

**THE PLANNING AND SITING OF
A MANUFACTURING FACILITY
USING HAZARDOUS MATERIALS**

by

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Newark, New Jersey 07102

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**"SHARED RESOURCES" MODULES
TO SUPPORT
ENVIRONMENTAL ENGINEERING EDUCATION**

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ABSTRACT

A freshman engineering design experience course was offered at New Jersey Institute of Technology in spring term 1997. Professors Eugene Golub, Deran Hanesian, Hsin-Neng Hsieh and Angelo Perna, were teamed together to teach the three hour per week, fourteen weeks course. Five lectures were given in the first five weeks and topics were Introduction of the Course, Siting a Facility, Aspirin Manufacturing Industry, Soil Conditions and Cost Estimate, and Written and Oral Communication. Students were asked to go through literature search for the homework assigned. During the lecture, a video tape, "Opportunities in Environmental Engineering" (produced by Institute of Chemical Engineers) was shown. A field trip was arranged to visit the Hoffmann LaRoche Pharmaceutical Manufacture Plant at Nutley, New Jersey.

Students were then grouped into four teams to site a facility and to perform mass balance calculation for such an aspirin manufacturing facility. USGS Quadrangle map and soil information (prepared by Soil Conservation Service, US Department of Agriculture) in Somerset County, New Jersey were provided to each group. Students were asked to prepare a work schedule, which should include the followings: aspirin production estimate, size determination, preliminary site selection, sites and surrounding area study, research on environmental restrictions, research on political restrictions, economics study, cost analysis, and report preparation. Each team should select at least three sites for their detailed study and conduct a field recon of the project areas. After that, professors Golub and Hsieh met individually with each group every week to assess their progress and discuss the problems encountered. Their progress was measured according to their proposed schedule. On the other hand, professors Hanesian and Perna discussed with each term production estimates and mass balance calculations. Work on site selection and mass balances were assigned weekly. Each week, work turned in from the previous week was evaluated, discussed, and returned to the team. At the end of the semester, each team handed in a report and presented their findings regarding site selection and aspirin production requirements to the class.

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Appendix B - Written and Oral Communication

Appendix C - Process to Manufacture Trimethoprim (Field trip to Hoffmann LaRoche
Pharmaceutical Manufacture Plant)

New Jersey Institute of Technology

FED 101- Freshmen Engineering Design (Spring 1997)

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Purpose of the course: Through basic engineering calculation and data analysis, students are working in groups to analyze and site a pharmaceutical manufacture plant.

Week	Topic	Assignment*
1	Lecture 1: Introduction to the course Video tape: "Opportunities in Environmental Engineering "	Assignment 1
2	Lecture 2: Siting a Facility	
3	Lecture 3: Aspirin Manufacturing Industry	
4	Lecture 4: Soil Conditions and Cost Estimate	
5	Lecture 5: Written and Oral Communication	
6	Site visitation (preliminary investigation)	
7	Field trip: Hoffmann LaRoche Pharmaceutical