work that is broken down into smaller tasks to achieve the project goals. On the other hand, project deliverables are measurable and tangible results that must be successfully produced for project completion.

BRIEF TEAM ON REQUIREMENTS

Team Briefings

Act or instance of supplying precise instructions or information to someone. The Team Briefing is a regular face-to-face meeting between supervisors and their teams to systematically communicate and exchange information and ideas.

It ensures that staff at all levels receives information that is relevant to them, which is a mixture of corporate and local issues. It is capable of being monitored by someone given responsibility to do so, including the satisfactory feedback of answers to questions at all levels. Its aim is to reduce misunderstandings and rumours and enhance cooperation.

The benefits of Team Briefing are:

- ✓ Provides a channel for delivering clear messages and encouraging open communication.
- ✓ Regular face-to-face communication prevents rumor from gaining credibility.
- ✓ Enables questions and suggestions to be fed back from staff to the top.
- ✓ Develops greater awareness and involvement at all levels.
- ✓ Develops a shared sense of mission, collective aims and reasons why we're here.
- ✓ Explains financial, commercial and strategic issues.
- ✓ Ensures that staffs are kept up to date on performance, progress and policy changes.
- ✓ Enables discussion of sensitive matter because it's face-to-face.
- ✓

Step by Step

1. Arranging your Team Briefing

- ✓ Timing: try setting dates for at least six months at a time so that your staff are well aware of the dates in advance and can put them into their diaries. Briefings should be held at least once a month.
- ✓ Size: the ideal team is made up of around 4-15 people.
- ✓ Venue: make sure you choose a suitable venue for your team briefing.
- ✓ Publicizing the briefing: once you've got all the arrangements in place, make sure that you give your team enough time so that they are able to attend.

Preparing the agenda

- ✓ Priorities: sort the items into Must know information (details essential to the team and its day to day activities), Should know information (details which staff should know about as a matter) and Nice to know information (information useful to know).
- ✓ Timing: work about how long each item should take and remember to allow time for questions after each item.

Presenting the Briefing: briefings should be fairly informal and by all means adopt an approach which best suits the culture and nature of your team.

- ✓ Core brief: it's the written briefing details from the CEO or board which will be passed on to every employee at every Team Briefing meeting.
- ✓ Local brief: it's a separate written brief prepared by each team leader, manager or supervisor, for his or her own team, containing local issues relevant to that team.
- ✓ Feedback form: it's a separate document which enables the questions arising at briefings to be recorded, answered, whether at the time or later, and that process to be monitored.

Attending a Team Briefing

1. **Before the Briefing.** Take a few minutes to think about the following points:

- ✓ Are you expected to do any preparation/bring anything with you to the meeting?

- ✓ Are there any items still outstanding? Look through the records of the last brief you received.
- ✓ Are you having problems with the mechanics of the team briefing which you'd like to raise with your manager/colleagues?

2. During the Briefing.

- ✓ Concentrate and listen so that you hear the questions asked by other people.
- ✓ Make concise notes.
- ✓ Ask questions to clarify the information you have been given.
- ✓ Delivering a team brief to your own team make sure you understand which points are of particular relevance to your area of work.

3. By the end of the Briefing you should have:

- ✓ A clear picture of the information you have received.
- ✓ An idea of when you can expect to receive more information from your manager if they weren't able to answer your question at the briefing.

Facilitator's Role

- ✓ **Frequency.** Team briefing meetings need to be held on a planned and regular basis.
- ✓ **Duration.** Your briefing should last around 30 minutes. If there isn't much information to impart then just reduce the length of the team briefing. Make sure you leave enough time for staff to ask questions - this is a two-way form of communication.
- ✓ **Feedback.** With any luck your team will give you some useful feedback and make some valid suggestions during your team briefing. It's really important that you do something constructive with this feedback - the team could be unsatisfied if they feel their views are not being taken seriously.
- ✓ **Monitoring the Team Briefing.** Managers at a senior level should make every effort to "sit in" on team briefings within their area of work to assess how successful team briefing is. The Internal Communications team will also carry out periodic research into the distribution and effectiveness of team briefing.

COMMENCE INSTALLATION, COMMISSIONING OR MODIFICATION TASK

Prior to the commencement of the installation, commissioning and modification of the sewerage system, it is vital that that we develop a good understanding of the sewerage system and its functions including details of its parts.

Orientate on the sewerage design and parts of the of the system

Students are encouraged to review the materials presented in the competency unit-13 "Operate and maintain sewerage treatment plant (STP) while progressing with the study in this course as the mentioned unit notes explain the design and parts of the sewerage system.

Install the New Sewage Pump

- ✓ **Clean debris out of the basin:** If you took out an old sewage pump, look into the pit for damage and other abnormalities. Carefully get rid of any materials or waste that may have accumulated on the basin walls. Use a scraping tool to take off the old seal so the new one will be strong and prevent gas leaks and odors.
- ✓ **Position the basin:** To prevent potential leaks, secure the container with hard hold glue before attaching the pump. Ensure the unit is stable so it doesn't tip or fall when water hits against it. Since this basin operates by gravity, you need to position it lower than the ground so the wastewater can flow into the tank.
- ✓ **Install the new check valve:** Set up the new check valve before putting the pump in the sewage basin. You may want to position it so the water can pass upward into the main sewer line. To glue this component to the pump, apply primer inside the fitting and outside the discharge pipe. Slide the coupling on top of the pipe, then attach the fitting to the discharge pipe with PVC cement. Twist it slightly and hold for a few seconds to secure the bond.
- ✓ **Set up the float switch:** Install the float switch on top of the pump and secure it with heavy-duty glue. Position it so the trigger is pointing at the basin and has a free range of motion. Open the vent outlet enough to release as much water as possible each time this component activates the sewage pump. Adjust the float so the tank's wastewater level doesn't get too low below the drain inlet.
- ✓ **Test the pump and float switch:** Connect the new pump to a dedicated circuit and test it by activating the float switch and making sure it turns on the system. Only allow the pump to run long enough to hear it working, or else it could become damaged. Make sure you've installed the float switch at the right height so the system can operate properly.
- ✓ **Measure and cut the PVC pipe:** If you need to install a brand-new discharge pipe, measure the old one and consider the proper dimensions given the new check valve's installation. Use a hacksaw to cut it on a raised surface, and smooth out the edges with a deburring tool.
- ✓ **Drill a weep hole:** A weep hole prevents the pump from drying out due to air locking in the pipe. It also controls the flow of water and air away from the pit, allowing the system to flow freely every time it needs to empty the basin. You may want to lean the pump at an angle and measure a few inches above the adapter. Drill a three-sixteenths-inch gap into the piping for the best results.
- ✓ **Connect the adapter and pump to the discharge pipe:** With primer and PVC cement, secure the male-threaded adapter to one side of the PVC pipe. Thread the side of the pipe attached to the adapter into the sewage pump, tightening it with a wrench. Be careful not to overtighten it so you don't crack the fittings.
- ✓ **Lower sewage pump into the pit:** After you've cut the discharge pipe and attached it to the sewage pump, bring both components into the basin. Position the float switch so it's away from the wastewater inlet. It may help to install the discharge pipe to block the inlet water from covering the pump directly. When you've confirmed every piece is in the right position, secure the electrical wiring with zip ties to prevent snagging.

- ✓ **Connect the discharge pipe to the check valve:** Using the primer and PVC glue, connect the coupling to the top of the PVC pipe. Slide the adapter from the check valve over the coupling before securing it to the discharge pipe. Connect the coupler with glue to the discharge pipe and attach it to the check valve. Slide the adapter up and tighten the check valve with your hands. Overtightening the system may crack the fittings, so avoid this.
- ✓ **Test the sewage system:** After you've securely placed the pump inside the basin, make sure the float switch can move freely within it. Connect the sewage pump to the designated electrical outlet and fill the basin with a bucket, putting in enough water to activate the float switch. Piggyback the pump plug off the float switch to ensure proper operation.
- ✓ **Confirm proper placement of all components:** Prepare the new gasket for connecting to the basin cover. Loosen the discharge pipe so you can slide the cover over it. Pull all electrical wires through the basin cover holes before sealing the top. Pull the wire slack up with an electrical wire grommet and fill the gap. Once you've placed the cover, make sure the vent pipe is about 2 or 3 inches below the cover when it's inside the basin.
- ✓ **Secure the sewage basin cover:** Permanently attach the cover to the basin with a bead of silicone around the opening's edge. Slide it over the discharge pipe and press it into place. Screw the new bolts and washers in place to hold the cover down. If you notice any additional wire slack, pull it above the cover and zip tie it to the discharge pipe, ensuring the wires are below the electrical outlet. Slide the donut gasket over the discharge pipe and lock the gasket into the grooves.
- ✓ **Connect the vent pipe to the top of the basin cover:** You must attach your sewage pump system's piping to the basin to vent odors and gases. These pipes need to vent outside or connect to the main stack in the home where your other piping connects. Make sure your system complies with all local and regional building codes. Once you've attached both pipes securely and safely, fill the remaining gaps with a bead of silicone to produce a proper seal.

Commissioning Equipment

Wouldn't be nice if every new piece of equipment or system worked flawlessly from the moment it was installed and initiated until the first breakdown occurred many years later. That would be an exception with most industrial equipment.

When it comes to setting up equipment, we may find some components were damaged during shipment, the field engineer has little expertise, or we're doing the beta testing on a new design (whether we agreed to this or not). The same can apply to rehabilitated equipment being installed in the original application and position.

Why is it that cars come off an assembly line and rarely run into serious warranty issues? The reason is that car manufacturers exhaustively test, improve and inspect both the design and the production processes on thousands of cars. Industrial equipment tends to run in small manufacturing lots; hence not all the bugs get worked out.

This is why commissioning industrial equipment is an art, and a necessary one at that. I call it an art because, by definition, setting up new equipment requires creativity,

craft skills and deductive reasoning. These very same attributes apply to an art in every sense of the word.

My facility, Upper Occoquan Service Authority (UOSA), has matured its maintenance and asset management approach to the point where focusing on commissioning is the next logical step. This thinking arrived as part of our overall pursuit of best practices in reliability and asset management.

Failing to follow a commissioning process is tantamount to installing your next failure. Proper commissioning of equipment can extend useful life, which is an important goal in asset management. Therefore, commissioning is an essential component of a good asset management program.

After several years of designing and implementing maintenance support processes, we will verify improved reliability by tracking mean time between failure (MTBF), mean time to repair (MTTR) and equipment availability.

A Commissioning Philosophy

The basic challenges in setting up new or rehabilitated equipment are fairly universal. They boil down to anticipation of problems, perception of problems and correction of problems. Let's take those words (anticipation, perception and correction) and examine how they apply to the commissioning process.

It may be difficult to imagine how to anticipate problems, but a good starting point is searching out repair histories. Repair histories can tell you what broke down, when, why, how, where and who was involved. This assumes your enterprise has accurate repair histories in a CMMS. If repair histories are not of sufficient quality, improve them as needed. Interviews with your operators and others who own and operate the same equipment are priceless.

As part of a commissioning plan, this valuable knowledge needs to be recorded in a retrievable format. This is a core part of the plan – the framework for recording information. Think of it as the rules of a game. The framework for recording should be available to participating users. The ability to change entries in the records must be monitored and controlled to ensure consistency and accuracy.

If the equipment to be commissioned is made up of subassemblies of familiar components, then anticipated failures can be defined by individual components. For example, a centrifugal blower should have a performance curve graph, an allowable vibration limit and other specifications. When the blower operates outside of any of these values, an investigation is required and followed by appropriate corrective action.

Some problems creep up so slowly that they are not detected until damage has occurred. This is a failure to perceive. This is where determining the vital test points and establishing the acceptable values is necessary. Sometimes we don't know what is acceptable; this is where conferring with the manufacturer or others with similar equipment provides guidance.

Once the source of a problem has been decisively established, the next step is correction. The solution should treat the core problem. For example, if a one-times-rotating speed imbalance is detected, balance the rotating body. If the structure of the

machine has a harmonic resonance so that the slightest excitation causes destructive vibration, address the structure rigidity.

When the corrective measures are completed, verify the anticipated improvements are perceivable. Use measuring tools to verify the correction did what it was supposed to do. This is where PdM tools shine – vibration analysis, ultrasound detection, motor current signatures, oil analysis and thermography.

None of the aforementioned efforts will produce desired results unless action is taken. Do something and document what was done. This enhances the value of the commissioning project.

Preparing for Commissioning

It is essential to become fully familiar with the equipment that is being commissioned. This means reading the manuals in advance (if possible), reading the cut sheets for components, studying the operations manual, getting the manufacturer to field your questions and contacting others with the same equipment to learn how they were successful.

It is useful to visit facilities where similar equipment is operating both successfully and unsuccessfully. Talk to the operators and maintenance people, as they have an intimate connection with the equipment.

I was talking with an electrician friend about some of the more interesting and difficult jobs we'd done over the years. We were discussing how to fit wires into a congested junction box. My friend said, "You've got to have a plan." This stuck with me because it shows that even the most mundane task, such as dressing wires in a tight space, requires a plan.

Commissioning also requires a plan. A plan is nothing more than a well-thought-out set of guidelines which may incorporate rules, drawings, [checklists](#) and procedures. A commissioning plan is something like a cooking recipe; you follow it but adjust as needed based on experience.

The Plan

- ✓ Select a project leader – one who will have the time and temperament to command resources in an effective manner
- ✓ Define the absolute requirements for acceptable operation – what work must the equipment do?
- ✓ Identify and address anticipated [failure modes](#) for the overall system and all subsystems.
- ✓ Verify operating conditions (as specified by the equipment seller) will be met – i.e., operating environmental conditions (temperature, humidity, pressures, voltage, etc.).
- ✓ Define the testing steps necessary and the order of those steps in the commissioning process. These steps are derived from experience, knowledge and research.
- ✓ Define the skills sets necessary – mechanical, electrical, controls and engineering
- ✓ Schedule the resources and personnel to accomplish the defined steps

- ✓ Record the observations and test point values measured (perceived) during each step
- ✓ Review the results (convert data into information)
- ✓ Take corrective actions as needed
- ✓ Verify that the corrective actions produce the desired results
- ✓ Train the operators to make certain they will know how to operate the equipment properly in all circumstances
- ✓ Implement a preventive maintenance (PM) program that addresses best practices
- ✓ Repeat these steps as necessary until all absolute operating requirements have been met
- ✓ Record the commissioning process describing what brought success and what did not for future reference.
- ✓ Create a body of knowledge for commissioning and update it when new information is revealed as part of the commissioning processes.

The Commissioning Leader

A commissioning project also requires a leader to manage the steps and execute the plan. This leader acts as the central hub of communication for the personnel assigned to the commissioning project. Similar to root cause investigations, it is wise to not choose a dominant personality as a leader.

People of dominant persuasions can corrupt the process with their predispositions. The optimal leader is one who follows the plan and verifies all steps are accomplished and documented. This leader must also have good organizational and communication skills in addition to being assertive.

Select a competent leader who will have sufficient time to dedicate to the project without getting pulled off to yet another project. This only makes sense and is how successful enterprises advance.

Failure to Get It Right (and Knowing Right from Wrong)

It is a fact of our times that we are expected to dramatically increase efficiency and accuracy with the feast of computer-based tools that are laid before us. Commissioning is not a process that can be rushed. It must be conducted in a thoughtful manner with adequate resources. “The faster we go, the behinder we get” is a time-worn expression that embodies both experience and folk wisdom.

There are occasions when commissioning teams dig too deeply looking for problems and overlook problems that are blatantly obvious. It is important to review all available information and take all reasonable steps when commissioning. Don’t be afraid to have an independent outside observer look at your processes. Expect some root cause discoveries during commissioning.

Many problems can be anticipated before new equipment is started for the first time. Getting critical tasks into the PM program is as much a part of commissioning as any of the other steps. Any required maintenance tasks that are burdensome, time-consuming or messy tend to get put off. Anticipate problems with filters plugging and fan blades loading up with dirt and becoming imbalanced.

Lessons Learned at UOSA

During the last few years, we have learned a few valuable lessons. We have uncovered issues with the lack of a proper commissioning process as well as the benefits of having proper procedures in place. Our lessons highlight the beneficial use of predictive maintenance technologies (PdM), such as ultrasound, vibration, oil analysis, thermal imaging and motor current signature analysis, but the human senses are also part of the evaluation process.

Electric Motors in Critical Applications

Whether a motor is new from the manufacturer or reconditioned, it is essential to check its condition with a motor current signature analysis instrument as soon as it arrives onsite. If this testing is not performed immediately, it tends to get forgotten or done in a hurry just before the motor is installed. Who wants to find out a motor has a problem just before it's installed, or worse yet as soon as it is powered up?

Our experience has been that installation is a bad time to discover equipment problems, because personnel and rigging equipment are mobilized and there may be operational constraints to deal with if the motor is not installed on schedule.

A full set of procedures must be established for quality control inspection of motors, new or rebuilt, when they are received. Vendors of motor test equipment are a good resource for developing these procedures. A set of guidelines is also needed for repair of a motor to verify what was done during repair. There are many online resources on how a motor should be repaired.

Compare recommendations from various motor shops to get a broad overview. Motors are the prime movers behind industry and must be given critical attention or process failure is certain.

Basic off-line tests should be performed before a motor is connected to its power circuit. A polarization index test and a surge test are essential. When the motor is powered up for the first time, measuring the current in all three phases is vital. If online testing is possible, it should be performed. If an ultrasound instrument is available, the bearing sound signatures should be recorded to obtain baseline decibel levels and time-domain graphs for future comparisons.

If the motor can be run prior to coupling it to the driven component, it is desirable to measure and record vibration characteristics. If any of these tests reveal problems, it will be necessary to halt installation and take corrective actions.

Vertical Turbine Pumps (VTP)

The water industries frequently employ VTP for processes. These pumps have their impeller mounted in a volute sitting up to 30 feet below ground. The impeller is driven by a long shaft, which is stabilized by a number of "spider" bearings along the inside of the pump column through which the water flows. The motor is mounted above ground on a pedestal in the vertical axis.

On the suggestion of a PdM technician from a neighboring water facility, we installed two hermetically sealed vibration sensors on the volute of a new VTP prior to lowering it into the wet well. The sensors were installed in the horizontal plane, positioned 90 degrees radially from each other. When the sensors detected high vibration during initial startup, the installing contractor was surprised. They'd never seen anyone test for vibration at the volute before. The motor was not vibrating significantly, so they assumed the installation was satisfactory.



The detection of this vibration led to the discovery that a group of mounting bolts in the sole plate was too long and bottomed out into blind threaded holes. The split-lock washers on these bolts were not fully compressed, and this allowed resonances, which manifested as the vibration detected at the volute. We are now installing these vibration sensors on all vertical turbine pumps when they are pulled for maintenance. We have also learned that there are a number of special considerations involved in setting up these types of pumps. The sole plate must be level and the pump column perpendicular. The sole plate must also be firmly grouted to prevent vibrations. The pump shaft sections should be within a nominal 0.005 inches of the total indicated runout.

The Hydraulics Institute (HI) vibration standards 2000 version provided a value for allowable vibration measured at the top of the motor for this type of pump. Later HI standards did not include this value. The owner must determine the allowable value. Our experience is that the pump manufacturers rarely specify a value. Generally speaking, less than 0.2 inches per second is acceptable based on our experience.

Centrifugal Blowers

A centrifugal blower (for induced draft application) was supplied with a regenerative thermal oxidizer system. The blower wheel was mounted directly on a 7.5 HP motor shaft, and a pressure gauge calibrated for inches of the water column was installed on the blower output piping. The blower vibration increased significantly after three years of operation, the motor failed and a critical process was shut down.

After the motor was replaced, vibration continued to be high. Surge resonance was suspected of causing the blower wheel to delaminate, which resulted in dynamic imbalance and the high vibration. Before further action was taken to correct the issue, the wheel jammed in the blower housing as a result of delamination. The wheel failure caused the critical process to shut down again.

During commissioning the contractor did not specify a vibration limit for this blower. When inquiring with the blower manufacturer after the failure, we found that the vibration limit was less than 0.2 inches per second. The blower was found to be operating at 0.7 inches per second before the failure, i.e., way out of specification. No

one had taken an initial baseline vibration reading, so there was no good data for comparison.

The gauge reading on the output piping was never recorded during commissioning. No one knew what the gauge reading should be during normal operation. The gauge needle had oscillated violently during surge conditions until it jammed at 19 inches of the water column (WC). A new gauge was installed, and the pressure at normal operation was recorded as 39 inches WC.

The commissioning lessons learned are to record vibration and output pressure values, comparing these to the manufacturer's allowable limits and instructing the operators on what conditions could cause damage. Trending of vibration was also added as a preventive maintenance (PM) task.

Sludge Dryer Mixer Bearing Failure

When a new sludge drying system was installed, every step of commissioning was carefully performed by the contractor. However, the large ball bearings on the mixing drum shaft still failed in a spectacular manner. They were completely lacking grease from the factory and chewed themselves up into misshaped balls of scrap metal. A simple measurement with a structure borne ultrasound instrument would have detected the absence of lubricating grease while the bearings were still salvageable. Ultrasound inspection has now been added to the commissioning processes where applicable.

Submersible Pump/Motor Units

Submersible pumps have become very popular in wastewater applications. They can be lowered into process wells where they slide into a coupling flange with relative ease and then be connected to electrical power. They are as close to "plug and play" as industrial equipment gets.

We have found it to be prudent to test the power wiring with motor current signature analysis instruments prior to connecting the pump motor to the circuit. This allows the technicians to prove that the power circuit has no resistance to ground issues which may generate variable frequency drive faults. The pump motor should receive both off-line and on-line testing.

Some of these submersible pumps have an oil reservoir for the shaft seals. As part of the PM, this oil must be pumped out and checked for the amount of process water that enters through the volute seal. The PM requirement for this check is generally around a 365-day cycle. However, when a new pump is installed, we have found that it is smart to check the water content in the oil after the first 90 days. It has revealed excess water on occasions.

Wastewater Clarifiers - Gear Drives

When the contractor installed a new, large (more than 7 feet in diameter) gear drive, they filled it with the manufacturer's specified oil. One of our tests prior to startup was to take an oil sample. When our tech sampled the oil, it was found to be critically low in viscosity compared to the specification.

After a bit of investigation, it was learned that the manufacturer ships these gear drives half-filled with diesel fuel. Unaware of this, the contractor added oil to the fill line, which resulted in low viscosity when the oil was tested. Rigorous oil testing was added to the commissioning checklist of all clarifier drives.

Rotary Screw Compressors

These types of compressors offer energy conservation benefits but come with important maintenance responsibilities. Particularly, the oil condition must be closely monitored. Satisfying the warranty requirements often relies on being able to prove preventive maintenance was performed.

Many rotary screw compressor manufacturers require owners to send oil samples to their designated oil test lab. Failure to do so may void the warranty. Commissioning of these compressors includes making certain a vigilant PM program is put in place with special attention to oil analysis.

After Commissioning

After commissioning, periodic checks must be done to verify that operations is running the equipment in a way that prevents failures. The best commissioning process will fail if the operators try to use the equipment in ways for which it was not intended.

Verify PM procedures are correctly performed or not performed at all. Failures resulting from these quarters may be unfairly attributed to faults in the commissioning process. You should review metrics, key performance indicators (KPIs) and PdM trends on a regular basis to verify the equipment is operating within specifications.

MONITOR PROGRESS AND DEAL WITH CONTINGENCIES

Monitoring

Monitoring is the systematic gathering and analysing of information that will help measure progress on an aspect of your project. Ongoing checks against progress over time may include monitoring water quality in a catchment or monetary expenditure against the project budget. Monitoring is not evaluation as such but is usually a critical part of your evaluation process and should therefore be included at your project planning stage.

Before undertaking any monitoring it is important to consider:

- ✓ Why you want to monitor
- ✓ What you will monitor
- ✓ Key features of effective monitoring

Why you want to monitor?

Keeping records and monitoring activities helps people see progress and builds a sense of achievement. Records can be useful and even essential when promoting the group or applying for funding.

Monitoring also has significance for the wider field of conservation. Ecosystem monitoring is not a fully developed science, so any work undertaken by your group has the potential to contribute to the refinement of measures of ecosystem health.

What you will monitor

The following list of questions will help you decide on your monitoring objectives:

- ✓ What information will help us make informed decisions? What will help us know that our project/group is on track?
- ✓ What's the appropriate scale for monitoring e.g. catchment, district, reserve boundary, whole forest or whole ecosystem?
- ✓ What are our timeframes for monitoring e.g. days, months or years?
- ✓ Do we need input from other groups or agencies?

Features of effective monitoring

Monitoring can be considered to be effective when:

- ✓ Scientifically valid techniques are used.
- ✓ Aspects relevant to your project are measured.
- ✓ It's carried out regularly and consistently.
- ✓ Accurate records are kept.
- ✓ It is used as part of your evaluation to support or adjust project goals and actions.

Evaluation

Evaluation provides an opportunity to reflect and learn from what you've done, assess the outcomes and effectiveness of a project and think about new ways of doing things. In other words, it informs your future actions.

Evaluation should ideally be factored into your initial project planning (see setting your direction). When you are setting your vision, goals and actions, you need to be considering how and when you'll check your progress against them. You may decide that you will:

- ✓ Refine your project as you go, so that evaluation is part of your regular project activities.
- ✓ Evaluate the project at agreed milestones e.g. on a yearly basis or after major activities.
- ✓ Carry out an initial baseline exercise against which you compare progress at the end of the project.

To ensure your evaluation is effective, it is important to consider:

- ✓ Your purpose - what to evaluate
- ✓ Your approach - how to evaluate

Once evaluation data has been gathered and analysed, remember to check your conclusions against your goals and objectives. Make sure you put your results into practice - take them on board and use them to influence how you work!

Your purpose - what to evaluate

When designing your evaluation, make sure you're clear about your purpose. It's helpful to determine what questions you want answered - make sure everything you ask or investigate during evaluation relates back to these questions.

As a first step, decide what it is that's important to evaluate. It might just be finding out what worked and what didn't, so you can improve things. It might be more specific,

such as the extent to which your project is achieving the outcomes set for it (in most cases, these will be conservation outcomes), how well organised you are or whether you met the expectations of sponsors.

Your approach - how to evaluate

There are many different ways to evaluate your project, depending on what your purpose is. However, it's important to make sure the evaluation process involves valid and sound methods for information gathering and analysis. This doesn't mean you need to go to great expense but requires that you be clear about the methods involved. A small project, for example, could be evaluated using a well-structured workshop at an evening meeting attended by all project partners. In comparison, a large, expensive multi-year project might warrant employing a specialist or at least getting their help with the evaluation design.

What is a contingency plan?

A contingency plan is a set of actions that you will take when something unexpected happens. Think of it as a backup plan, or a Plan B. It should have instructions that you can follow when your original plan doesn't work out due to changes in the situation. A contingency plan prepares you to deal with any future troubles you may encounter, and gives you some sort of escape route out of any accident.^[1]

What happens if you don't have a contingency plan?

If something goes wrong with your Plan A unexpectedly, or if accidents force you to change your current plan, chances are you will panic. Especially if you're not well prepared to deal with contingencies, you probably can't think straight enough to come up with the solution you need at that moment. You won't know what to do.

What's worse, until you're able to get the situation under control, business can't go back to normal. You'll have to fix the trouble and make new plans.

What if the contingency plan is a bad one?

Don't think making a contingency plan is a simple task. A contingency plan should be comprehensive, which requires lots of careful consideration. Otherwise, it is not helpful.

For instance, you may be prepared for the wrong kinds of accidents. And when your plan doesn't work out as expected, you won't be organized enough to handle the crisis. That is, you'll panic.

How can a contingency plan benefit you?

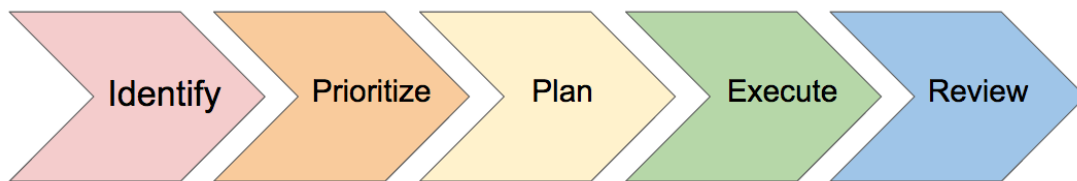
For instance, a contingency plan allows you to deal with accidents quickly and effectively.^[2] In a business scenario, it can even help you save time and cost in repairing the situation.

Also, a contingency plan helps minimize the negative consequences or losses caused by the unexpected event. It guides you to start dealing with the situation as soon as something goes wrong and keeps you safe.

After all, having a contingency plan ready is reassuring, because you won't have to worry about making new plans in a rush.

You may think that accidents are unlikely. You may think that your Plan A is perfect. However, you should keep in mind that the future is uncertain until it becomes the present, and that we as human beings can't control 100% of what happens. You don't want to regret not having a contingency plan when it's too late!

How to write a good contingency plan?



1. Identify

As a contingency plan has to do with what's unexpected, you have to first try and predict the risks:

- ✓ What could possibly go wrong?
- ✓ How likely it would go wrong?
- ✓ What's the impact and consequences of the contingency?
- ✓ What should be your reaction or solution?
- ✓ How can you prepare for it in advance?

2. Prioritize

Using what you've written down in Step 1, rank your risks by their possible impact and likelihood. The more likely the risk will happen and the more serious the impact will be, the higher it should rank.

You have to decide how much weighting to put on each risk according to your situation.

3. Plan

The next step is to actually write your contingency plan. Keeping in mind the resources available to you, design solutions to the risks you want to cover in the plan. Be realistic about your needs: perhaps some issues have to be dealt with before some others, or perhaps you have to take actions within a certain time frame, etc.

It is also important to give clear and simple instructions, so that you won't forget what you've written months later, or that someone will misunderstand them.^[5]

4. Execute

If your contingency plan involves other people, say, your colleagues or your family members, talk it through with them. Let them know what they're supposed to do when certain things happen. Prepare them.

Then, if your plan includes actions to prepare for future accidents, execute them. This can help you lower the risks.

5. Review

Changes happen all the time. For your contingency plan to be practical, you should review it and make adjustments regularly. Evaluate the items in your plan. Over time, some risks may become more or less likely, or may bring about different outcomes. Learn your situation well, and update your solutions accordingly.

If your plan is about large-scale risks such as natural disasters or server failures, conducting drills is very helpful to identifying any weaknesses of the plan, as well as making sure the people involved will be prepared to act according to the plan when they have to.

Some concrete examples to put things into perspective:

Example 1: Contingency plan for an outdoor exhibition

- ✓ Potential risk: Rain
- ✓ Who will be affected: Exhibitors, visitors, organizers and crew members
- ✓ Action 1: Secure exhibit items
 - Who will take action: On-site crew members
 - Preparation: Rain-proof covers for exhibitors' stalls, email exhibitors with weather forecasts 3 days in advance
- ✓ Action 2: Lead visitors to sheltered areas
 - Who will take action: On-site crew members, security guards
 - Preparation: Mark designated areas as no-parking areas, waterproof jackets for crew

Example 2: Contingency plan for delivering a speech to a big group of audience (co-workers)

- ✓ Potential risk: The projector or the computer doesn't work
- ✓ Who will be affected: Me
- ✓ Action: Write outline and key points on whiteboard as I speak
 - Who will take action: Me
 - Preparation: Notes in hard copy, 3 colored markers, printed handouts

FINALIZE INSTALLATION, COMMISSIONING OR MODIFICATION

A Serious and Effective Method for Conducting a Geometric Check On a Machine Tool

The purpose of this chapter is to provide an overview of the final testing to be carried out on a machine tool and, specifically, of the geometric check, by describing how an efficient final testing service should be set up at a company that manufactures machine tools.

Here is a model of how a final testing service should be organized at a company that produces machine tools. Four functional areas can be identified:

- ✓ Incoming acceptance test

- ✓ Inter-operational test
- ✓ Test during assembly
- ✓ Final test and inspection

INCOMING ACCEPTANCE TEST

This includes activities aimed at guaranteeing the company conformity of the products supplied by the marketplace to the technical specifications contained in the order.

The incoming acceptance test is a test that checks external supplies, meaning that it looks outside the company and only verifies whether the finished product meets the requirements specified in the order, without worrying about the work process.

It is important to underline that all test actions have to start from a reference document: if this is not clear, the test cannot be carried out as it would not have any sense.

In the case of the incoming acceptance test, the reference document is the purchase order of the material.

Materials usually purchased on the market by a company that produces machine tools belong to the following categories:

- ✓ Semi-finished goods;
- ✓ Mechanical parts made to customer specifications;
- ✓ Parts available on the market not made to specifications (catalogue parts);
- ✓ Technical installations (electrical, hydraulic, electronic, mechanical).

The reference documents as far as the incoming acceptance test is concerned are usually:

- ✓ Supply order;
- ✓ Supply technical specifications;
- ✓ Drawing;
- ✓ Technical standards.

If the material is declared to be conformant after the test, the company is authorized to accept the material and consider it available for the subsequent operations.

In case of non-conformity, the material is analyzed by a committee that should be made up of all company functions concerned by the decisions taken.

The criteria used to evaluate non-conformities should almost always be of a technical nature, even though sometimes they may be affected by scheduling needs of the subsequent processing phases, or influenced by the type of supplier involved and by its relationships with the company.

A non-conformity may entail one of the following opinions:

- ✓ Acceptance as an exception;
- ✓ Permanent scrap;
- ✓ Acceptance with repair.

In order to complete this structure, it would also be appropriate to have a metrology room and a laboratory where to check the chemical-physical mechanical and integral characteristics of the materials.

Inter-Operational Test

A company's testing does not end with the incoming acceptance test as part of the purchased material may be subjected to internal processing.

In this case, the material is taken from the warehouse and processed by the various machines during the production phase.

The check phase that takes place while the piece is being processed is known as inter-operational test.

It can be considered as a product verification, but more often as a process check (see the SPC techniques).

Unlike the incoming acceptance test, the inter-operational test included in the world of company production specifically follows the processing, consequently, from a certain standpoint, it has to take into account the difficulties of the production.

Inter-operational tests must be planned during the phases deemed to be more delicate from the point of view of quality, in other words those phases in which there is a high risk of generating non-conformities.

The last operation of the inter-operational test is the final product check.

All checks planned by the processing cycle have to result in an opinion of conformity or non-conformity, exactly as it happens during the incoming acceptance test.

When the inter-operational test identifies a conformity, the conforming piece is allowed to continue on to the next processing phase; if, on the other hand, a non-conformity is detected, the piece is stopped.

The non-conformity must be immediately examined by the pertinent department so that one of the following decisions can be taken: acceptance as an exception, permanent scrap and acceptance with repair.

Test During Assembly

The test during assembly includes checks that are carried out during the course of the assembly operations of the units and/or of the general assembly of the machine.

The assembly phase brings together all pieces produced and those that have been purchased from external companies.

The assembly department is usually split into two sub-departments: one where the units are assembled, and one where the final machine assembly is carried out.

The individual units are assembled in the unit's assembly department; each unit that makes up the machine is assembled separately.

Once the assembly is finished, the individual units are taken to the final assembly sub-department, where they are joined together and where the final machine assembly is carried out.

The test during assembly is a particularly delicate check, since it is highly dependent upon the tester's individual skills.

This test has references which are very difficult to identify correctly.

Indications of a general nature are provided but, aside from this, the individual experience of the employee assigned the task of conducting the check is extremely important.

The assembly operations are identified by the assembly cycle similar to the processing cycle that identifies the processing sequences.

During the assembly cycle, the assembler is shown the sequence of operations to be followed.

The assembly tester is an assembler who has acquired significant experience, allowing him to act as a guide during the assembly operations.

The testing operations during the assembly must be planned by an assembly cycle at those points of the cycle deemed especially delicate from the quality standpoint.

These operations must be defined by means of suitable operational instructions and testing protocol that each company draws up based on its own experience.

The operational instructions accurately describe the methods that must be used in order to carry out the testing operations.

The testing protocol is a document that indicates the expected results and in which the obtained results are recorded.

These documents are crucial to the execution of the testing operations during assembly, and they represent reference documents.

The testing operations during assembly usually concern:

- ✓ The functionality of the units
- ✓ Alignments
- ✓ Couplings between structures

An example of UNIT FUNCTIONALITY is the functional check of an operating head or of a cross carriage.

An example of ALIGNMENTS is checking the proper alignment of the supports of a translation screw of a linear axis and its nut.

An example of COUPLINGS BETWEEN STRUCTURES is the mounting of a slide and the base of the machine itself.

Let's suppose, for example, that we have a slide which mounts on a base and we want to check the coupling between these items.

Obviously, the coupling is the one between the slide guides and the base.

This means that you need to check the compatibility of the surfaces that define the coupling of the base with the slide.

It is necessary to ensure that the coupling between the surfaces of the slide and of the base is properly carried out, so as to avoid, for example, the slide only resting on a part and not mounted to the other guide.

In this particular case, the entire load would end up on one guide only, leaving the other one with no load, thus losing its basic function which is to support the weight of the slide.

In order to check these couplings, there are procedures aimed at verifying the contact between the coupled rigid surfaces.

One procedure entails staining one of the elements of the coupling, for example the base guide, with some Blue pigment, then resting the slide on the surface stained with the pigment.

As the carriage moves along the surface, the Blue is transferred to the contact areas generated by the coupling, thus staining the slide surface with the blue pigment.

This allows you to see where the carriage is working.

Through manual adjustment operations, the operator then tries to widen the contact surface as much as possible by planning, until it is equal to approximately 80-90% of the theoretical contact surface, also trying to have the contact points evenly distributed along the entire surface.

For some machine tool manufacturers, the coupling is considered acceptable if, after placing a template that leaves a free space of one square inch anywhere on the contact surface to be checked, at least 5 contact points are found.

The results of the testing during assembly must also conform to the expected results. In case of non-conformity, all operations aimed at restoring conformity need to be carried out.

Final Test and Inspection

Basically, the final test and inspection of machine tools consists of a series of actions that can be described as follows:

- ✓ Final internal test and inspection
- ✓ Contractual preliminary test and inspection with the customer at the supplier's facilities
- ✓ Contractual final acceptance test and inspection with the customer at the latter's facilities

These are the traditional phases that characterise the final test and inspection of a machine tool; all of these phases have a specific relevance, which we will attempt to identify here below!

Final Internal Test and Inspection

Extremely important operation that basically has two purposes:

- ✓ The first is to check conformity of the construction to the product plan requirements.
- ✓ The second concerns the search, if requested by the technical office, for performance levels that are more advanced compared to the ones indicated in the product plan, or for more in-depth information on constructive, functional or performance-related aspects, information that may not have been included in the product plan but that is nevertheless useful for the purpose of continuously improving the company's products.

Clearly, this testing activity is of crucial importance in terms of knowing the quality of the product that has been developed, and it is an activity that basically represents an assessment of the efforts made by all members of the company organization in order to achieve the objective set by the company itself.

During the test, the machine must be analyzed in all its aspects with great diligence, intellectual honesty, utmost metrological accuracy and refined methods, of course within the limits of that which is requested by the product plan and by any additional requests made by the technical office.

The conclusive document of this testing cannot be a schematic document but rather a technical report that, considering all the indications and requirements contained in the product plan, points out whether or not the construction is able to safely meet all such indications and requirements.

Together with this, the technical report also has to provide answers to the technical office's questions.

However, in an industrial environment, this activity is very often just an aspiration, since industrial times almost never allow this activity to be carried out in a complete and satisfactory manner;

It is nevertheless clear that it is of basic importance in terms of gaining in-depth knowledge of the developed machine, of evaluating its potential capabilities and of understanding its limits and difficulties, consequently obtaining the information needed to improve the quality of future productions.

Contractual Preliminary Test and Inspection with The Customer at The Supplier's Facilities

This is the final test and inspection activity that, for the first time, puts the customer in contact with the object of the supply contract which, if properly drawn up, should specifically indicate in detail the testing conditions which the machine will have to be subjected to during the preliminary test and during the final acceptance test.

The contract for a machine tool is a complicated topic precisely because the machine tool is a piece of equipment used to produce other pieces of equipment that very often have extremely high qualitative demands and are subjected to stringent tests, which immediately reveal any shortcomings of the production machine.

The contract for a machine tool should start from a well-done product plan in which all the characteristics that the tool machine will be required to meet are identified and defined in detail.

Moreover, the contract should only involve those general, functional, performance, safety and testing characteristics that have been clearly and expressly specified in the product plan.

If the contract is prepared as described above, the preliminary contractual test becomes part of the final internal test.

Generally speaking, this preliminary test is developed by referring to a set of standards acknowledged at the international level.

Once the standards have been established, the preliminary contractual test with the customer at the supplier's facilities is quickly defined.

In other words, it entails subjecting the machine tool to a set of checks which are defined exactly and in detail by specific standards per machine type, adopting for each check the metrological procedures and the relevant operational methods defined by the procedural standards.

We should point out that, during the contractual testing activity, no change can be allowed with respect to that which has been defined in the contract.

This means that, during the course of contractual testing activities, the testing diagrams defined by the specific standards and the measuring methods required by the procedural standards cannot be changed, either in substance or form.

It is important to underscore this aspect since it is easy to witness the onset of disputes generated by different interpretations of the measuring methods.

Upon completion of the preliminary testing activities, which are generally carried out on a fully operational machine but not necessarily set up in its final layout, it is a consolidated practice for the customer's managers and the supplier's manager to sign a document.

This document details the results of the tests carried out are recorded, for any non-conformities to be highlighted, details the jobs to be carried out prior to disassembling and shipping the machine to the customer's facilities, and for the disassembly to be authorized upon completion.

In this way and with this document, the preliminary testing phase of the machine can be considered finished. This document is then used for those administrative activities which are associated with said document.

Contractual Final Acceptance Test And Inspection With The Customer At The Latter's Facilities

This is the last testing activity that, once it is completed, results in the following situations:

- ✓ The machine is definitively accepted by the customer
- ✓ The customer takes charge of the machine
- ✓ The contractual warranty period starts
- ✓ The supplier can consider the project completed

The contractual final acceptance test with the customer at the latter's facilities is carried out once the machine has been shipped and reassembled at the customers' plant.

Prior to reassembling the machine at the customer's plant, if need be, the supplier is required to test the foundations which, together with the elements used to anchor the machine to said foundations, is considered an integral part of the machine itself.

The characteristics of the foundation profile and structure, must be defined during the contract stipulation phase, and they have to establish a testing protocol agreed by the parties in terms of both deformation under load and the control method to be adopted. Once the foundations have been tested, the supplier signs the testing protocol, declaring their conformity to requirements, then authorizes the assembly of the machine on foundations that have been positively tested.

The final testing operations at the customer's facilities are the same as the ones carried out at the supplier's, except for the fact that at the customers, in order for the final testing to be considered conformant, it has to prove that all contractual requirements have been met.

Hence, the final testing of the machine at the customer's is nothing but a complete repetition of the preliminary testing operations, this time carried out on the permanently installed machine and therefore on the machine presented to the customer in its definitive state.

10. LOCATE AND CLEAR BLOCKAGES

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 identifies 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 non-routine situations

Emergencies present hazards that need to be recognized and understood. Non-routine 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 non-routine 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
 - Non-routine 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.

LOCATE AND CLEAR BLOCKAGE

Common blockage materials

Toilets and toilet pipes get blocked when people put the wrong things down the toilet. Some of the things which should never be put down the toilet are food scraps, paper, rags, cans, bottles, grease and fat.

Wastewater pipes from sinks, basins and laundry tubs can get blocked if people put food waste, especially tea leaves, hot fat and other rubbish down them. If hot fat is poured down an outlet pipe, it will set in the pipe when it cools and cause a blockage.

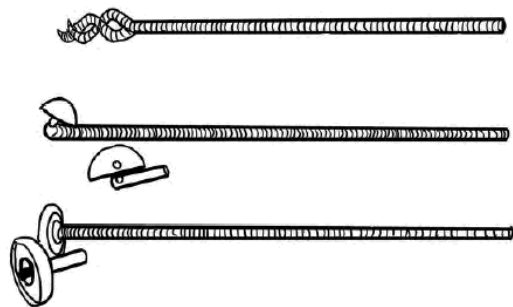
In addition to blockages caused by these materials, main sewer pipes can get blocked in other ways, for example, tree roots growing into the pipe joints and soil blocking the pipe when it is broken by vehicle traffic.

Plumbing rods

Plumbing rods are pieces of equipment used to remove most blockages from sewer pipes. However, when sewer pipes are broken plumbing rods are not effective and the damaged pipe must be replaced.

The rods screw together so that they can be made as long as needed. They have different kinds of endings to help remove the blocking objects.

To unblock the sewer pipe it is important to find an inspection opening (IO) below the blockage and push the rods up the pipe to the blockage.



Always remember which way the rods and endings have been screwed together and always twist the rods in the same direction.

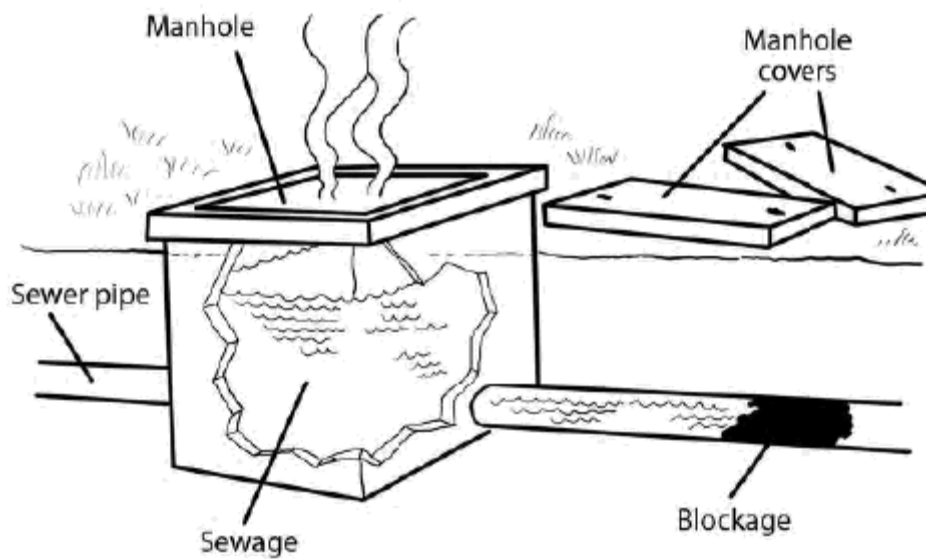
If this is not done, the rods are likely to become unscrewed and be left in the sewer pipe. This will create a worse problem because the rods will also block the pipe. If this happens it will probably be necessary to dig up the sewer pipe and break it to unblock the pipe and get the rods back. This would have to be done by a licensed plumber.

Unblocking sewer pipes

The larger sewer pipes have manholes set in them allowing access to the pipe. They are often about a metre underground and are large boxes which usually have walls made of concrete. The pipe opens into the box on one side and starts again on another side.

The lids, which are made of metal, can be lifted to allow someone to look down into the sewer to see if there is evidence of a blockage, for example, wastewater build-up in the

manhole.



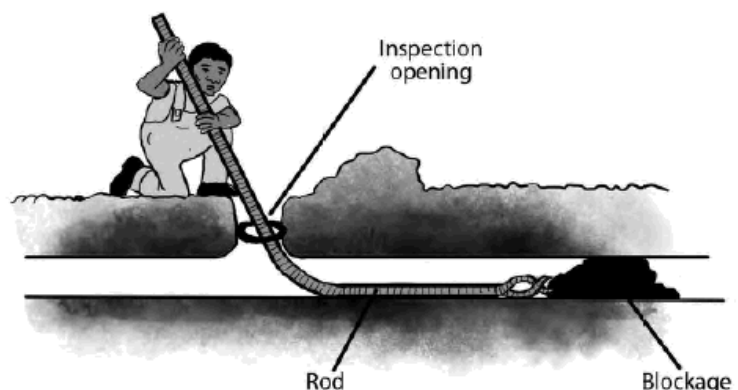
Extreme care must be taken when opening the lids of sewer pipes as poisonous and explosive gases can build up in these pipes.

Before attempting to unblock a sewer pipe it is important to remember:

- ✓ Before making an inspection, always wait several minutes to allow any poisonous or explosive gases to escape
- ✓ Never smoke while doing this work
- ✓ Never do this work alone
- ✓ Never enter a manhole without proper safety measures. It may be necessary to wear breathing equipment or to ventilate (add fresh air) to the manhole and sewer pipe. The gases in it can kill.

It is always safest to check with the Water Authority, the local government EHO or supervisor before opening the lid or entering the manhole.

If there are no manholes, then there will be IOs with cement or plastic caps on the pipes. There may be a concrete box around the inspection opening. Sometimes these are below the ground and are not easy to find. It may be necessary to dig to find them.



It is a good idea to get the sewer pipe plans for your community so that you can refer to the plans before starting to dig.

Unblocking Vacuum sewer system

Operational and maintenance skills required

Cost is not the only consideration that needs to be taken into account when selecting a sewer system. The availability of knowledge and skills should also influence the decision for an alternative. Vacuum systems have the reputation of being O&M intensive. While this has been true for earlier systems newer projects have benefitted from many technical and operational improvements which have reduced O&M requirements.

Operating and maintaining a vacuum sewer does indeed require technical expertise and demand a lot from the operator in terms of knowledge and skills. While effective operation of a vacuum sewer system begins with proper design and construction O&M requires at least one trained operator that is familiar with the system, including the locations of all the collection chambers, lines, division valves and other key components. The operator must understand how the main components of the vacuum sewer system are interrelated and work together as a system. Ideally, the training of operator(s) should commence while the system is still under construction in order to become familiar with the system and its components.

Maintenance of the vacuum sewer system can be divided into two groups: normal including preventative maintenance, and emergency maintenance.

Normal and preventive maintenance

Concentrating on the normal and preventative maintenance minimizes the need of emergency maintenance [15]. As vacuum systems must operate and be maintained all year long variations in workload can occur. Thus, it is important to plan and schedule preventative maintenance. A maintenance schedule for all components should be developed which highlights the priority of tasks and any special information, e.g. tools, equipment or parts required for the job. The schedule should consider the manufacturers recommendations for the individual components. Normal and preventive maintenance of the vacuum sewer system is done by regular inspection of system components by staff or remote monitoring.

Vacuum Station

Most vacuum stations are equipped with monitoring systems which monitor the operation at the station as well as the collection system and automatically notify the operator (e.g. via phone) when an alarm was triggered, for example, in cases of low vacuum, high levels of sewage or power outages. During normal operation the operator visits the station on a daily basis to record pump running hours and check oil and block temperatures. Especially at the beginning this is important in order to gain familiarity with the system. Remote monitoring and recording may facilitate these tasks. An overview of the maintenance tasks and their frequency is given in the Table.

Overview of normal and preventive maintenance tasks and their frequencies

Frequency	Task
Daily	- Visually check gauges/ charts

	<ul style="list-style-type: none"> - Record all pump run times - Check oil level in vacuum pump sight glass
Weekly	<ul style="list-style-type: none"> - Exercise generator (if applicable)
Monthly	<ul style="list-style-type: none"> - Change oil and oil filters (depends on manufacturer's recommendations) - Remove and clean inlet filters on vacuum pumps - Test all alarm systems - Check all motor couplings and adjust if needed - Clean all sight glasses - Exercise all shut off valves (vacuum station)
Semi-annually to annually	<ul style="list-style-type: none"> - Conduct external leak test on all vacuum valves
Every Year	<ul style="list-style-type: none"> - Exercise division valves - Inspect vacuum and sewage pumps for wear - Visual inspection of all pits and valves - Check valve timing and adjust if needed
Every 3 Years	<ul style="list-style-type: none"> - Rebuild controller (buffer tank valves only)
Every 5 Years	<ul style="list-style-type: none"> - Rebuild controller (most valves)

Vacuum network / collection systems

Under normal operation there should be no need for the operator to visit the collection systems. The pipe network has very low maintenance requirements. However, it might be desired to inspect areas where difficult or unusual conditions have been encountered during construction. If in place, division valves should be inspected once a year and put through the entire opening and closing cycle at least once. This will also familiarize new personnel with the location of these valves.

Vacuum valves

Routine maintenance of the vacuum valves and controllers involves visual inspection once a year. Visual inspection can be carried out easily from the ground surface and the only tools required are a cover pick to gain access to the collection pit and a sensor pipe puller to drain accumulated water. The valves should be manually cycled to see whether they are operating properly, and the controller timing is still in accordance with the original setting. The operator should check whether dirt or water is in the controller, valve and tubing which could affect functionality in the future and remove any unwanted substances. Visual inspection should take around 10 – 30 minutes per connection.

Every 5 years the controller should be replaced with a new one. The removed unit can then be returned to the workshop where it is inspected for mechanical wear and repaired, if applicable. For valves with higher cycle frequencies renewal should take place every 3 years. This usually applies to valves installed in buffer tanks. Each vacuum valve should be replaced every 10 years and inspected for mechanical wear at the workshop, similar to the controller after 5 years. The worn parts can then be replaced and the valve can be reassembled and reused. Removal and replacement procedure at the valve pit should take around 5-10 minutes. Rebuilding of components at the workshop should take around 1 hour for the controller and 1-2 hours for the valve.

Emergency maintenance

The vacuum sewer system has recommended maintenance tasks and in case of a failure there is a troubleshooting method to track the failure. Modern systems are usually equipped with a set of alarms which inform the operator of the fault via a mobile phone. Emergency incidents can occur anytime of the day requiring personnel to resolve the problem after working hours on an overtime basis. Emergency or breakdown maintenance can occur at the vacuum valve, the vacuum station or the pipe network.

Vacuum station

If the preventive maintenance measures described above are carried out accordingly there are very few emergencies that occur at the vacuum station. However, most systems are designed in a way that redundancy allows for a lot of time before the fault affects the normal operation. The number of pumps is selected so that the system continues to work normally with one pump offline. Thus, the operator has enough time to identify the problem and recondition the pump (e.g. replace parts etc.). Further, the vacuum tank is designed to have sufficient capacity to accept sewage while the wastewater pumps are out of service, for example during a power blackout. The vacuum tank also functions as a vacuum buffer for the collection system. This way, drops in system vacuum are slowed down giving the operator more time to recondition the system. Backup electricity supply, such as a generator or a connection for quick deployment of an external power source, should be provided as well as a procedure how to restore power in cases of power blackouts. Emergencies related to power blackouts are rare but the most common faults at the vacuum station. Other faults may involve clogging of the wastewater pumps. The operator needs to have adequate skills to identify and solve faults in a timely manner.

Vacuum network / collection system

If the design and construction of the pipe network has been carried out properly there are few things that can lead to emergencies affecting the collection system. The high transport velocities of wastewater minimise the precipitation and scaling of solids. For systems with separated black water streams this risk is increased and needs to be addressed. But since most vacuum sewers transport mixed wastewater the greatest risk for the vacuum collection system arises from landslides or excavations for other utilities. When these events result in line breaks system vacuum will be lost. If the incident is not reported by the utilities the operator can isolate different lines and localise the defective section by closing and opening division valves along the piping route in a logical manner. Additionally, the operator can use the inspection valves and check for vacuum conditions in various sections. However, any rupture or damage to the pipe network needs to be resolved in a timely fashion most likely by exchanging the affected pipe. Collaboration with the impact causing entity may facilitate and accelerate reconditioning, especially since the excavation machines are already at the site.

Vacuum valves

Most service calls related to the vacuum valves are caused by the users. Around 70% of faults result from flushing objects that lead to clogging in the valve or other parts of the pipework in the collection pit. Other faults are caused by extraneous water for example from rainwater entering the pit and damaging the controller or mechanical wear of valve components. In most cases maintenance is fairly simple. The controller is taken out, dried and reinstalled. The operator needs to initiate action so that the design error of water entering the pit is corrected. Waterproof controllers are also available however it is undesirable to have stormwater entering the collection pit. Exchanging a faulty valve is

relatively simple and can be completed within 10-15 minutes by a single person. But where no remote monitoring is installed emergency maintenance usually requires more than one person to locate the affected valve pit using the inspection valves. This can be difficult and adequate training of the personnel is imperative. The faulty valve is then taken back to the workshop where it is rebuilt and made fit for reuse.

Since valve failures can cause failures in other parts of the system it is crucial that the operator is capable of identifying and resolving any emerging issues quickly. If the vacuum pumps cannot keep up with the loss of vacuum then other valves will have insufficient vacuum to perform their function. This can lead to backups which possibly result in waterlogging since an increased amount of sewage will have to be transported at a changed, possibly inadequate, water to air ratio when vacuum is restored.

The design, construction and operation of the system affect the maintenance. In many cases it can be advisable to develop a maintenance agreement with the system provider to ensure adequate maintenance and advisory services. This especially applies to municipalities or regions that have no or little experience with operating and maintaining vacuum sewers. The maintenance agreement increases operational safety and reliability and ensures that local operating personnel is trained accordingly. Since a high degree of technical knowledge is required the project should budget 3-6 months on-site training.

(https://www.unescap.org/sites/default/files/Guideline_VacuumSewerSystems_FraunhoferIGB_2016_0.pdf)

Unblocking fixtures

For the plumbing system to work, the pipes must be free of blockages. If the pipes are blocked, the toilet, shower, laundry tubs and/or the kitchen sink will not carry the wastewater away properly.

If a fixture is blocked, the wastewater may flow onto the floor of the house. If the sewer pipe is blocked, the wastewater may flow from the DT onto the ground outside. Contact with this wastewater may cause disease.

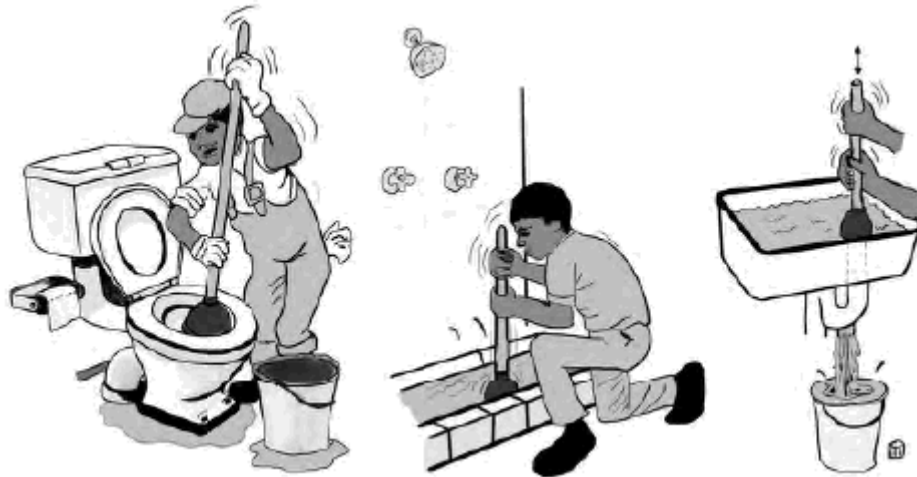
To unblock a sink, shower recess or any tubs, first remove any larger pieces of rubbish and then try using a plunger or a mop to finish unblocking the pipe. Pipes from sinks, basins and tubs and the small waste pipes leading to the larger sewage pipes outside the building will have small IOs.

These may be sealed with a screw plug, either close to the fixture or on a bend. The plugs on these IOs can be removed to allow access to blockages.

A plunger consists of a heavy rubber cup which is attached to a handle on the closed side. It is used by placing it over the opening to the blocked outlet pipe and then thrusting it up and down quickly over the hole. The suction caused by this action will help to move the blockage.

A mop can be used to unblock a pipe in the same way. It is best to use a mop to unblock a toilet pan.

If using a plunger or a mop does not work, the pipes will need to be examined through IOs or a manhole to find the blockage. This can then be removed with plumbing rods. If these are not available, a hose may work.



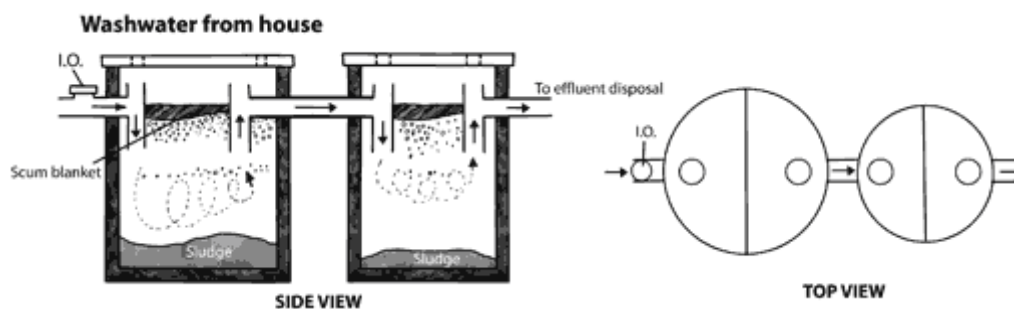
The septic tank

A septic tank can be used to treat the sewage from individual buildings at the building itself or for the whole community, at the lagoon. The sewage will pass through sewer pipes to the septic tank either at the house or at the lagoon.

The septic tank is a sealed round or rectangular container which is used to break down the sewage so that it becomes effluent through the action of bacteria living on the waste matter.

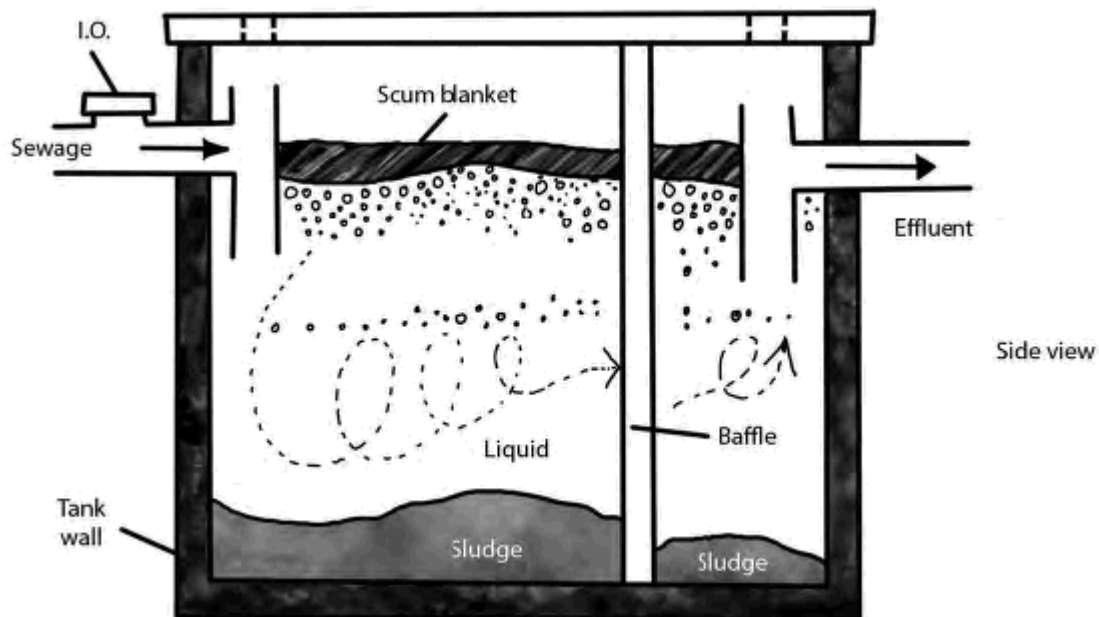
Septic tank design

A household septic tank usually consists of two round concrete tanks with lids placed close to each other. They are connected by a pipe. This type of septic tank is designed to be used by up to 10 people. Round tanks are constructed (built) at a factory and transported to the site (place) where they are to be used.



A septic tank can also be a single rectangular concrete tank with a dividing wall in it. A

rectangular septic tank is designed to be used by more than 10 people and is often used for sewage treatment at a lagoon. The tank is constructed on the site where it is to be used.



Septic tanks are always divided into two sections, the first being twice the size of the second. In round septic tanks, the separation into two tanks provides this division. In rectangular tanks the dividing wall provides the division. This wall will have a hole in it below the level of the sewage to allow effluent to pass from the first to the second section.

Round septic tanks have concrete bottoms and lids. Rectangular tanks usually have concrete bottoms and lids, but some may have metal lids. The lids can be lifted off for maintenance and will have IOs in them.

There are many regulations (rules) which require septic tanks to be constructed, positioned and installed in a particular way. These rules are controlled by local authorities.

It is very important to find out if the regulations are being followed by contractors or anyone else installing (putting in place) new septic tanks in the community. It is a good idea to contact the local EHO to check that the necessary approval has been given to construct and/or install the septic tank disposal system.

If anyone wants to know anything about septic tanks, including the rules relating to their construction, or there are any problems with these tanks in the community, contact the EHO or Environmental Health Practitioner.

How a septic tank works

A septic tank must be filled with water before it is used. The water helps start the treatment of the sewage by the bacteria.

The sewage treatment by the bacteria turns the waste matter into effluent (wastewater) and a solid substance called sludge. The effluent gets carried to the leach drain, French drain or lagoon.

The material in the septic tank gets covered by a hard crust known as a scum blanket. This blanket acts as an air seal keeping air away from the sewage. The lack of air helps in the breakdown of the sewage by the bacteria.

The sludge gathers at the bottom of the tanks. Eventually there will be too much sludge in the tank and it must be pumped out and the sludge disposed of correctly.

By having two tanks or a rectangular tank divided into two sections, most of the sludge stays in the first tank or section. In the second tank or section, the sewage undergoes further treatment to remove solid matter.

The effluent is then piped to the effluent disposal system, such as the lagoon. This water still contains germs and parasites.

Problem Signs in Septic Tanks

The septic tank will need to be checked if there are signs that it is not working properly.

Some signs that a septic tank is not working properly are:

- ✓ The sewage in the toilet or the liquid waste from other fixtures flows away very slowly
- ✓ Liquid waste overflows from the disconnecter trap
- ✓ Wet areas are seen at the top of the septic tank
- ✓ There is a strong unpleasant smell near the septic tank
- ✓ The grass around the tank is very green and growing well

In the case of on-site disposal systems, it is important to remember that some of these signs may indicate problems with the leach or French drain. Therefore, these drains will need to be checked at the same time as the septic tanks are checked.

If the septic tank and the leach or French drain need to be pumped out, both should be done at the same time.

Pumping out septic tanks

Septic tanks should be pumped out every five years to keep the disposal system working properly. However, this may need to be done more often, for example, if they overflow or become blocked.

If there are any signs of a problem with the septic tank (see Section 9.3), it will need to be checked.

The inside parts of the tank system which will need to be checked are:

- ✓ the scum blanket (as it may become too thick and block the inlet pipe)
- ✓ the inlet or outlet pipes (as they may be blocked by solid matter)
- ✓ the sludge (as it may have accumulated so that it fills most of the tank)
- ✓ the tank's bottom, sides or lids (as one or more of these may have been cracked or broken. For example, vehicle movements over septic tanks are likely to damage the lids and sides.)

For the first few times an EHP pumps out a septic tank, it is important to always check with the local EHO or Environmental Health supervisor before any pump-out work is commenced.

These people will provide information on disposal sites and the correct pump-out methods as well as technical help in assessing the inside parts of the septic tank.

Emptying a septic tank

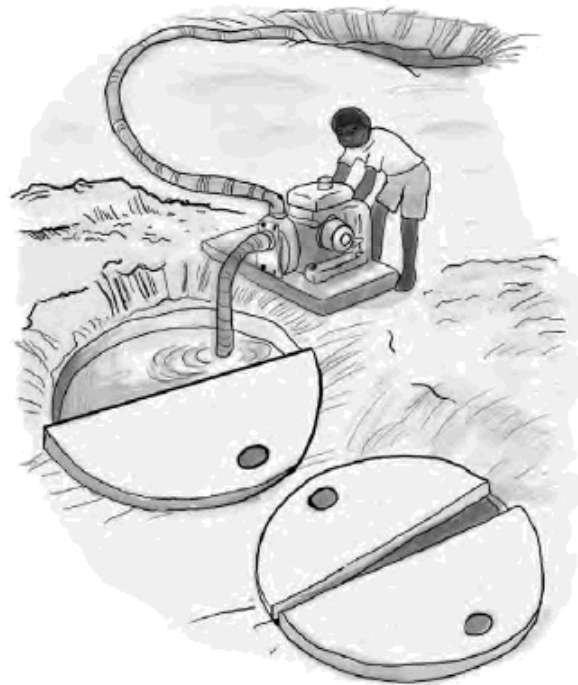
Before commencing Pump-out

- ✓ Find out if the community has or can obtain a pump-out tank or tanker. Make sure the sludge pump (pump-out equipment) is available and working.
- ✓ Locate an appropriate disposal site.
- ✓ If a tank or tanker is used, the disposal site must be a place which is suitable for getting rid of the dangerous sludge and effluent and be able to take all the pumped out materials. For example, the site must be well away from water supplies, children's play areas, camp places, rivers and streams, and downwind if possible. Often this place will be a hole dug in a separate part of the community rubbish tip.
- ✓ If there is no tank or tanker available, the pumped-out material must be disposed of in a hole near the septic tank.
- ✓ The distance between the septic tanks and the disposal hole will depend upon the length of the pump-out hose. The hole must be away from water supplies.
- ✓ Where possible, remove any tins, bottles, rags, newspaper and other rubbish that may be in the septic tank. This material can either be disposed of in the pump-out hole at the site or at the rubbish tip.

- ✓ All sewage material which is to be taken to the tip should be transported in sealed drums.

When pumping out the septic tank:

- ✓ Pump out the sludge into the tanker or the hole.
- ✓ If using a tanker the sludge can be deposited at the appropriate site away from the community.
- ✓ If the disposal site is near the septic tank and the pump-out has commenced, the hole must be guarded at all times even if the pump-out stops for some reason, for example, for a lunch break or because of an equipment breakdown. The sewage must be covered with soil if the pump-out is not finished by the end of the day.
- ✓ After covering the sludge with this layer of soil there may still be space in the hole to complete the pump-out the next day.
- ✓ When covering the sludge with soil, remember that some time must allowed for the liquid to soak away before putting soil in the hole.
- ✓ When the job is finished the hole should be filled with a thick layer of soil.
- ✓ Once the septic tank has been completely emptied, it must be filled with water before it is used again.



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.

11. INSTALL BELOW GROUND INDUSTRIAL SEWERAGE SYSTEMS

PREPARE FOR DRAINAGE SYSTEM INSTALLATION ACTIVITIES

Below ground industrial sewerage systems are laid down by the utility providers in the Maldives and are regulated by the respective government authorities.

It is imperative that existing regulations and guidelines are followed while preparing for design and installation of below ground industrial sewerage systems across any part or area within the Maldives.

Putting Together a Drainage Plan

Before a trench is excavated, site surveys and drainage design works will combine to create an overall plan of sustainable drainage features that are part of gaining planning permission.

Establishing facts such as soil type and water table level not only help in the design of the drainage plan, they also help the groundworks or drainage contractor to plan the practical aspects of the works.

Drainage Construction – Design Vs Reality

As with many areas of construction above ground, being careful to ensure the agreed specification for below ground works like drainage is followed is an important part of making sure design intent is achieved in reality.

A contractor may think they can save money, perhaps by omitting a rodding point or manhole, and thinking it won't be an issue, but falling into that trap can cause real problems later if there is no adequate maintenance access. On large developments particularly, drainage systems are carefully engineered and even an apparently small problem could impact on many properties at once.

Similarly, preparing trenches to receive the correct pipe sizes, and achieve the correct levels to provide the right falls and connect into the existing drainage system, is an important part of site preparation. Understanding what needs to be achieved before starting work, and how best to achieve it once work has started, is key to a smooth-running project.

Drainage flows are also affected by the pipe material – installing a corrugated plastic pipe rather than a specified smooth-sided pipe can dramatically impact on the drainage flows achieved and on the success of the system. Having an appreciation of what has been specified in order to be able to achieve it on site is an important aspect of preparation.

Eliminating Potential Problems

Part of preparing for the drainage works can include planning and scheduling testing and survey activities for when the works are complete, before construction of the superstructure begins.

While the temptation is to get on with developing the site above ground as quickly as possible, taking the time to test the system and record it 'as-built' before covering it over could save time and money later on, should a problem be discovered.

Ultimately, the potential for many problems to occur can be reduced or removed entirely by working with an experienced, trusted drainage contractor. If they also provide the groundworks as part of a complete package, there is greater flexibility in scheduling across the site and more 'joined-up thinking' towards implementing the drainage plan as a whole.

Where the services are provided separately, a groundworks contractor might unintentionally damage drainage works already installed, then leave that work to be redone by the drainage contractor. A single contractor hopefully knows where they have already carried out drainage work – but can take responsibility and rectify things quickly if an unfortunate mistake occurs.

Prior to the commencement of the project, make sure following procedures are compiled and developed and use these procedures during implementation of the project.

Topography/levelling/pipe bed/excavation/backfilling

In progressing with the design, following needs to be performed.

Topographic Survey

A complete topographic survey of the island shall be carried out prior to the designing of the network. This survey shall be based on the existing benchmarks (where available) shown in the drawings included in the bid document. We shall obtain data of mentioned benchmarks from the relevant authorities and shall transfer those data to different locations during this survey in order to fix sufficient number of temporary benchmarks in various locations of the island. Total Station and prism shall be used in this survey. The survey shall be carried out in accordance with the guidelines set out from Maldives Land Survey Authority (MLSA).

Bathymetry and Geo-Technical Surveys

A bathymetry survey shall be carried out prior to design to generate a depth profile of sea outfall area. GPS and GPS integrated echo sounder shall be used for this survey. Points shall be taken at 2.5m grid and accuracy level shall be 0.5m horizontally and 0.005m vertically. A permanent benchmark of the island shall be used as a control point and coordinate system shall be UTM Zone 43. Data shall be collected from vegetation line to 15m beyond the reef line. The data collected from this survey shall be considered while designing the sea outfall line.

Environmental Impact Assessment (EIA)

IA works shall be initiated and reported in accordance to EPA guidelines and regulations. It shall be conducted by an authorized external EIA consultant. EIA report shall be submitted 100 days after the commencement.

Maintenance of line and grade.

In order to ensure that the sewerage line to function as intended, it shall be laid according to the plans (approved design) and specifications of the tender document. All care shall be exercised that the line and grade of each sewer line is carefully established and maintained so that the self-cleansing velocities is obtained.

Prior to the construction the contractor shall have a setting out of the required line and grades and put the required markings on all junctions, inlet and outlet points at manholes. Reference markings shall be established and well protected from disturbance.

Excavation, Trenching.

Excavation shall be done with mechanical equipment / excavator or manual labor depending upon the site condition. Works shall be done in sections so as to keep the pit open and the excavated material to lie on site on a limited period only. Proper caution shall be observed in carrying out excavation not to damage existing utilities encountered underground.

The trench shall be excavated a minimum of 200 mm below the final grade so that suitable bedding materials can be placed beneath the pipe. A minimum width of 600 mm shall be maintained for proper working and laying of the pipes.

Since “bell and spigot” pipe is to use, hand-excavation of the bedding material shall be made at each bell end. Hand excavation is also required in the other subsurface utilities in order to ensure that they are not damaged.

Sheeting and Bracing, Caissons.

Soft sand and underground water shall be encountered in the course of the works. Vertical sheeting may be used in shallow trenches, and shoring sheets shall be used in deeper excavations so as to avoid damage and cave-in in the trench.

Dewatering.

When groundwater is already reached, the use of dewatering pumps shall be employed. Pumped groundwater can be drained on ground at a distance from the trench. Whenever local regulations disallow draining on ground, pumped water shall be collected in tanks or other alternative methods shall be used to transport to specified drain locations.

Pipe Laying and Level Checking

The sewer shall be laid with the aid of suitable boning rods and sight rails at intervals not less than 10 meters. Before the pipe is lowered into the trench, the grade of the bedding material shall be checked with digital levels to ensure that invert levels are as per the drawing.

The pipe shall be inspected to ensure that it is sound and that ends are not damaged. The pipe sections are placed on line and grade in the bottom of the trench/dewatered trench (where dewatering is required) and shall be pressed together with a hand-lever or a winch. Y and Tee sections shall be provided in the mains for the household connections.

Before back-fill levels shall further be checked from the top of the Pipe (upward level), using digital levelling instrument. The upward level minus pipe diameter shall be equal to the invert level.

Leak Testing.

Checks and tests shall be undertaken for every laid section for any damage on pipes or fittings, leaks, and suitability of flow. The leak test shall be carried out with the presence of consultant from Client side and to his acceptance. The water used for leak testing might be used for cleaning the pipe.

Backfilling.

Backfilling material must be free from debris, large rocks and other sharp objects. No rocks shall be placed within 900 mm on top of the pipe nor within 400 mm of the ground surface. The fill shall be carefully placed in layers not more than 150mm thick and be tampered under, around and over the pipe to a height of 600 mm above the crown. Until this level has been reached, the sand shall be placed very carefully. Warning tapes shall also be laid prior to the final layers of the backfilling.

Surface Reinstatement.

Areas affected by the excavations shall be reinstated to the original condition.

Disposal of surplus excavated material.

The excavated material shall be evenly distributed right around the excavated area with compaction up to the existing ground levels of the roads in that area. If there are any surplus excavated sand that cannot be used, it shall be transported to sites approved by the Island Council/ consultant from the client side.

CO-ORDINATE INSTALLATION WORK**5 Steps to Successful Team Coordination**

Teamwork. It's one of the oldest buzzwords in the business. Every business owner dreams of assembling an unstoppable team of skilled, driven individuals and driving them to excel. But the reality is often much more challenging. Assembling a team is hard work, and keeping them coordinated even harder. Even the most specialized team can fall apart if not properly managed.

To make your team work like the well-oiled machine you want them to be, you need the right approach and the right tools for the job:

Know the Big Picture.

Good planning is all in the details, but before you can get there, you'll need a strong vision of your team's overall goal. Without a clear, concise, and concrete goal, your team will be floundering from the first minute. As circumstances change and unforeseen obstacles arise, a team leader must keep the big picture in mind at all times and make changes accordingly.

Create Well-Defined Roles.

Teams work best when everyone has a role that plays to their strength. The last thing you want is team members competing with each other over resources or tasks. That's why it's

critical to know the strengths and weaknesses of your team members, and assign them where they'll be able to work best. Some people like to joke about org charts, but they can be a lifesaver when it comes to team coordination.

Foster Great Communication.

Good communication is at the heart of any successful project, business or otherwise. This doesn't just mean meetings – too many meetings can drag down productivity and erode morale. Good communication should run through everything you do, whether it's via email, text, communication software, or in-person interactions. Transparency, clarity, empathy and respect are all critical. A good team leader must have great communication skills to keep their team motivated and coordinated... and the right tools don't hurt, either.

Master Your Planning.

The most crack team in the world won't get good results unless you start with a plan. There's a strong temptation among many small business owners to "figure things out as they go" or place heavy emphasis on improvisation — and this is in part why so many businesses fail so quickly. To be successful, you need to know your objectives, know the time and resources necessary to reach them, and deal out tasks accordingly. Of course, a plan must be flexible and adapt to changing circumstances – but it remains the backbone of your business' success.

Don't Overdo It.

Believe it or not, there can be such a thing as too much coordination. Even the well-designed team may have disagreements about how to manage their resources and time... in fact, it's pretty likely. Don't fall into the trap of assuming everyone has to work like a well-oiled machine all the time. Too much coordination can cost you productivity in terms of pointless meetings, long presentations, disagreements between colleagues, and poor results. Know when to loosen the reins and let people work.

Team coordination isn't always easy. It can be a challenge to keep teammates working together smoothly, and there are bound to be obstacles and mistakes along the way. One of the most important skills you can cultivate is learning from these challenges and refining your approach, so your next team – and your next project – will be better than ever.

PREPARE THE SITE FOR INSTALLATION OF DRAINAGE SYSTEM

Checking the site before installation

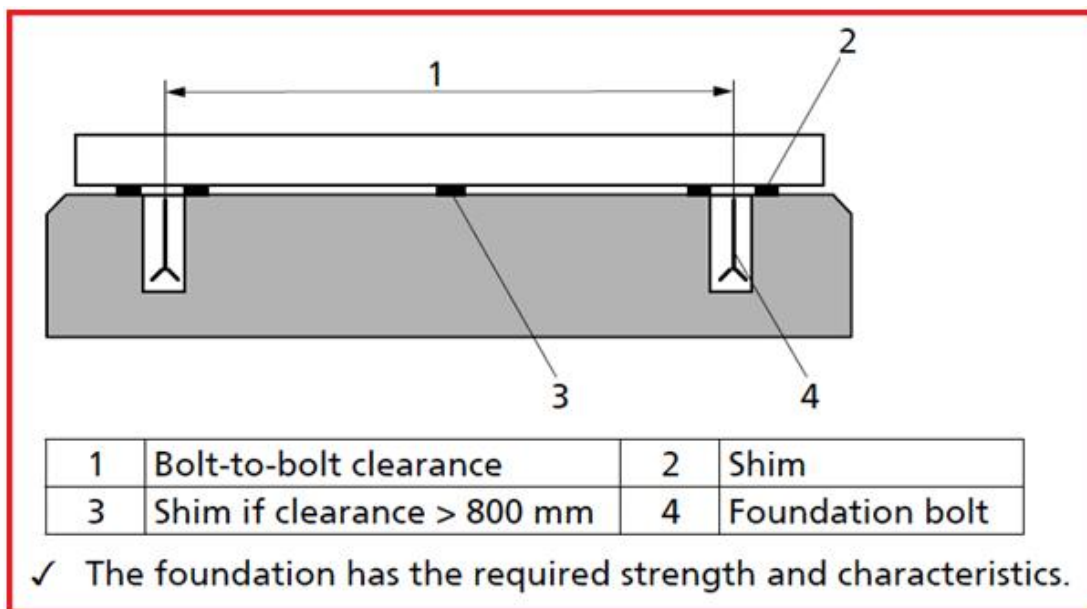
- ✓ Make sure the foundation concrete is of sufficient strength.
- ✓ Only place the pump set on a foundation whose concrete has set firmly.
- ✓ Only place the pump set on a horizontal and level surface.
- ✓ Refer to the weights given in the Pump general arrangement (GA) drawing.
- ✓ All structural work required must have been prepared in accordance with the dimensions stated in the outline drawing/general arrangement drawing.

Improper installation in potentially explosive atmospheres

- ✓ Comply with the applicable local explosion protection regulations.
- ✓ Observe the information in the datasheet and on the nameplates of the pump and motor.

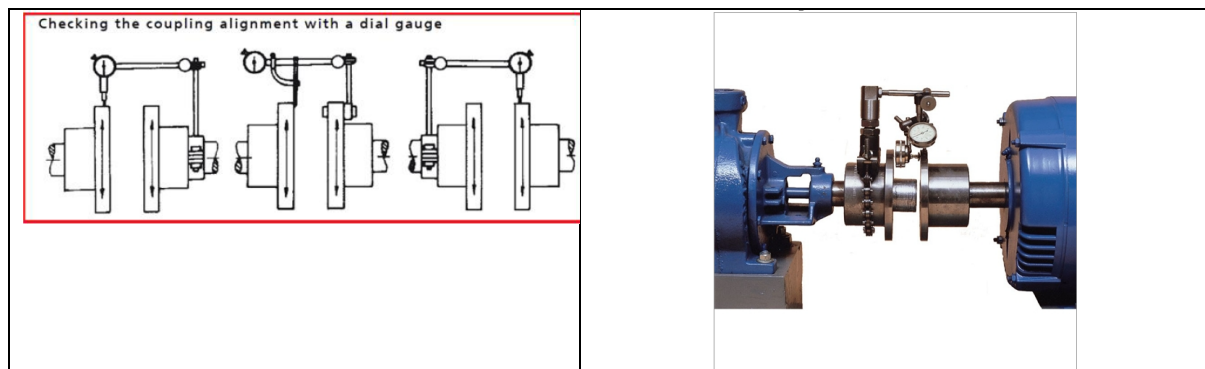
Installing the pump assembly

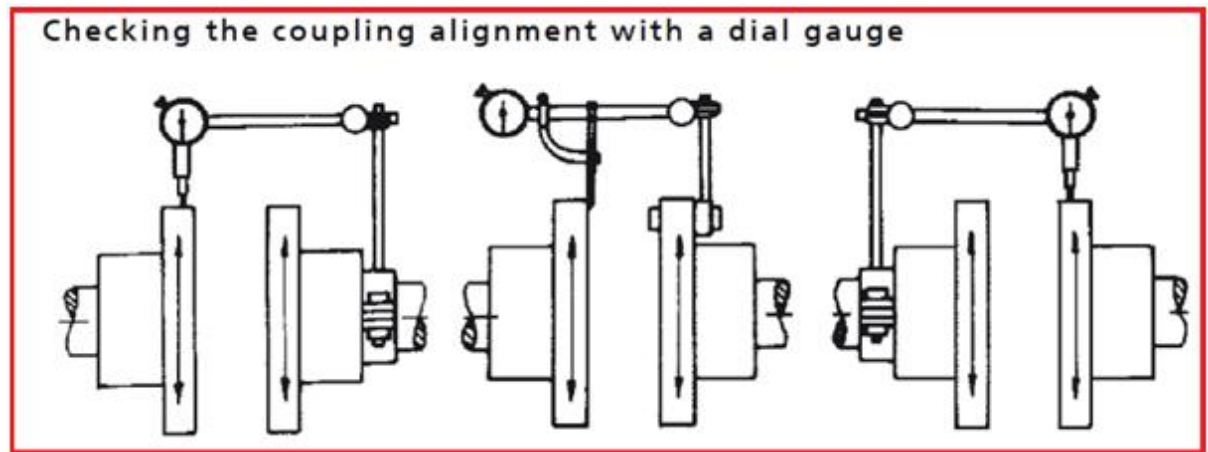
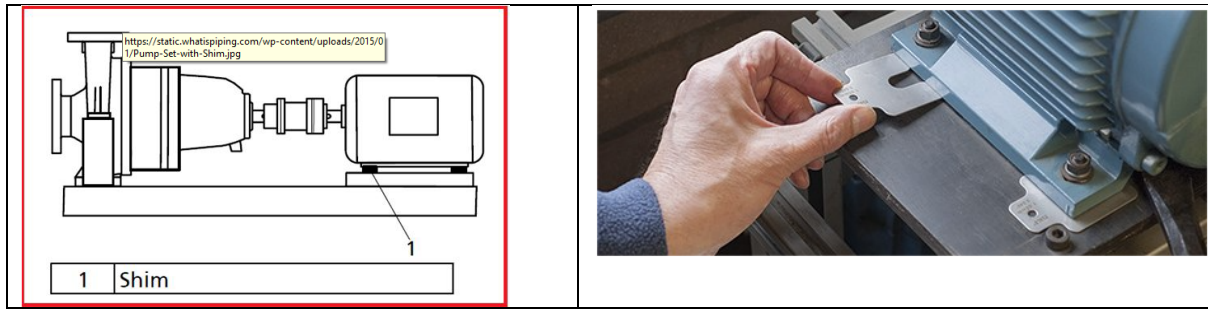
Always install the pump set in a horizontal position to ensure proper self-venting of the pump. Refer to Figure below.



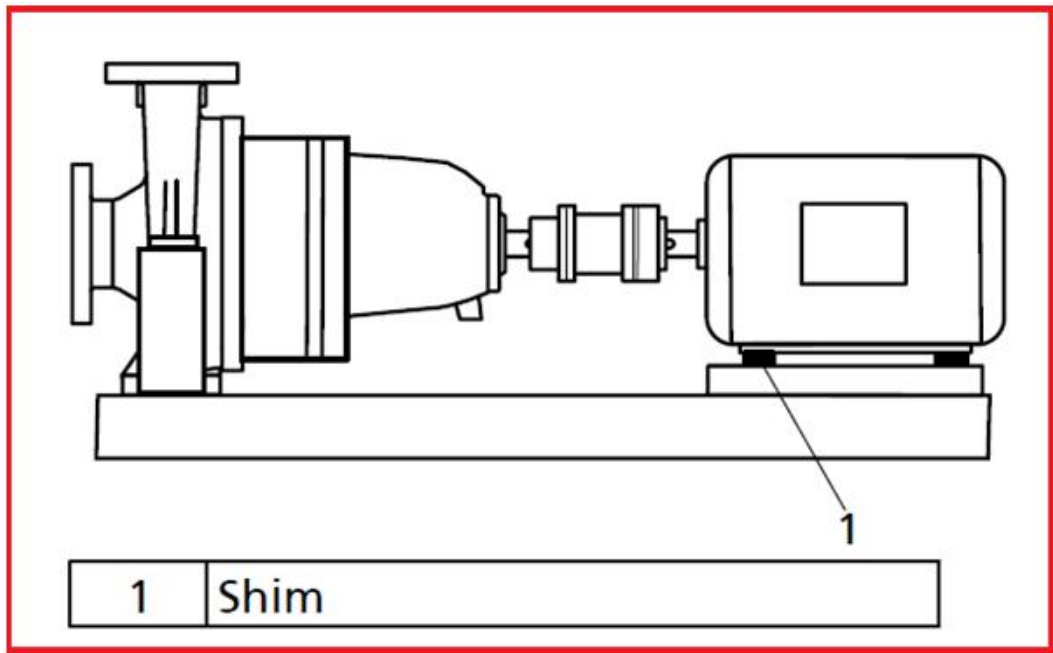
- ✓ Position the pump on the foundation and use a spirit level to align the shaft and discharge nozzle. Permissible deviation: 0.2 mm/m.
- ✓ If required, use shims (2) to adjust the height. Fit shims between the baseplate/foundation frame and the foundation itself; always insert them to the left and right of the foundation bolts and in close proximity to these bolts.
- ✓ For a bolt-to-bolt clearance > 800 mm, insert additional shims halfway between the adjoining holes. All shims must lie perfectly flush.
- ✓ Insert the foundation bolts (4) into the holes provided.
- ✓ Use concrete to set the foundation bolts (4) into the foundation.
- ✓ Wait until the concrete has set firmly and then align the baseplate.
- ✓ Tighten the foundation bolts (4) evenly and firmly.
- ✓ Grout the baseplate using low-shrinkage concrete with standard particle size and a water/concrete ratio of ≤ 0.5 .
- ✓ Produce flow-ability with the help of a solvent.

- ✓ For low-noise operation, the pump set can be mounted on vibration dampers upon confirmation by the manufacturer. In this case, only fasten the flexible elements at the baseplate after the piping has been connected.
- ✓ Expansion joints can be fitted between the pump and the suction/discharge line.
- ✓ Observe the permissible forces and moments at the pump nozzles.
- ✓ Take appropriate measures to compensate for the thermal expansion of the piping.
- ✓ The suction lift line/suction headline has been laid with a rising/downward slope towards the pump.
- ✓ The nominal diameters of the pipelines are at least equal to the nominal diameters of the pump nozzles.
- ✓ To prevent excessive pressure losses, adapters to larger diameters have a diffuser angle of approximately 8°.
 - ✓ Thoroughly clean, flush and blow through all vessels, pipelines, and connections (especially of new installations).
- ✓ Before installing the pump in the piping, remove the flange covers on the suction and discharge nozzles of the pump.
- ✓ Use a filter with laid-in wire mesh (mesh width 0.5 mm, wire diameter 0.25 mm) of corrosion-resistant material. Use a filter three times the diameter of the piping. Conical filters have proved suitable.
- ✓ The volute casing and casing/discharge cover take on the same temperature as the fluid handled.
- ✓ Make sure the space between the casing cover/discharge cover and the bearing cover is sufficiently vented.
- ✓ Never close or cover the perforation of the bearing bracket guards.
- ✓ Never insulate the casing cover and the bearing bracket.
- ✓ Make sure that the coupling is correctly aligned at all times.
- ✓ Always check the coupling after the pump has been installed and connected to the piping.
- ✓ Also, check the coupling of pump sets supplied with pump and motor mounted on the same baseplate. Refer Figure below.





- ✓ Mark the installation position of the coupling by dotting marks (balancing condition).
- ✓ Remove the coupling spacer.
- ✓ While the pump's coupling is disengaged, also check the direction of rotation.
- ✓ Check the alignment of the coupling halves with a dial gauge (see Fig. 2). Admissible run-out of coupling face (axial) maximum 0.1 mm. Admissible radial deviation, measured over the complete circumference, maximum 0.2 mm.
- ✓ After having installed the pump set and connected the piping, check the coupling alignment and, if required, re-align the pump set (with the motor). Any differences in shaft center height between the pump and the motor are compensated by means of shims.
- ✓ Check the coupling alignment.
- ✓ Unscrew the hexagon head bolts at the motor.
- ✓ Insert shims underneath the motor feet until the difference in shaft center height has been compensated. Refer Figure below.



Re-tighten the hexagon head bolts.

- ✓ Check that the coupling and shaft can easily be rotated by hand.
- ✓ Always operate the pump set with a coupling guard. If the customer specifically requests not to include a coupling guard in Vendor's delivery, then the operator must supply one! Observe all relevant regulations for selecting a coupling guard.
- ✓ Reinstall the coupling guard and step guard, if any.
- ✓ Check the distance between coupling and coupling guard. The coupling guard must not touch the coupling.
- ✓ Check the available mains voltage against the data on the motor nameplate.
- ✓ Select an appropriate start-up method.
- ✓ Change the motor's direction of rotation to match that of the pump.
- ✓ Observe the manufacturer's product literature supplied with the motor. Never check the direction of rotation by starting up the unfilled pump set. Separate the pump from the motor to check the direction of rotation.
- ✓ Never insert your hands or any other objects into the pump. Check that the inside of the pump is free from any foreign objects.
- ✓ The correct direction of rotation of the motor and pump is in the clockwise direction (seen from the motor end). If the direction of rotation is incorrect, check the connection of the motor and the switchgear, if any.

UNDERTAKE INSTALLATION OF DRAINAGE SYSTEM

Industrial sewerage systems are laid down by utility providers and it is important that we follow and abide to the rules and regulations related to installation of sewerage system networks.

Step 1: Understanding the legislation

Teams mobilized for the design and installation works need to review available acts and guidelines related to design and installation of sewerage system networks.

The installation of an off mains drainage system can be a daunting prospect when you start looking into all the legal aspects. There are rules and regulations for everything from the type of tank that is appropriate for a property, to where it can be installed, where it can discharge to, and what kind of ground conditions are acceptable.

Complying with all of these regulations is of paramount importance, as failure to do so can be disastrous for the environment and leave you, the property owner, open to prosecution. Your Local Authority and/or relevant environment agency have the power to test any off-mains/private drainage system that they feel isn't complying with the regulations and can ultimately take legal action if that is/continues to be the case.

It is therefore imperative that you ensure full understanding of, and adherence to, all the regulations that will affect your installation, and running, of a sewage treatment plant. This is the sole responsibility of the property owner and should be taken very seriously.

Step 2: Site Survey

Before you can even think about buying and installing your sewage treatment plant you need to first evaluate the area of install to know what type of system you will need.

Refer to available regulations and guidelines prior to making any conclusions related to finalization the plan. It is also important to check whether you would need building regulations approval and/or planning permission for your sewage treatment plant before you go any further. Failure to comply with, or acquire any one of these may prevent your installation altogether.

Step 3: Design the system

The results from your site survey will all have an impact on the design of your system. From what type of discharge method you can choose, to how deep your tank can be installed and where it can be located, your available options should already be zeroing in on finding the most suitable system for you. Now comes the time to start looking for a sewage treatment plant that will fit criteria.

Again, make sure the available guidelines and regulations are followed while selecting the design for the sewerage network.

But before you disappear to peruse our comprehensive catalogue of product range of sewage treatment plants there are a few more calculations to make and things to consider to help you find the right one. These include:

- ✓ Sizing the tank to your needs
- ✓ Choosing the right tank
- ✓ Sizing the drainage field

Any design developed, need to comply with regulations and guidelines of the Utility Regulatory Authority of the Maldives.

Step 4: Installation

It is an important recommendation that the installation of a sewage treatment plant should always be carried out by a suitably trained and qualified professional. If any part of sewage system is installed incorrectly, it has to be rectified prior to considering the installation complete.

Introduction to Sewerage Treatment Plant (STP)

It includes physical, biological and sometimes chemical processes to remove pollutants. Its aim is to produce an environmentally safe sewage water, called effluent, and a solid waste, called sludge or biosolids, suitable for disposal or reuse. Reuse is often for agricultural purposes, but more recently, sludge is being used as a fuel source.

Water from the mains, (toilets, baths, showers, kitchens, sinks), hospitals, commercial and industrial sites, is reduced in quality as a result of the introduction of contaminating constituents. Organic wastes, suspended solids, bacteria, nitrates, and phosphates are pollutants that must be removed.

To make wastewater acceptable for reuse or for returning to the environment, the concentration of contaminants must be reduced to a safe level, usually a standard set by the Environment Protection Agency.

Sewage can be treated close to where it is created (in septic tanks and their associated drain fields or sewage treatment plants), or collected and transported via a network of pipes and pump stations to a municipal treatment plant. The former system is gaining popularity for many new ECO towns, as 60% of the cost of mains sewerage is in the pipework to transport it to a central location and it is not sustainable. It is called 'Decentralization' of sewage treatment systems.

The job of designing and constructing sewage works falls to environmental engineers. They use a variety of engineered and natural systems to meet the required treatment level, using physical, chemical, biological, and sludge treatment methods. The result is cleaned sewage water and sludge, both of which should be suitable for discharge or

reuse back into the environment. Sludge, however, is often inadvertently contaminated with many toxic organic and inorganic compounds and diseases and the debate is raging over the safety issues. Some pathogens, for example, 'Prion' diseases (CJD or 'Mad Cow Disease is a Prion disease) cannot be destroyed by the treatment process.

The features of wastewater treatment systems are determined by:

1. The nature of the municipal and industrial wastes that are conveyed to them by the sewers.
2. The amount of treatment required to keep the quality of the receiving streams and rivers.

Discharges from treatment plants are usually diluted in rivers, lakes, or estuaries. They also may, after sterilization, be used for certain types of irrigation (such as golf courses), transported to lagoons where they are evaporated, or discharged through underground outfalls into the sea. However, sewage water outflows from treatment works must meet effluent standards set by the Environment Protection Agency to avoid polluting the waters that receive them.

Sewage treatment plant processes fall into two basic types:

Anaerobic Sewage Treatment

Sewage is partly decomposed by anaerobic bacteria in a tank without the introduction of air, containing oxygen. This leads to a reduction of Organic Matter into Methane, Hydrogen Sulphide, Carbon Dioxide etc. It is widely used to treat wastewater sludge and organic waste because it provides volume and mass reduction of the input material to a large extent. The methane produced by large-scale municipal anaerobic sludge treatment is currently being examined for use in homes and industry, for heating purposes. Septic tanks are an example of an anaerobic process, but the amount of methane produced by a septic tank (it is only the SLUDGE at the bottom that produces methane) serving less than 100 people is miniscule. In addition to this, septic tank effluent still contains about 70% of the original pollutants and the process smells very badly, due to the Hydrogen Sulphide, if not vented correctly. The effluent produced by this process is highly polluting and cannot be discharged to any watercourse. It must be discharged into the Aerobic layer of the soil (within the top metre of the ground) for the aerobic soil bacteria to continue the sewage treatment via the aerobic process below.

Aerobic Sewage Treatment

In this process, aerobic bacteria digest the pollutants. To establish an aerobic bacterial colony you must provide air for the bacteria to breathe. In a sewage treatment plant, air is continuously supplied to the Biozone either by direct Surface Aeration using Impellers propelled by pumps which whisk the surface of the liquid with air, or by Submerged Diffused Aeration using blowers for air supply through bubble diffusers at the bottom of the tank. (The most modern aerobic sewage systems use natural air currents and do not require electricity, though these are only used for small scale

sewage systems at the moment. Once again, the general public leads the way!) Aerobic conditions lead to an aerobic bacterial colony being established. These achieve almost complete oxidation and digestion of organic matter and organic pollutants to Carbon Dioxide, Water and Nitrogen, thus eliminating the odour and pollution problem above. The effluent produced by this process is non-polluting and can be discharged to a watercourse

Conventional sewage water treatment involves either two or three stages, called primary, secondary and tertiary treatment. Before these treatments, preliminary removal of rags, cloths, sanitary items, etc. is also carried out at municipal sewage works.

Primary Treatment

This is usually Anaerobic. First, the solids are separated from the sewage. They settle out at the base of a primary settlement tank. The sludge is continuously being reduced in volume by the anaerobic process, resulting in a vastly reduced total mass when compared to the original volume entering the system.

The primary settlement tank has the sludge removed when it is about 30% of the tank volume.

Secondary Treatment

This is Aerobic. The liquid from the Primary treatment contains dissolved and particulate biological matter. This is progressively converted into clean water by using indigenous, water-borne aerobic micro-organisms and bacteria which digest the pollutants. In most cases, this effluent is clean enough for discharge directly to rivers.

Tertiary Treatment

In some cases, the effluent resulting from secondary treatment is not clean enough for discharge. This may be because the stream it is being discharged into is very sensitive, has rare plants and animals or is already polluted by someone's septic tank. The Environment Agency may then require a very high standard of treatment with a view to the new discharge being CLEANER than the water in the stream and to, in effect, 'Clean it up a bit'. It is usually either Phosphorous or Ammoniacal Nitrogen or both that the E.A. want reduced. Tertiary treatment involves this process. If Phosphorous is the culprit, then a continuous dosing system to remove it is the tertiary treatment. If Ammoniacal Nitrogen is the problem, then the sewage treatment plant process must involve a nitrifying and then de-nitrification stage to convert the ammoniacal nitrogen to Nitrogen gas that harmlessly enters the atmosphere.

(https://www.crystaltanks.com/sewage_treatment_explained.html)

Stages of installing a sewage treatment plant

Inspect tank for damage

Tanks will normally have been fully tested and checked before being dispatched to you, but it isn't uncommon for them to become damaged during transportation and

offloading. Make sure to thoroughly inspect the tank when it arrives as, once the tank is installed, most manufacturers won't accept claims for damage.

Check you have correct invert depths

You should have already checked the depth of your incoming pipework during the site survey and design stage of your project, and ordered a tank with the appropriate invert levels. However, it is worth checking this again to ensure that the physical tank delivered will still connect to your existing pipework and remain within the maximum permissible depth.

Siting the tank

Double check your planned install location against the guidelines in the install manual, as they may recommend extra conditions and minimum distances specific to their tank.

Excavate the hole

Make sure it is large enough for the tank and any recommended backfill, then install the right type of base (often a concrete one) for the tank to sit on. Please ensure that you follow the manufactures detailed health and safety guidelines that will be provided in the manual when excavating your hole.

Consider drainage falls

This should have been part of your planning already, but it is worth double checking, especially for a gravity system. Typically these will be 1 in 60/70 between the house and tank, and a maximum of 1 in 200 for a drainage field.

Place the tank

Carefully lower the tank into the hole, using the recommended lifting system, while checking that the inlet and outlet orientation is correct and ensuring the tank is level.

Use correct backfill

Concrete, gravel or sand are the most common recommendations, but check the instruction manual to see what the manufacturer advises and follow their steps for adding backfill to the site.

Install the inlet and outlet

Should be a straightforward task if everything has gone to plan, but a qualified plumber should be consulted if you are unsure.

Install the inlet and outlet

Assuming that everything has gone to plan thus far, connecting up the pipe work should be fairly easy. It is worth noting though that some manufacturers advise the added install of inspection chambers before and after the treatment plant for easier maintenance access should problems arise in the future.

Wire up the electrical connection

Unless you are a qualified electrician yourself, please leave all electrical work to a professional. The installation manual will detail the steps required but we strongly advise against trying to do this yourself.

Fit correct cover and frame

Assuming you provided the sewage treatment plant supplier/manufacturer with the correct details of your site, the most suitable cover and frame should already be provided. However, it is worth noting that manufacturers will always assume the plant is going to be installed in a traffic free area. If this is not the case, it is highly recommended that you contact a structural engineer before installing your system.

Consider ventilation arrangements

This can often be overlooked, but it is important to ensure your system is well vented to prevent odor issues on site. Ideally, there should be a vent on the treatment plant and, if you have a drainage field, venting at the ends of the percolation trenches too. Contact our technical team for advice if you are unsure of the best arrangements for your site.

That's a basic look of the things you need to do when installing your sewage treatment plant. It is not a comprehensive guide by any means, that is what the manufacturer's installation manual is for, but it should give you an idea of the general steps involved.

Step 5: Operation

The biological treatment process of a sewage treatment plant is generally self-regulating and will require no specialized knowledge to operate. However, it is important to know how it works and to understand that there are some restrictions to use when compared with a normal mains sewer connection.

Sewage treatment plants use colonies of live natural micro-organisms (also known as biomass) to break down the pollutants in the sewage that you flush, wash and drain away. This biomass can be damaged or destroyed by certain chemicals found in household cleaning products, especially if they are used in excessive amounts. This can lead to unpleasant smells occurring and, in extreme cases, the ultimate failure of the sewage treatment plant. For this reason, it is important to follow the manufacturer's guidance on what should and shouldn't be flushed into the tank.

The following is a list of the things that could be affected:

- ✓ **Detergents (washing machine & dishwasher) and washing up liquids.** These are generally okay to use in the normal concentrations for typical household applications. Problems can occur, however, if you find yourself having to do unusual amounts of clothes washing, for example. Should this be the case, it is advisable to spread the extra cleaning out over a few days just to be safe. Excessive use of Biological washing powders can cause degradation of the biomass. Other ways you can help protect your tank's biomass are by switching to non-biological detergents, without enzymes, or using liquid detergents instead of powder. Always avoid excess use.
- ✓ **Floor cleaners, disinfectants, and bleaches.** Generally safe to use, in accordance with makers recommendations, but it is advisable to do so with the

minimum necessary concentrations. However, you should never pour neat disinfectant or bleach down sinks or outside gullies, as this would be damaging to the biomass. If there is a smell arising from the drains it will usually indicate a problem in the system that will need fixing by a professional.

- ✓ **Nappy disinfectants and bottle sterilizing fluids.** These can still be used, but you should ensure that the used fluid is well diluted with water before pouring it down the drain.
- ✓ **Waste disposal units.** Using a waste disposal unit won't cause damage to the biomass, but it can put a considerable extra load on the sewage treatment plant, both in terms of organic load and liquid, as the ground up material is flushed into the unit. If you intend to use one of these with your sewage treatment plant system, please speak to the manufacturer of your chosen tank to find out if their product will be able to deal with the extra loads.

Some things must NEVER be discharged into the drains if you have a sewage treatment plant. These include:

- ✓ Motor oil, grease, anti-freeze, brake fluid etc.
- ✓ Cooking oil and fat
- ✓ Weed-killers, insecticides, fungicides and other gardening chemicals
- ✓ Paint, thinners, white spirit, turpentine, creosote etc.
- ✓ Chemical drain cleaners/commercial cleaning products
- ✓ Acid based brick/stone floor cleaners
- ✓ Medicines (return unused medicines to a pharmacist for safe disposal)
- ✓ Photographic developing fluids
- ✓ Nappies, sanitary towels, toilet wipes etc. (even biodegradable ones as they do not fully degrade in a treatment plant and can lead to blockages and malfunctions)

Step 6: Maintenance

Before installing any sewage treatment plant, you should have already planned for future maintenance needs. Things like making sure there is suitable access for desludging to take place, and keeping covers clear of obstruction (i.e. don't cover them with soil or grass to try and hide them away). But once the system is installed, what can you do to help keep it in good working order and problem free?

First and foremost, you are going to want to take out some kind of maintenance agreement and service plan with either the manufacturer, if available, or a suitably qualified maintenance company. Annual desludging and servicing is critical to operation of your system, but it can be costly. Taking out a service plan at the time of purchasing your tank though, could save you money in the long run, and will certainly save you the hassle of remembering to get it done yourself.

The annual servicing, which should be conducted by a qualified professional, will usually check things like:

- ✓ Sludge return
- ✓ Functionality of blower and/or pump
- ✓ Pump pressures
- ✓ Replacement of pump filters
- ✓ Pump diaphragm
- ✓ Alarm functionality
- ✓ Ventilation functionality
- ✓ Covers and locks

Between these services though, there are some checks you can make yourself to ensure the system is operating correctly. These include:

- ✓ Checking all vents to make sure they are not blocked or obscured
- ✓ Checking the air blower is working by listening for a gentle hum when standing beside the plant

The installation manual provided by the manufacturer will most likely have other recommendations of checks you can make yourself. Please ensure that you always follow their health and safety guidance for any maintenance you plan to do.

CLEANING THE JOBSITE

It is important we properly clean the site after completing installation of the sewerage system network.

In managing the site, we may be required to recycle materials like metal, wood and sometimes, concrete. It is important that in managing the site, we follow and comply with local regulations in managing the waste produced from the work involved with the installation of the sewerage networks.

12. INSTALL SEWERAGE PUMP STATION AND SEA OUTFALL

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 non-routine 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 identify 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 non-routine situations

Emergencies present hazards that need to be recognized and understood. Non-routine 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 non-routine 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
 - Non-routine 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.

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.

Calculate the average monthly use.

Add the planned growth rate for the product line.

Check parts catalogs or call the source for best buy rates.

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.

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.
- Run product through heat-shrink.
 Place product in package.
 Glue ends of package together.
 Place label on front of package.
 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:
 - move cursor to middle of word
 - double-click mouse button
- ✓ IF text is a section of words or letters THEN:
 - move cursor to beginning of text
 - press mouse button down
 - move cursor to end of text
 - 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:
 - Give lots of clear instructions (training) because the task is new.
 - 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
- ✓ 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):
 - 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 with several examples to provide context
 - practice the task
- ✓ Identify the critical decision points (what do experts ask themselves when deciding on what learning technique to use):
 - What is the experience level of the learners?
 - 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):
 - Ask learners for their experience level to gain a background.
 - Ask questions that provide clues.
 - Observe how they react to new and difficult information.

- ✓ Prioritize the decision points:
 - 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.
 - 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:
 - Program in HTML (HyperText Markup Language).
 - Design and build on-screen layout and messages using company templates.
 - Use Dreamweaver or similar remote publishing tool.
 - Works with others (teamwork) by interacting with the Merchandising department group.
 - Constructs pictures using digital cameras and photo editing software.
 - 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.

What is 'coordinating with others'?

There is an African proverb that goes "If you want to go quickly, go alone. If you want to go far, go together."

Fundamental to good teamwork and therefore the success of your team is the ability to coordinate successfully with one another.

This is often easier said than done and it can be traced back to the following three elements:

1. Clear communication

How can you coordinate well with others if they can't understand you?

When speaking keep your language simple and jargon free. Speak slowly and clearly and don't be afraid to ask your audience to confirm that they've understood what you mean.

This applies as much to listening as it does to speaking. Learn to listen actively and devote your whole attention to the person speaking.

Again, don't be afraid to ask questions for clarification.

2. Understanding each other's personality types

We are all motivated in slightly different ways.

In order to get the best out of your colleagues, take time to observe the way they prefer to work.

For example, people's approach to time varies considerably. Some like to be given plenty of time up front to complete the task whilst others prefer to work 'under pressure'.

If you work with rather than against their natural tendencies then you will find that your working relationship is smoother.

3. Get organized

You need to be organized.

It's your responsibility to manage your own workload and ensure that it fits with the overall output of the organization.

This also gives you the flexibility to handle problems as and when they arise.

Why is it important?

- ✓ Poor coordination leads to suboptimal outcomes. You and your organization will suffer.
- ✓ When things go wrong it enables you to get back on track more quickly.
- ✓ It gives you the ability to foresee potential problems and obstacles before they happen.

How do I become better at it?

Here are 6 ways to improve your ability to coordinate with others:

1. Learn how to be a clear communicator. Check your team have understood you correctly.
2. Learn to be a better listener.
3. Learn how to give feedback.
4. Learn how to receive feedback.
5. Become better at managing deadlines.

6. Check-in regularly with your team to find out how they are progressing with their individual tasks.

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 day's 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 itemized 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, and 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

SEWAGE TREATMENT PLANT- STARTING, STOPPING

As mentioned earlier, every machinery system on the ship requires a proper procedure to be followed for starting and stopping and failure to follow this step-by-step procedure will lead to either failure in starting or stopping the machine or to some other fault.

Sewage treatment plant is one of such equipment in the ship's engine room that requires a step-by-step procedure during starting and stopping.

Starting



Sewage Treatment Plant

Generally, the sewage plant is running all the time while the ship is sailing. However, the plant might be required to be started manually if it is newly installed.

This is because the new plant needs to be stopped at regular intervals of time for improving its performance and maintenance procedures.

Following are the points that need to be followed for starting a sewage treatment plant:

Make sure if any maintenance is carried out on the sewage treatment system and all the openings have been closed properly before starting

The sewage plant is be filled with fresh water inside the chamber

At this stage, there are no aerobic bacteria inside the chamber, but the sewage would have started coming to the plant. In order to increase the efficiency and starting rate of the plant, a bio-pacis added to the plant by flushing the amount specified in the manual

This bio-pacis mixed with warm water, which helps in the growth of bacteria and also in efficient functioning of the plant

If the bio-pacis not added, the plant might take up to 5 to 7 days to become completely functional. However, with the bio-pacit becomes functional within 24 hours

Start the air compressor or open the air valve as per the design of the plant. The pressure is maintained as per the manual. Generally 0.3-0.4 bars

Open the sewage overboard valve and close the holding tank valve when the ship is out of restricted waters

The plant is to be continuously monitored and checked for the flow through the transparent plastic tubes

A sample is taken for checking for suspended solids and chlorine content

The test must be performed every week to check the performance of the system

Some STPs are provided with 7 bar air line with solenoid valve in case the blower has to be stopped



S.T.P Pumps

“Do not turn off the power source of the aeration blower under any circumstances. If this happens, the micro-organism will die and thereby reduce the overall effectiveness of the device.”

Stopping

Stopping of the sewage treatment plant is generally done either before entering the dry dock or in case some maintenance has to be carried out inside the treatment plant. For stopping the system, close the inlet valve to the sewage plant, then close the overboard valve and let the sewage go overboard.

Empty all the three chambers of the plant i.e. aeration, settling and chlorination chambers.

If the chambers are not emptied, it will lead to growth of anaerobic bacteria which forms the toxic H₂S gas.

If entry has to be made inside the tank, the later should be checked for hydrogen sulphide gas H₂S with the help of a dragor tube by taking a continuous sample from the plant.

Entry needs to be made wearing mask and rubber gloves.

In case the ship is going to the dry dock, the overboard should be connected to the shore reception facilities.

CONTROL AND MONITOR THE COMPRESSOR

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.

4. Review Your Facility's Layout for Possible Dangers

You may have worked at your facility for years and know where everything is, but that doesn't mean everyone else does, too. Verify that there is quality lighting in every area of your facility, especially around signs. Also, the message behind each sign must be fully understood by all employees to ensure everyone knows what safety precautions to take.

If your facility has piping systems, take great care in labeling each of the pipe's contents. When there is a damaged pipe, repair or replace it before the damage increases. Always expect the worst and prepare accordingly.

If there are chemicals in your facility, each worker must have sufficient understanding of the hazards and risks involved in the unfortunate event of a chemical leak. This would include what steps must occur, how to deal with an accident and what to do if you have been exposed to the chemical.

Floor markings provide another great way to stay on top of possible dangers. These types of markings are used to alert facility personnel of dangerous chemicals. They can notify anyone in the area about which places are not safe to walk and can alert personnel of hazardous zones in a facility that are normally safe.

Routine Machinery and Building Safety Checks

Scheduled safety checks are key. Set a date at the beginning or end of the month and devote a large portion of the day to evaluate the following:

- ✓ Employees are using protective equipment at all times.
- ✓ Daily proactive maintenance checks are being performed.
- ✓ Walkways and stairwells are free of debris.
- ✓ Emergency exits are unlocked and easily accessible.
- ✓ Stray cords are put away.
- ✓ Liquids are dried and cleaned from all surfaces.
- ✓ All chipped concrete or holes have been covered or smoothed out.

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.

4. Review Your Facility's Layout for Possible Dangers

You may have worked at your facility for years and know where everything is, but that doesn't mean everyone else does, too. Verify that there is quality lighting in every area of your facility, especially around signs. Also, the message behind each sign must be fully understood by all employees to ensure everyone knows what safety precautions to take.

If your facility has piping systems, take great care in labeling each of the pipe's contents. When there is a damaged pipe, repair or replace it before the damage increases. Always expect the worst and prepare accordingly.

If there are chemicals in your facility, each worker must have sufficient understanding of the hazards and risks involved in the unfortunate event of a chemical leak. This would include what steps must occur, how to deal with an accident and what to do if you have been exposed to the chemical.

Floor markings provide another great way to stay on top of possible dangers. These types of markings are used to alert facility personnel of dangerous chemicals. They can notify anyone in the area about which places are not safe to walk and can alert personnel of hazardous zones in a facility that are normally safe.

5. Routine Machinery and Building Safety Checks

Scheduled safety checks are key. Set a date at the beginning or end of the month and devote a large portion of the day to evaluate the following:

- ✓ Employees are using protective equipment at all times.
- ✓ Daily proactive maintenance checks are being performed.
- ✓ Walkways and stairwells are free of debris.
- ✓ Emergency exits are unlocked and easily accessible.
- ✓ Stray cords are put away.
- ✓ Liquids are dried and cleaned from all surfaces.
- ✓ All chipped concrete or holes have been covered or smoothed out.

Lessons Learned

Safety is the backbone of all plants. Without safety, you have accidents and machine failures, which lead to delays and people getting hurt. However, with safety, you have efficient and consistent output, which is the goal of all organizations. By keeping safety at the heart of every decision you make in your facility, there's no question you will lead a successful operation.

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

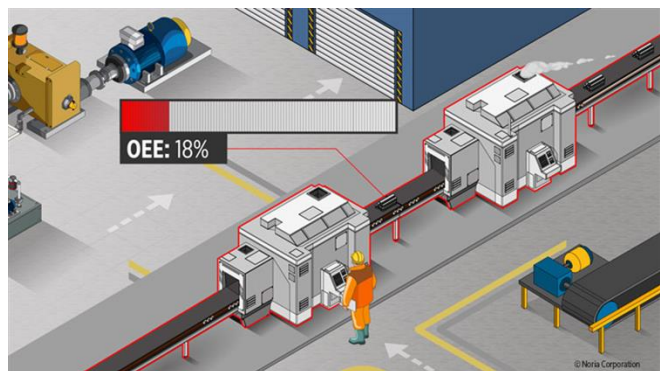
- ✓ Demobilize the work site: Plan the logistics for returning any external resources or equipment. Determine how unused resources will be disposed. Clean the work site to prepare it for operations. Get rid of the equipment removed from the system. Tear down any trailers/offices constructed for the purpose 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)?

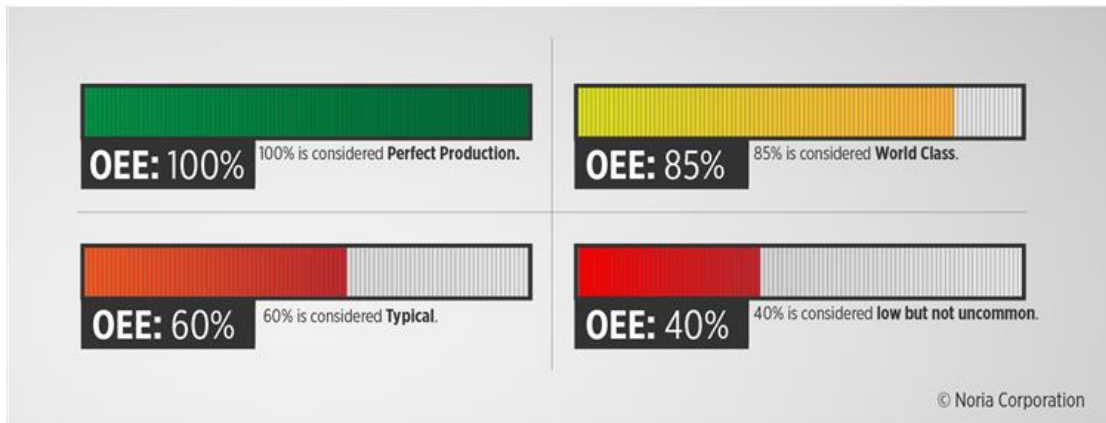
Overall equipment effectiveness (OEE) is a term used to evaluate how efficiently a manufacturer's operation is being used. In other words, overall equipment effectiveness helps you notice a problem in your operations, identify which percentage of manufacturing time is actually productive and fix it while 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 $Quality = \frac{Good\ Count}{Total\ Count}$.
- ✓ **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 $Performance = \frac{Ideal\ Cycle\ Time \times Total\ Count}{Run\ Time}$.
- ✓ **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 $Availability = \frac{Run\ Time}{Planned\ Production\ Time}$.

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: $OEE = (Good\ Count \times Ideal\ Cycle\ Time) / Planned\ Production\ Time$.
- ✓ **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: $Availability \times Performance \times Quality = OEE$. 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 into 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.

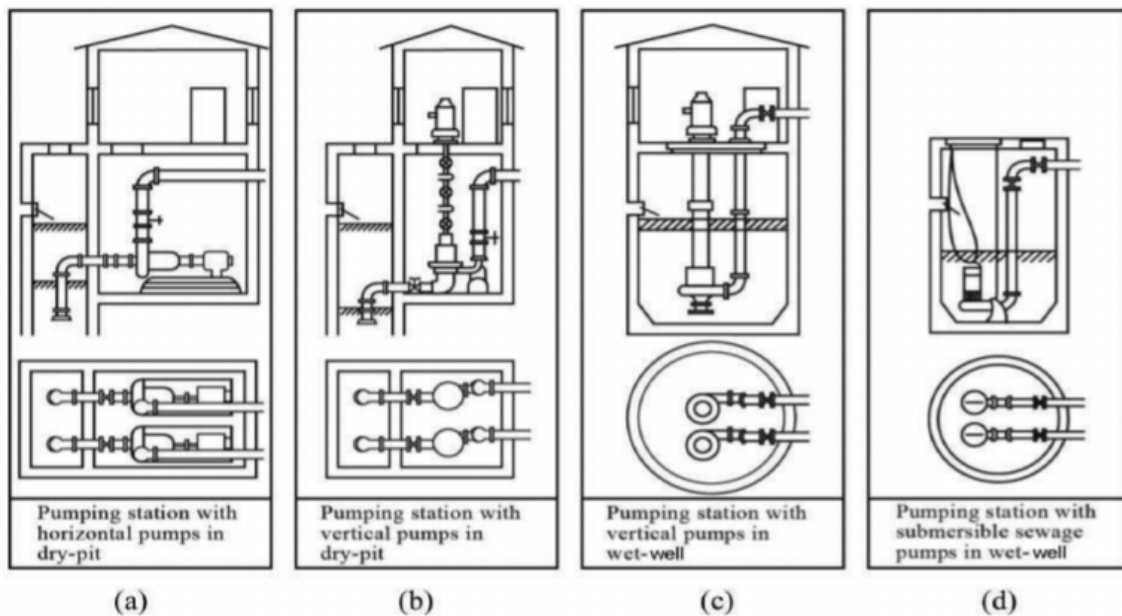
13. OPERATE AND MAINTAIN SEWERAGE TREATMENT PLANT (STP)

Components in a Sewage Systems

Pumping stations are either as in-line for lifting the sewage from a deeper sewer to a shallow sewer or for pumping to the STP or the out fall. They are required where low lying development areas cannot be drained by gravity to existing sewerage infrastructure, and/or where development areas are too far away from available sewerage infrastructure to be linked by gravity. The O&M of pumping systems presented here applies to all such types of pumping stations.

Types and Structure of Pumping Stations

The type of pumping stations can be (a) Horizontal pumps in dry pit, (b) Vertical pumps in dry pit, (c) Vertical pumps in suction well and (d) Submersible pumps in suction sump. All these types include a sewage-receiving sump, which is called suction sump or wet well. These types of pump arrangements are shown in Figure.



Dry Pit

The size of the dry pit should be adequate for the number of pumps planned and should be such as to handle the sewage load at the desired pumping capacity. Allowance should also be made for future requirements of additional or larger pumps. In the configuration, (a) separate dry pit and wet well are required: one to hold the sewage, and one to house the pumps and appurtenances. This option is required for installations where the pumps will otherwise need separate priming and where-as otherwise long suction pipes are needed.

It is typically used to pump large volumes of raw sewage, where uninterrupted flow is critical and sewage solids could clog suction piping. It is also used to pump solids in pipe galleries between digesters or other solids-handling equipment. While construction costs may be higher and a heating, ventilation and cooling system is

necessary when installed below the floor level, this configuration is best for O&M activities because operators can see and touch the equipment.

Suction Pump or Wet Well

Sewage sump is a compartment or tank in which sewage is collected. The suction pipe of a pump may be connected to the wet well or a submersible pump may be located in the wet well. Sewage sump design depends on the type of pumping station configuration (submersible or dry well) and the type of pump controls (constant or variable speed). Wet wells are typically designed to prevent rapid pump cycling but small enough to prevent a long detention time and associated odour release.

Sewage sumps should always hold some level of sewage to minimise odour release. Bar screens or grinders are often installed in or upstream of the wet well to minimise pump clogging problems. Instead of manually operated screens at the bottom, which requires the staff to get down into the screen sump, it is better to install mechanical bar screens, which can automatically remove the screenings and lift the same safely above the ground level. There can also be two such screens one after the other for coarse screenings and fine screenings. This will require rectangular channels to maintain longitudinal non-turbulent linear flow.

Lift Stations

In general, lift stations are invariably used in gravity sewer network where depth of cut of sewers poses a problem in high water prone areas. The procedure is to sink a wet well on the road shoulder or an acquired plot after the shoulder and divert the deeper sewer there. The submersible pump will lift the sewage and discharge it to the next on line shallow sewer. This is a very useful practice in such locations.

Equipment located in the wet well should be minimized, including suction and discharge valves, check valves, or other equipment that require routine, periodic maintenance. This equipment can be located in separate and suitable dry pits located adjacent to the wet well to facilitate accessibility and maintenance for the operator.

OPERATION SYSTEM ACCORDING TO PROCEDURE

Operation and Maintenance

Pumping machinery is subjected to wear & tear, erosion and corrosion due to its nature of functioning, and therefore it is vulnerable to failures. Generally, failures or interruptions are mostly attributed to pumping machinery rather than any other component. Therefore, correct operation and timely maintenance and upkeep of pumping stations and pumping machinery are of vital importance. Sudden failures can be avoided by timely inspection, follow up actions on observations of inspection and planned periodical maintenance. Downtime can be reduced by maintaining inventory of fast moving spare parts. Obviously due attention needs to be paid to all such aspects for efficient and reliable functioning of pumping machinery.

Operation of the Pumps

The following points should be observed while operating the pumps.

- ✓ Dry running of the pumps should be avoided.
- ✓ Centrifugal pumps if installed with negative suction should be primed before starting.
- ✓ Pumps should be operated only within the recommended range of the head-discharge characteristics of the pump.
 - If pump is operated at a point away from duty point, the pump efficiency normally reduces.
 - Operation near the shut-off point should be avoided, as it causes substantial recirculation within the pump, resulting in overheating of sewage in the casing and consequently, overheating of the pump.
- ✓ As far as possible positive suction is to be provided to avoid priming during design itself.
- ✓ Voltage during operation of the pump-motor set should be within $\pm 10\%$ of the rated voltage. Similarly, current should be below the rated current shown on the name plate of the motor.
- ✓ When parallel pumps are to be operated, the pumps should be started and stopped with a time lag between two pumps to restrict change of flow velocity to minimum and to restrict the dip in voltage in the incoming feeder and should be adequate to allow the pump head to stabilise.
- ✓ When the pumps are to be operated in series, they should be started and stopped sequentially, but with minimum time lag. Any pump next in sequence should be started immediately after the delivery valve of the previous pump is even partly opened. Due care should be taken to keep open the air vent of the pump next in sequence, before starting that pump.
- ✓ The stuffing box should allow a drip of leakage to ensure that no air passes into the pump and that the packing gets adequate wetness for cooling and lubrication. When the stuffing box is sealed with grease, adequate refill of the grease should be maintained.
- ✓ The running of duty pumps and standby pumps should be scheduled so that no pump remains idle for a long period and all pumps are in ready-to-run condition. Similarly, the running schedules should be ensured so that all pumps do not wear equally needing simultaneous overhaul.
- ✓ If any undue vibration or noise is noticed, the pump should be stopped immediately and the cause for vibration or noise should be checked and rectified.
- ✓ Generally, the number of starts per hour shall not exceed four. Frequent starting and stopping should be avoided as each start causes overloading of motor, starter, contactor and contacts. Although overloading lasts only for a few seconds, it reduces the life of the equipment.
- ✓ Troubles in a sewage pumping station can be mostly traced to the design stage itself. This is all the more true when too much grit is likely to come into the

sewage pumping stations from sewage at monsoon time, which is difficult to handle. Hence, sewers should not collect any storm water.

Undesirable Operations

The following undesirable operations should be avoided:

- ✓ Operation at higher head A pump should never be operated at a head higher than the maximum recommended head otherwise such operation may result in excessive recirculation in the pump, and overheating of the sewage and the pump. Another problem that arises if a pump is operated at a head higher than the recommended maximum head is that the radial reaction on the pump shaft increases causing excessive unbalanced forces on the shaft, which may cause failure of the pump shaft. As a useful guide, appropriate marking should be made on the pressure gauge. Efficiency at a higher head is normally low and such an operation is also inefficient.
- ✓ Operation at lower head If a pump is operated at a lower head than the recommended minimum head, the radial reaction on the pump shaft increases causing excessive unbalanced forces on the shaft, which may cause premature wear of bearings and possibly shaft failure if persisted. As a useful guide appropriate marking should be made on both pressure gauge and ammeter. Efficiency at a lower head is normally low, hence such an operation is inefficient. In such cases, it is advisable to throttle the delivery side valve to create more head to work within safe head. This will also reduce the power. If this is a design flaw additional head has to be created at tail end by elevating the delivery. However, these are not energy efficient solutions; change of impeller to suit the actual head is the solution.
- ✓ Operation on higher suction lift If a pump is operated on suction lift higher than the permissible value, pressures at the eye of impeller and the suction side fall below vapour pressure. This results in flashing of sewage into vapour. These vapour bubbles collapse during passage, resulting in cavitation in the pump, causing pitting on the suction side of impeller and casing, and excessive vibrations. In addition to mechanical damage due to pitting, pump discharge also reduces drastically. Typical damage to impeller and sometimes to the casing is shown in Figure



- ✓
- ✓ Operation of the pump with low submergence Minimum submergence above the bell-mouth or foot-valve is necessary to prevent entry of air into the suction of the pump, which gives rise to the vortex phenomenon, causing excessive vibration, overloading of bearings, reduction in discharge and in the efficiency. As a useful guide, the lowest permissible sewage level should be marked on the water level indicator. Usually the pump manufacturer indicates the minimum

height of submergence. In the case of submersible pumps, the minimum depth is needed to ensure cooling of the motor while running.

- ✓ Operation with occurrence of vortices
- ✓ If vibration continues even after taking all precautions, vortex may be the cause. Vortex should be stopped by using anti vortex fittings as described in chapter 4 of Part A of the manual:
- ✓ A well-planned maintenance programme for pumping systems can reduce or prevent unnecessary equipment wear and downtime. (The following maintenance information applies to both sewage and solids pumping systems.)

The following is a maintenance checklist for a basic pumping-station:

- ✓ Check the wet well level continuously (whenever necessary).
- ✓ Record each pump's "run time" hours (as indicated on the elapsed-time meters) at least once in a day and confirm that the pumps' running hours are equal.
- ✓ Ensure that the control-panel switches are in their proper positions.
- ✓ Ensure that the valves are in their proper positions.
- ✓ Check for unusual pump noises.
- ✓ At least once a week, manually pump down the wet well to check for and to remove debris that may clog the pumps.
- ✓ Inspect the float balls and cables and remove all debris to ensure that they operate properly. Twisted cables are to be released that may affect automatic operations.
- ✓ If a pump is removed from service, adjust the lead pump selector switch to the number that corresponds to the pumps remaining in operation. (This allows the lead pump levels to govern the operating pump's starts and stops.).

Piping and Appurtenance Maintenance

Properly maintaining pumping-station pipelines and other appurtenances can minimize pump loads.

Excessive head losses on either the suction or the discharge side of a pump can increase energy use and the wear rate and consequently, the O&M costs. Excessive head losses also may lead to process or treatment problems because solids move slower, so the proper solids balance is not maintained. Operators can monitor head losses by routinely checking the pressure gauges on both sides of the pumps.

When operators notice excessive head losses (indicated by a pressure drop on the suction side of the pump or an increase in pressure on the discharge side), they should determine whether the losses are a result of partial clogging, a restriction somewhere in the line, or materials built up on the pipe wall. To find clogs, operators should start by checking the pressure at various points in the suction and discharge piping, and look for spots with abrupt head loss (such as valves or other constrictions). If something is caught in a valve or other appurtenance, the operator should stop the pump and physically open out the valve head and remove the blockage. In smaller pumps, it is easier to remove the entire valve, disassemble and remove the blockage, reassemble and refit. During such time, other pumps shall be run. Scum build-up

problems typically are addressed via source control (for instance, by installing grease traps in the collection system at locations suspected or known to generate grease, such as restaurants, etc.).

Gate, Valves and Actuators

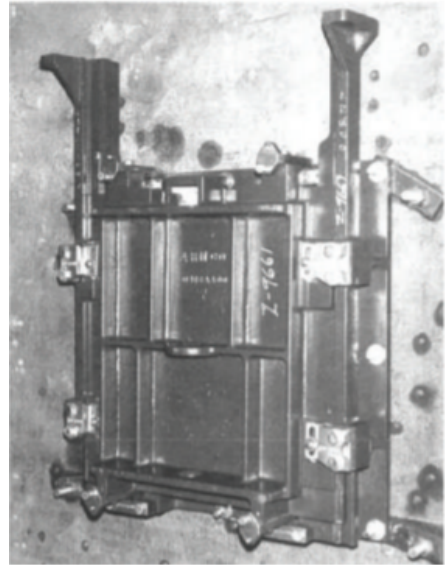
Sluice Gate

A sluice gate (Figure) is traditionally a wooden or metal plate, which slides in grooves in the sides of the guide channel.

Sluice gates are commonly used to control sewage levels in STPs.

Attention should be paid to the following points for proper operation:

- ✓ Test for proper operation Operate inactive sluice gates by smearing grease on stem threads.
- ✓ Clean and paint Clean sluice gate with wire brush and paint with proper corrosion-resistant paint.
- ✓ Adjust for proper clearance.
- ✓ For gates seated against pressure, check and adjust top, bottom, and side wedges until each wedge applies nearly uniform pressure against gate in the closed position. This shall be done by the manufacturer and not the operator.
- ✓ Check for the following:
 - Ensure unobstructed operation of gate and headstock.
 - Ensure that the spindle is not touching the stem guide.
 - Remove foreign matter like paint, concrete, etc. in the fully open position of gate.
- ✓ Do's for sluice gates
 - Operate the gate at least once in every three months.
 - Check the nuts of all construction and foundation bolts once in a year. Tighten the bolts, if loose.
 - Examine the entire painted surface for any signs of damage to the protective paint.
- ✓ Don'ts for sluice gates
- ✓ Do not remove lock plates until the gate has been properly installed.
- ✓ Do not keep the gate out of operation for more than three months.
- ✓ Do not forget to set the stop nut in the correct position.
- ✓ Do not disturb the adjustment of wedge block bolts/studs. • Do not over torque the crank handle/hand wheel.

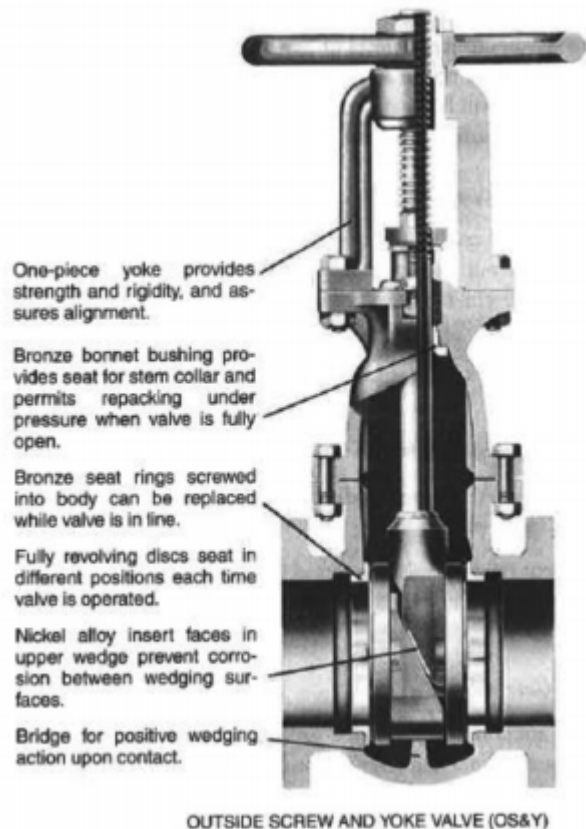


Valve

On the delivery side of centrifugal pumps, a non-return valve is necessary to prevent back-pressure from the delivery head on the pump, when the pump is shut off. To avoid water-hammer, which is likely to be caused by the closure of the valve, the valve may be provided with an anti-slam device, which may be either a lever and dead-weight type, a spring-loading type or the dash pot type. Pumps may be run in parallel with different permutation of the standbys. Isolation valves would be needed to isolate those pumps, which are to be idle. Generally, the isolating valves are gate valves, which should preferably be of the rising stem type, since this type offers the advantage of visual indication of the valve-position. For exterior underground locations, gate valves area generally used.

Gate Valve

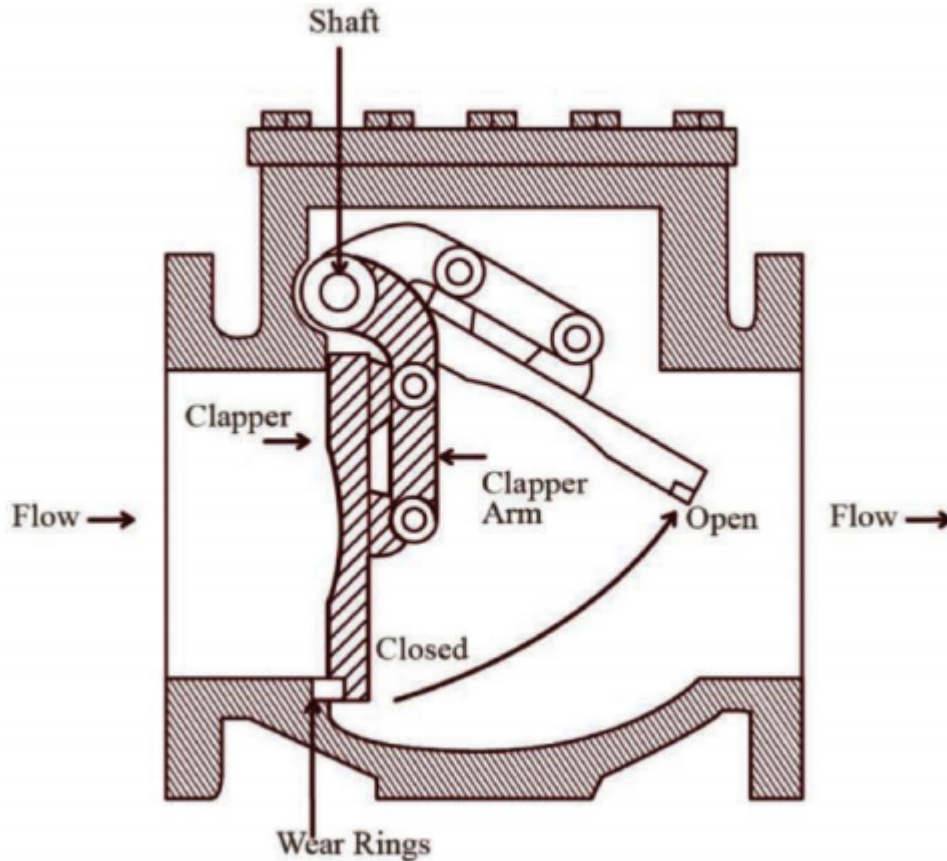
A gate valve is a valve that opens by lifting a round or rectangular gate/wedge out of the path of the fluid as shown in Figure overleaf. The distinct feature of a gate valve is that the sealing surfaces between the gate and seats are planar. The gate faces can form a wedge shape or they can be parallel. Typical gate valves should never be used for regulating flow, unless they are specifically designed for that purpose. Gate valves require maintenance.



- ✓ Replace packing : Modern gate valves can be repacked without removing them from service. Before repacking, open the valve wide. This prevents excessive leakage when the packing or the entire stuffing box is removed. It draws the stem collar tightly against the bonnet bushing on a rising stem valve.
- ✓ Operate valve : Operate inactive gate valves to prevent sticking.
- ✓ Lubricate gearing : Lubricate gate valves as recommended by the manufacturer. Lubricate thoroughly any gearing in large gate valves. Wash open gears with solvent and lubricate with grease.
- ✓ Lubricate rising stem threads : Clean threads on rising stem gate valves and lubricate with grease.
- ✓ Lubricate buried valves : If a buried valve is hard for working, lubricate it by pouring oil down through a pipe that is bent at the top end oiling the packing follower below the valve nut.

Non-Return Valve (Check valve)

Normally, a check valve is installed in the discharge of each pump to provide a positive shutoff from force main pressure when the pump is shut off and to prevent the hydraulic force from draining back into the wet well. The most common type of check valve is the swing check valve, which is shown in.



This valve consists of a valve body with a clapper arm attached to a hinge that opens when the pump starts operating and closes to seal when the pump is shut off.

Check valves must close before the water column in the pipe reverses flow; otherwise, severe water hammer can occur when the clapper arm slams against the valve body seat. If this occurs, an adjustment of the outside weight or spring is usually required. A traditional clapper type of check valve has a lever on the extended shaft, which allows adjustment of the weight on the arm or spring to vary the closing time. Wear occurs within the valve primarily on the clapper hinge-and-shaft assemblies and should be checked annually for looseness.

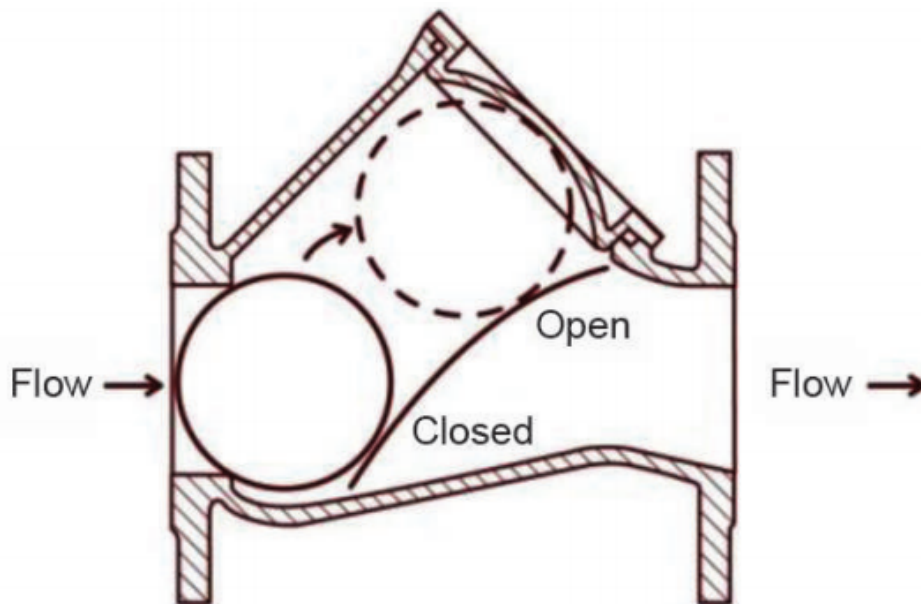
The preventive maintenance is to be done only by the manufacturer.

- ✓ Inspect Clapper Facing : Open valves to observe condition of facing on swing check valves equipped with neoprene seats on clapper. If metal seat ring is scarred, dress it with a fine file and lap with fine emery paper wrapped around a flat tool.

- ✓ Check Shaft Wear : Check shaft wear on balanced disc check valve since disc must be accurately positioned in the seat to prevent leakage.

Non-Return Valve (Ball Type)

Non-return valve depends on a light weight and suitable coated ball moving inside the flowing pipe to occupy an elevated angular position while the fluid is in pumping and dropping back to close the reverse flow through the pipe. Because it is a sphere sitting over a circular opening, it is expected to seat properly and seal the reverse flow. The material of the ball, the coating and its sturdiness against dents caused by the slide are important aspects. The ball is replaced by opening the top flange after switching off the pump. This can be installed in any position, vertical or horizontal. A non-return valve is shown in Figure.



When flow occurs, the ball is lifted into the angular piping and is held there because its weight is lighter than the sewage and the velocity of flow. When the flow stops, it slides back and seals.

Butterfly Valve

Butterfly valves are another type of valve that have been successfully used as suction and discharge isolation valves in pumping stations. They are frequently used in sewage plants where waste streams with a high solids content are encountered, such as in sludge pumping systems. A butterfly valve consists of the valve body and a rotating disc plug that operates through 90 degrees. This is usually a disc rotated by 90 degrees by external handle. In the open position, the disc is in line with the flow. In the closed

position, the disc is at 90 degrees to the flow and it stops the flow. Usually, the axis is vertical although horizontal axis arrangement may also be used in smaller sizes.

The closing and opening can be manual or mechanized. The butterfly valves occupy less space and are generally preferred for pipe sizes larger than 150 mm.

Many agencies specify butterfly valves as opposed to gate valves because they are less susceptible to plugging.

Butterfly valves require the following preventive maintenance to be done by the manufacturer:

- ✓ Adjust gland : The adjustable gland holds the plug against its seat in the body and acts through compressible packing, which functions as a thrust cushion. Keep gland tight enough at all times to hold plug in contact with its seat. If this is not done, the lubricant system cannot function properly, and solid particles may enter between the body and plug and cause damage.
- ✓ Lubrication : Apply lubricant by removing lubricant screw and inserting stick of butterfly valve lubricant for stated temperature conditions. Be sure to lubricate valves that are not used often to ensure that they are always in operating condition. Leave lubricant chamber nearly full so that extra supply is available by turning the screw down. Use lubricant regularly to increase the valve efficiency and service, promote easy operation, reduce wear and corrosion, and seal valve against internal leakage.


Actuators

These are replacements for physical operation by the operators. Actuators are used for automation of valves. An actuator rotates the valve spindle or lifts and drops the same.

- ✓ Electric geared motor actuator : The actuator consists of a rotor stator unit driving an output shaft through a single stage-worm reduction gear, which incorporates an automatic mechanical device for changing manual drive to power drive. The actuator includes a



travel-limit switch unit and a torque switch unit, and is of totally enclosed construction. When power fails, electric motor driven gear actuators retain their positions. When power supply returns, pay attention how the valves move. The electric motor driven gear actuator is shown in Figure.

- ✓ Solenoids : Solenoids are the most common actuator components. It consists of a moving ferrous core (a piston) that moves inside wire coil. Normally the piston is held outside the coil by a spring. When a voltage is applied to the coil and current flows, the coil builds up a magnetic field that attracts the piston and pulls it into the centre of the coil. The piston can be used to supply a linear force. Diaphragm valve have small holes on it. The holes should be free from clogging by debris otherwise the diaphragm may not open
- ✓ Pneumatics : Pneumatic systems have much in common with hydraulic systems with a few key differences. The reservoir is eliminated as there is no need to collect and store the air between uses in the pneumatic system. Also because air is a gas, it is compressible and regulators are not needed to recirculate the flow; however, since the gas is compressible, the systems are not as stiff or strong. In general, the pneumatics are liable to cause accidents such as when the air hose suddenly pulls out of the hose clamp and jets high pressure air on persons nearby. This should be avoided. The electric geared motor type is to be preferred. The pneumatic valve is shown in Figure.
 
- ✓ Hydraulic System : Actuator (hydraulic motor and hydraulic cylinder) is operated by hydraulic fluids (hydraulic oil), which is pressurised by hydraulic pump driven by an electric motor. Generally, a smooth movement and variable speed can be achieved. Moreover, the installed relief valve can prevent the system from breakdown. It should be noted that hydraulic oil leaks as pressure increases. Check for oil leakage regularly. Hydraulic system should be kept clean because it is vulnerable to dust or rust. Take precautions to avoid fires because the hydraulic oil is combustible. In all cases, preventive maintenance by manufacturer shall be done periodically and a wall chart exhibited on site.

Screen

Screenings in sewage from the incoming sewer below the ground level need to be separated and lifted above ground level, and removed either by mechanical or manual method.

Types of Screens

Coarse Screens

Coarse screens are usually bar screens consisting of vertical or inclined bars spaced at equal intervals across a channel through which sewage flows. The openings are usually 25 mm. Hand-cleaned screens are usually inclined at 45 degrees to the horizontal.

Medium Bar Screens

Medium bar screens have clear openings of about 12 mm.

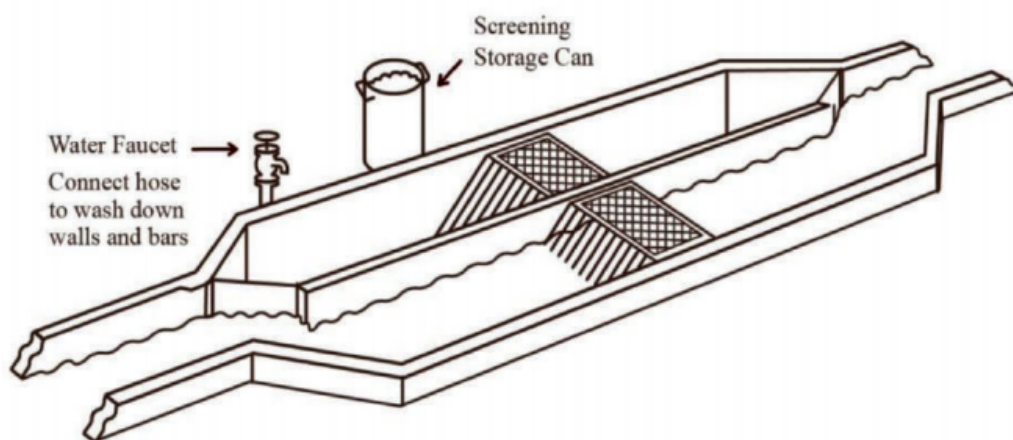
Fine Screens

Fine screens are mechanically-cleaned devices. Fine screens may be of the drum or disc type, mechanically cleaned and continuously operated. They are also used for protecting the beaches where untreated sewage may have to be discharged into the sea for disposal by dilution.

Screenings Removal Method

Manual Bar Screen

Hand cleaned screens should be cleaned as often as required to prevent backing up of sewage. A manually-cleaned bar screen is shown in Figure.



The following are important for O&M of manual bar screen:

- Preventive maintenance for checking and repairing the following once a week
Check whether the standing platform is at least 2 m wide with the first 1 m as slotted. An example of a risky platform is presented in Figure.

There is no space for the operator to stand after he has lifted and dumped screenings on the platform. Because of the lack of space, he may move backwards and fall into the sewage channel. Also, screens should be inclined to the horizontal by an angle of 60 degrees or more, otherwise, the operator has to bend forward. The rear side of the platform should have handrails. If handrails are not provided, enter this point in the site book.



1. Check the condition of ladders and paint them periodically.
Verify that there are no broken metal parts that protrude outside.
Once a month check the rigidity of handrails.

Verify the platform for its sturdiness by gently setting the foot on it.

Verify that the lighting is not in front or behind the operator. It should be above the operator, at least 2.5m high and mounted on the sidewall or separate lamp posts. These lights should not have local on-off switches and must be fully lit in the nights. Verify that the operator platform and slotted platform have 3m head room and provided with roof so that the operator is not drenched and he can lift the cleaning rake freely.

- Regular maintenance on a daily basis and repairs

1. Verify that the screen rods have not broken loose.

Verify that the cleaning rake is well washed in running water after each use.

Verify that gum boots are kept inside a locker covered with mesh.

Verify that disposable gloves are available for all 3 shifts and a stock of one month is available.

Verify that helmet is available.

- Operation

1. Before daily operation, verify all the above. If these points are not met, do not enter the screen area. Enter all missing items in the site register.

If all items are in order, do the cleaning once in four hours in each shift.

Ensure that operators do not stand one behind the other. This may cause an accident because while pulling the rake backwards, the operator in the front may hit and push the operator in the rear into the sewage channel.

Once the screens are cleaned and screenings are deposited on the slotted platform allow them to drip dry till the next cleaning after 4 hours.

Push the screenings with the rake to the side of the platform to drop them into the tipper positioned there.

Move the tipper to the vermin compost site, dump the contents in the pit and cover with earth as prescribed in Sec.3.4.4 "Disposal of Screenings."

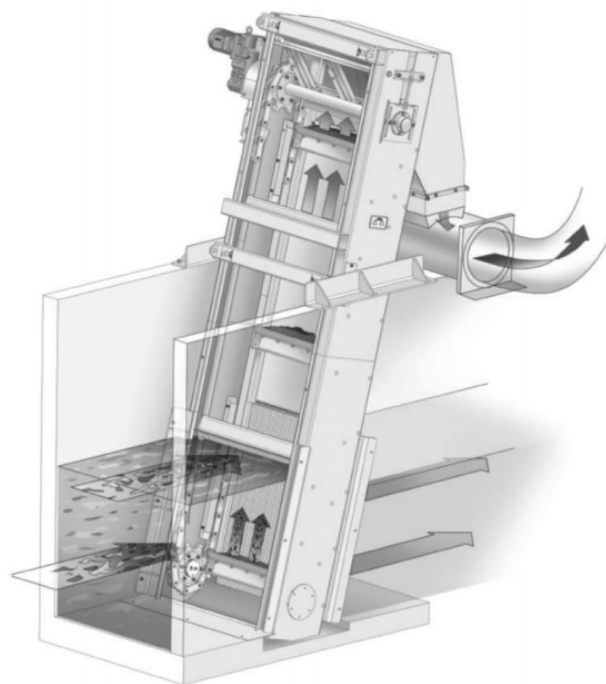
Mechanical Screen (Intermittent and Continuous)

Mechanically cleaned racks are generally erected almost vertically. Additional provision should be made for manual raking in case the mechanical rakes are temporarily out of order. Plants using mechanically cleaned screens have controls for:

1. Manual start and stop

Automatic start and stop by clock control

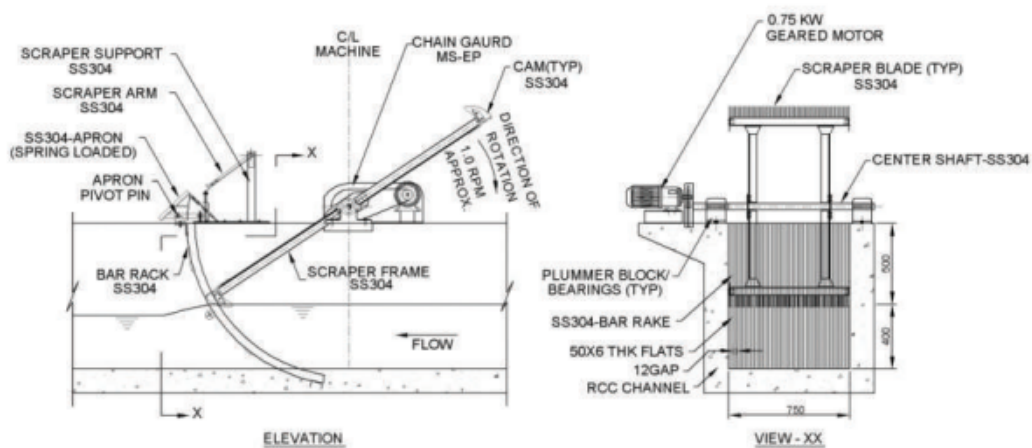
High level switch



High level alarm

Starting switch or overload switch actuated by loss of head and
Overload alarm.

There are various types of mechanisms in use, the more common being traveling rakes that bring the screenings up out of the channel and drop them into hoppers or other debris containers. A typical mechanically cleaned bar screen is shown in Figure. The rotary drum screen otherwise known as arc screen by United Nations Industrial Development Organization (UNIDO) is shown in Figure.



In the drawing, the screening rods are in the form of arc. The cleaning takes place when the meshing teeth at both ends of a diametrical rotating arm plough through the screen openings and push the screenings upwards. Upon exiting the upper end of the screen, which is well above the operating sewage level, a built in spring loaded arrangement in the diametrical rods jacks out the meshing teeth gently, which pushes the screenings gently into a collection trough.

The screenings can be manually removed or a conveyor belt can collect the screenings and drop them into a container on the ground through a drop chute.

✓ Preventive Maintenance

1. Verify the equipment manufacturer's manual for preventive maintenance instructions and carry out the same (if permitted to be done by the operator).

Switch off electrical power before doing any work on the mechanical screen.

✓ Regular maintenance on a daily basis and repairs

1. Before start of the day's work, check for any friction between metal parts. If friction exists and the sound is disturbing, disconnect the electric supply and divert all sewage to manual screens. Enter this action in the site register. Do not perform repairs by unauthorized personnel because it is dangerous.

Check the alignment of the tipper plates. If the screenings are slipping back and are not going up, allow the machine to work and do not stop it. Enter the abnormality in the site register and request for visit by the manufacturer's engineer. Do not perform repairs by unauthorized personnel because it is dangerous.

✓ Operation

1. Before start of the day's work, do not approach the mechanical screen unless you are wearing, electrical gloves, safety helmet and safety boots.

Before start of the day's work, switch off the mechanical screen and restart it. Watch for any friction or sparks. If you notice sparks, disconnect the electric supply and divert all sewage to manual screens. Enter the abnormality in the site register. Sometimes, these sparks can be dangerous and may cause electrocution.

Follow the procedure for disposing screenings as described earlier.

Accessories (Conveyors)

Belt conveyors are used in conveying the screenings to the trolley parked by the side of the screen chamber. Generally, these are meant only for mechanical screens. For manually operated screens, the water content has to first drip out fully before the screenings can be put on the conveyor. In the case of mechanical screens, the angle is close to vertical, the height is more and dewatering is automatic, but this is not the case with manual screens. If it is to be used, then the conveyor belt has to be behind the operator. The operator first picks up the screenings, drops it on the slotted platform and allows four hours for the screenings to drip fully. Thereafter, he can lift it by the same fork and turn it around 180 degrees and place it on the conveyor belt behind him. On the other hand, in smaller plants he can directly push the screenings to the slotted platform and into the trolley on the ground after the sidewall. All the guidelines for preventive maintenance, regular day-to-day maintenance and operation, and site register entries by the operator are the same as before .

Disposal of Screenings

Screenings generally consist of non-bio degradable stuff like plastic sachets, milk packets, shampoo packets, etc., with very little organic content. Hence, it is best disposed of as a secure landfill, which should be prevented from direct rainfall and flow of overland rainwater. The procedure specified by the pollution control authority should be adhered to without fail.

Grit Removal

The different types of grit removal equipment are given in chapter 5 of Part-A of the manual. These are velocity controlled channels, detritors, aerated grit chambers, vortex type, etc.

Preventive Maintenance

Almost all of these equipment are patented. Each manufacturer has proprietary schedules for preventive maintenance. These schedules should be followed. Preventive maintenance should be done only by the manufacturer or the erection contractor who has installed the equipment, and not by the operators.

Regular Day to Day Maintenance

The operator should hose the mechanical parts using the high-pressure hose, and pump the final treated sewage so that slime does not accumulate. Where flap gates or turnstiles are provided, the operator should necessarily “exercise” these once a day.

The operator should not enter the chambers unless the sewage entry is blocked, the chamber has been dry for at least two hours and the operator is wearing an oxygen mask. In the case of velocity-controlled channels, the trip switch controlled traveling bridge with suspended suction hoses for each channel connected to a vacuum pump set are standard items. If this system fails and grit accumulates in the channel, each channel should be taken out of sewage flow. The scour valve should be opened below the chamber and the sewage after filtering through the in-built filter port should be allowed to drain to the site drain. Thereafter, the chamber should be allowed to air dry for at least two hours, high pressure water jetting, draining and air drying cycle carried out at least three times.

Subsequently, labourers can be deployed to scrap the grit, provided the labourers wear goggles, gloves, safety shoes and oxygen masks.

In general the vacuum pump is the main source of failure and these types of channels are to be used only in large STPs where other such equipment are also functioning and qualified operators are available in all the shifts.

The vortex type grit separators described in chapter 5 of part A manual are simpler devices to lift and clean the grit and discharge at a convenient elevation above the ground level.

Disposal of Grit

The grit is usually pre-rinsed in the grit removal chamber itself before it is evacuated from it. Figure shows a typical grit chamber.

Clean grit is characterized by the lack of odour. Washed grit may resemble particles of sand and gravel, interspersed with inert materials from households. Grit washing mechanism has to be included whenever the detention time is more and flow through velocity is less. Unless washed, it may contain considerable amount of organic matter. This becomes an attraction to rodents and insects and is also unsightly and odorous. The grit should be contained in a secure landfill as directed by the local pollution control authority or disposed along with the municipal solid wastes, if permitted.



Pump Equipment

The types of pumps are dealt with in chapter 4 of Part-A of the manual. These are horizontal centrifugal, vertical shaft centrifugal, dry submersible and wet submersible pumps.

Preventive Maintenance

This shall be done only by the manufacturer / his authorized service agency / properly trained staff. The operator shall not carry out preventive maintenance.

Regular Day-to-Day Maintenance

This should include the tasks as given in the Table.

Description	Comments	Maintenance Interval			
		D	W	M	Y
Earthing	Check whether earthing is proper	yes			
Visual Appraisal	Check that safety aids and first aid are in place		yes		
Gland packing	Check for leaks & condition of mechanical seals			yes	
Alignment	Check alignment using computerized monitor				yes
Oil & Grease	Check for lubrication as per manufacturer			yes	
Motors	Check vibration and temperature		yes		
Mountings	Check for vibrations from foundation bolts			yes	
Bearings	Check for unusual sounds			yes	
Pump sequence	Start & stop the pumps as per duty condition	yes			
Foundation	Check for spalling or cracking			yes	

Proper operation of submersible pump systems requires that minimum submergence should always be maintained. This is for two primary reasons:

- ✓ Prevention of motor overheating
- ✓ Prevention of “vortex” and associated problems

The following should be inspected:

- ✓ Inspect seal for wear or leakage and repair, if required.
- ✓ Visually inspect the oil in the motor housing.
 - Remove pipe plug from housing.
 - Make sure oil is clean and clear, light amber in colour and free from suspended particles.
 - Milky white oil indicates the presence of water. If the system fails to operate properly, carefully read the instructions supplied during the time of purchase and perform maintenance recommendations.

Operation and Maintenance

Before starting the pump, check the following:

- ✓ Check insulation resistance by megger at free end of cable and verify with pump manual.
- ✓ Check continuity between ends of motor in the same phase and in all phases.
- ✓ Check resistance across moisture sensing wires and verify with pump manual.
- ✓ Physically rotate the coupling joint and verify smooth movement.
- ✓ Check for leaky oil plug and fix it before starting.
- ✓ Check for the bulbs indicating the on-off status of the pump and replace fused bulbs.
- ✓ Look for warning lamps for alerting the pumped liquid entering the oil chamber.
- ✓ Close the discharge valve before starting the pump. This is also taken care by check valve.
- ✓ Open the discharge valve gradually and not all of a sudden.

- ✓ While the pump is running at full flow, check the power consumed to be within the duty point.
- ✓ If the power consumed is very high, stop the pump and inform the manufacturer.
- ✓ Switch off the pump only after the discharge valve is closed.

Accessories

Oil and Grease

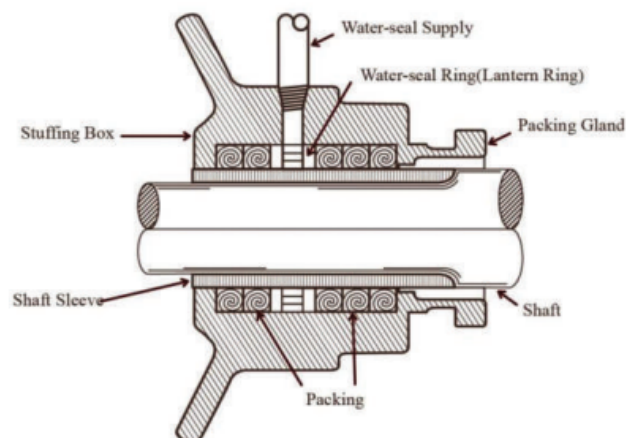
- ✓ Pumps, motors and drives should be oiled and greased strictly in accordance with the recommendations of the manufacturer. Cheap lubricants may often become the most expensive in the end.
- ✓ Oil should not be put in the housing while the pump shaft is rotating because a considerable amount of oil will be picked up and retained due to the rotary action of the ball bearings. When the unit comes to rest, an overflow of oil will occur around the shaft or oil will flow out of the oil cup

Bearing

- ✓ Pump bearings should usually last for many years if serviced properly and used correctly.
- ✓ There are several types of bearings used in pumps such as ball bearings, roller bearings and sleeve bearings. Each bearing has a special purpose, such as thrust load, radial load and speed. The type of bearing used in each pump depends on the manufacturer's design and application.
- ✓ Whenever a bearing failure occurs, the bearing should be examined to determine the cause and, if possible, to eliminate the problem.

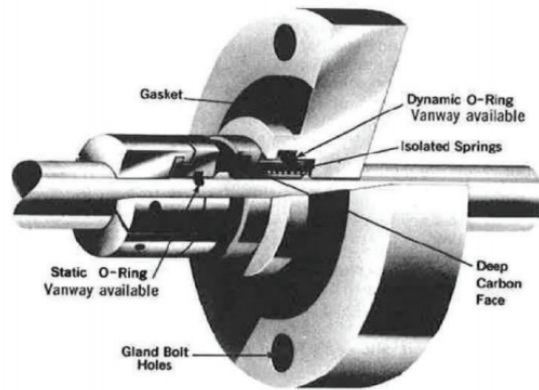
Packing Gland

- ✓ Check packing gland, which is usually neglected and is a troublesome part as shown in Figure.
- ✓ If the stuffing box leaks excessively when gland is pulled up with mild pressure, remove the packing and examine the shaft sleeve carefully.
- ✓ Replace grooved or scored shaft sleeve because packing cannot be held in stuffing box with roughened shaft or shaft sleeve.
- ✓ Replace the packing a strip at a time, tamping each strip thoroughly and staggering the joints. Position the lantern ring (water sealing) properly
- ✓ If grease sealing is used, completely fill the lantern ring with grease before placing remaining rings of packing in place.
- ✓ The proper size of packing should be available in the plant's equipment files.



Mechanical Seal

- ✓ Many pumps use mechanical seals instead of packing as shown in Figure.
- ✓ Mechanical seals serve the same purpose as packing; that is, they prevent leakage between the pump casing and shaft. The seals have two faces that close tightly and prevent the sewage from passing through them.
- ✓ The different materials are selected for their best application. Some of the factors for selection of material are:
 - Liquid and solids being pumped
 - Shaft speed
 - Temperature
 - Corrosion resistance
 - Abrasives
- ✓ Initially, mechanical seals are more expensive than packing when installed in a pump. This cost is recovered through maintenance savings over a period of time.
- ✓ Some of the advantages of mechanical seals are as follows:
 - They last from three to four years without any maintenance, resulting in labour savings.
 - Usually, there is no damage to the shaft sleeve at the time of their replacement.
 - Continual adjusting, cleaning, or repacking is not required.



The construction of a mechanical seal is shown below.

- ✓ Whatever be the method used, the mechanical seal must be inspected frequently.
- ✓ Grease cups must be kept full at all times and inspected to make sure they are operating properly. When a pump is fitted with a mechanical seal, it must never run dry or the seal faces will be heated up and ruined.
- ✓ Mechanical seals should not leak from the gland. If a leak develops, the seal may require resurfacing or it may have to be replaced.
- ✓ Repair or replacement of mechanical seal requires the pump to be removed and dismantled.
- ✓ Seals are quite delicate and special care must be taken when installing them. Mechanical seals differ widely in their construction and installation, and the manufacturer's instructions must be followed.

Flow Measuring Devices

Flow, similar to water level, is one of the most important parameters to be measured. The various types of flow-measuring devices have three basic criteria that determine

their performance namely: area, velocity, and device characteristics. The two basic types of flow measurements are open-channel and closed-pipe. For good measuring device performance, both types require approach conditions free of obstructions and abrupt changes in size and direction. Obstructions and abrupt changes produce velocity-profile distortions that lead to inaccuracies.

Weir Flow-meter

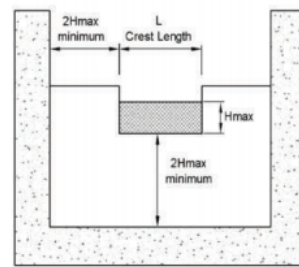
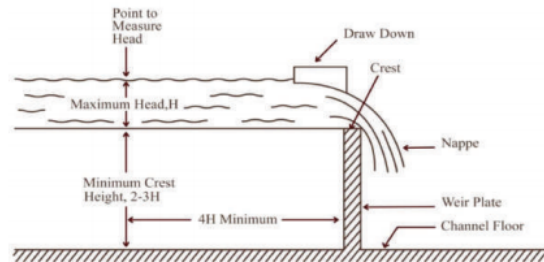
A weir measures the liquid flowing in open channels or partially filled pipes under atmospheric pressure as shown in Figure.

This device causes the flow to take on certain characteristics (such as shape and size) depending on the device used. Changes in flow-rate produce a measurable change in the liquid level near or at the device.

This level is related to flow-rate by an appropriate mathematical formula. The specific device determines the location and accuracy of level measurements and is extremely important for accurate performance.

Measurement errors occur if the actual crest height differs from the designed height due to accumulated matter on the channel floor. The sediments must be removed.

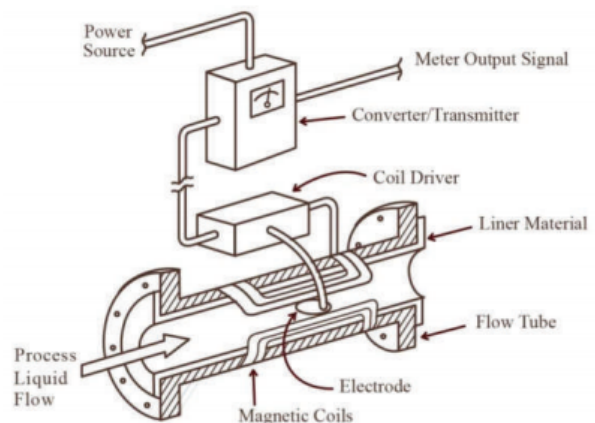
Floating matter or surface wave may cause incorrect level measurements and lead to errors in flow measurements. Therefore, floating matter should be removed immediately.



Electromagnetic Flow-Meter

Magnetic flow meters are used extensively in applications ranging from filtered sewage to thickened or digested solids.

They function by electromagnetic induction, in which the induced voltage generated by a conductor moving through a magnetic field is linearly proportional to the conductor's velocity. As the sewage (the conductor) moves through the meter (generating the magnetic field), the voltage produced is measured and converted to a velocity and, thus, a flow-rate. Magnetic meters require a full pipe flow for proper operation. Proper grounding is important for certain brands. In applications where greasing of electrodes is likely, additional equipment for

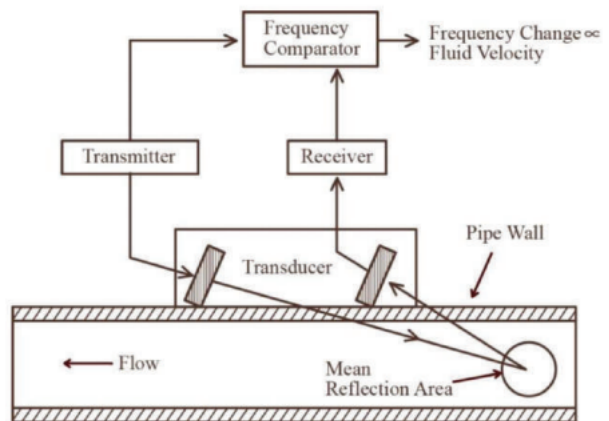


degreasing the electrode may be required. Magnetic flow meters provide no obstructions and are manufactured with abrasion-and corrosion-resistant liners, which is why they are frequently used in solids metering. Repairs should be done only by the manufacturer's representatives. Electromagnetic flow meters rarely break down because they have no moving parts. Dirt on sensors should be cleaned because that may cause error in measurements. The working principle is shown in Figure.

Ultrasonic Flow-Meter

Ultrasonic flow meters are based on the measurement of ultrasonic wave transit time or frequency shift caused by the flowing fluid. An instrument that measures wave-transit time is called a time-of-flight or counter-propagation ultrasonic flow meter.

Ultrasonic waves of known frequency and duration are beamed across the pipe at known angles. The waves are sensed either directly by an opposing receiver or indirectly as reflected waves. The changes in wave transit time or frequency caused by the flowing liquid are linearly proportional to the liquid velocity. This velocity is converted from flow and output to a display by conversion electronics. The presence or absence of air bubbles and density of solids in the fluid being metered affect the meters. Operators should follow the manufacturer's specifications and carefully match the meters to the application. The working principle is shown in Figure.



Fluorescent Tracers

Florescent tracer method requires the use of a tracer like Rhodamine B Dye, which is injected using a peristaltic pump from a small volume of a known concentration of dye solution. The dye is injected into the gravity or pumping main. After traveling and getting mixed, the dye concentration is measured at a distance away. The mass of the dye is the same in the beginning and after traveling. The instrument used is called Fluorometer. The dye will automatically degrade and it does not affect the water body.

OPERATE SYSTEM ACCORDING TO PROCEDURE

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 meeting 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;

Know your team skills and capabilities for effective resource utilization and understanding of training needs;

Develop clear key performance indicators and metrics to measure cost and progress;

Obtain senior management support and engagement;

Program sponsor with authority to change;

People, process, then equipment;

Balance quick wins with continuous improvement;

Focus on the trouble areas;

Engage people with trust and respect; and

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 override 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.



GOOD SHIFT HANDOVER

Best Practices

When handing over shift always explain WHAT and WHY decisions were taken.

<h3 style="margin: 0;">FORMAL</h3> <p style="color: white; font-size: small;">Written communication for each handover should be recorded in a simple logbook, ideally electronic</p>	<h3 style="margin: 0;">EXPERIENCED</h3> <p style="color: white; font-size: small;">You should only handover to someone competent and experienced enough to accept the responsibility</p>
<h3 style="margin: 0;">VISIBLE</h3> <p style="color: white; font-size: small;">Use big shared displays, white boards, notice boards to communicate the status of the plant to all</p>	<h3 style="margin: 0;">SHARE</h3> <p style="color: white; font-size: small;">Make it easy for people to share information about shift handover with each other - use mobile devices, alerts and notifications</p>
<h3 style="margin: 0;">ALIGNED</h3> <p style="color: white; font-size: small;">Always stay aligned with the short term production goals and targets</p>	<h3 style="margin: 0;">FACE-TO-FACE</h3> <p style="color: white; font-size: small;">Make sure people meet face to face to discuss their handover</p>

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



PERMIT TO WORK

ALL open permits need to be properly considered and ALL responsibility transferred to the next shift.

- ✓ 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.

Preventive Maintenance

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.

IDENTIFY AND RESPOND TO ABNORMAL SITUATIONS DURING OPERATION

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.

SHUT DOWN AND PREPARE SYSTEM FOR MAINTENANCE

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.

PREPARE AND START SYSTEM

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

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 identifies 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 non-routine 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.

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.

14. APPLY ACCIDENT-EMERGENCY PROCEDURES

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**
 - Determine what tracks may have been left behind by the threat actor.
 - 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 medical 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.

Do not move a casualty unless they are exposed to a life-threatening situation.

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.

Notify SafeUSC (Security) Ext 1168 or 5430 1168.

Remain with the casualty and administer first aid (if trained to do so) until assistance arrives.

Follow the instructions of relevant Emergency Services personnel or First Aid personnel.

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.

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.

- ✓ **Sign off**

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

15. REFERENCES

REFERENCES

- ✓ <https://www.pmi.org/learning/library/determining-project-requirements-best-practices-7278>
- ✓ <https://fractory.com/engineering-drawing-basics/>
- ✓ <https://medium.com/abilista/technical-drawings-product-3bd1fe0be4c4>

- ✓ <https://www.buyplm.com/document-control/engineering-drawings-data-document-control.aspx>
- ✓ <https://www.physicsclassroom.com/class/1DKin/Lesson-1/Scalars-and-Vectors>
- ✓ <https://courses.lumenlearning.com/introchem/chapter/three-states-of-matter/>
- ✓ <https://courses.lumenlearning.com/introchem/chapter/physical-and-chemical-changes-to-matter/>
- ✓ <http://www.nwlink.com/~donclark/hrd/tasks.html>
- ✓ <https://blog.mindmanager.com/blog/2020/03/202003202003how-to-manage-tasks-better-with-4-basic-planning-components/>
- ✓ <https://www.productiveflourishing.com/reviewing-enhance-success/>
- ✓ <https://www.ehs.washington.edu/fire-life/basic-electrical-safety#:~:text=Electrical%20shock%20happens%20when%20current,become%20part%20of%20the%20circuit.&text=Electrocution%20refers%20to%20the%20injury,forceful%20muscle%20contraction%20or%20falls.>
- ✓ <https://www.omag.org/news/2020/1/21/basic-electrical-safety#:~:text=To%20prevent%20electrical%20hazards%2C%20always%20make%20sure%20equipment%20is%20properly%20grounded.&text=Equipment%20with%20a%20grounding%20prong,into%20a%20non%2Dgrounded%20outlet.>
- ✓ <https://www.electrical4u.com/electricity/>
- ✓ <https://www.physicsclassroom.com/class/estatics/Lesson-1/Neutral-vs-Charged-Objects>
- ✓ <https://www.electrical4u.com/electricity/>
- ✓ <https://www.electrical4u.com/electric-circuit-or-electrical-network/#:~:text=Short%20circuit-,Open%20Circuit,to%20be%20an%20open%20circuited.>
- ✓ <https://www.electrical4u.com/electric-circuit-or-electrical-network/#:~:text=Short%20circuit-,Open%20Circuit,to%20be%20an%20open%20circuited.>
- ✓ <https://www.electrical4u.com/ammeter/>
- ✓ https://www.osha.gov/sites/default/files/2019-03/electrical_safety_manual.pdf

- ✓ <https://www.dfliq.net/blog/install-concealed-electrical-wiring-system-step-step-guide/>
- ✓ <https://electrical-engineering-portal.com/planning-installation-low-voltage-switchgear>
- ✓ <https://www.safesecureopenings.com/home/document/12182949/osha-injury-and-accident-prevention-safety-checklists>
- ✓ <https://www.simplilearn.com/project-scope-management-importance-rar89-article>
- ✓ http://www.click4it.org/index.php/Team_Briefing#:~:text=The%20Team%20Briefing%20is%20a,or%20corporate%20and%20local%20issues.
- ✓ <https://www.zoellerathome.com/en-na/how-to-install-a-sewage-pump>
- ✓ <https://www.reliableplant.com/Read/31170/commission-equipment-asset-management>
- ✓ <https://www.doc.govt.nz/get-involved/run-a-project/community-project-guidelines/monitor-and-evaluate-progress/>
- ✓ <https://www.flexibleproduction.com/how-to-carry-out-a-final-test-on-machine-tool/>
- ✓ <https://www1.health.gov.au/internet/publications/publishing.nsf/Content/ohp-enhealth-manual-atsi-cnt-l~ohp-enhealth-manual-atsi-cnt-l-ch2~ohp-enhealth-manual-atsi-cnt-l-ch2.7>
- ✓ <https://es.unitedrentals.com/project-uptime/expertise/6-tips-keeping-jobsite-clean>
- ✓ <http://www.fieldandcivilengineering.co.uk/prepare-drainage-construction/>
- ✓ <https://www.linkedin.com/pulse/team-work-coordination-santosh-bakhshi>
- ✓ <https://whatispiping.com/pump-installation-best-practices-checklists>
- ✓ <https://www.jdpipes.co.uk/knowledge/sewage-treatment/sewage-treatment-plant-installation-guide.html>
- ✓ https://ucanr.edu/sites/DANRISXHelp/DANRIS_ANNUAL_REPORT_Help_Parent_Page/Reporting_on_a_Project_Program/Reporting_Outcomes_for_a_Project_Program
- ✓ <https://www.osha.gov/safety-management/hazard-identification>

- ✓ <https://www.linkedin.com/pulse/plant-machinery-pre-start-checklist-your-complete-guide-mcpherson>
- ✓ <https://mirmarine.net/stati-na-anglijskom/engine-room/706-sewage-treatment-plant-starting-stopping>
- ✓ <https://www.reliableplant.com/Read/31513/maximizing-plant-safety>
- ✓ <https://www.vortexglobal.com/resources/how-to-plan-for-plant-maintenance-shut-down>
- ✓ <https://www.reliableplant.com/Read/11785/overall-equipment-effectiveness>
- ✓ http://cpheeo.gov.in/upload/uploadfiles/files/engineering_chapter4.pdf
- ✓ <https://www.wateronline.com/doc/the-o-and-the-m-in-operation-and-maintenance-of-water-and-wastewater-treatment-plants-0001>
- ✓ <https://www.intellipermit.com/shift-handover-and-the-permit-to-work/>
- ✓ <https://www.ilo.org/global/topics/labour-administration-inspection/resources-library/publications/guide-for-labour-inspectors/machinery-plant-equipment/lang--en/index.htm>
- ✓ <https://www.enersyscorp.com/alarm-management-abnormal-operating-conditions/>
- ✓ <https://www.vortexglobal.com/resources/how-to-plan-for-plant-maintenance-shut-down>
- ✓ <https://digitalguardian.com/blog/five-steps-incident-response>
- ✓ <https://safetyculture.com/topics/incident-report/#:~:text=An%20incident%20report%20is%20a,and%20misconducts%20in%20the%20worksite.>



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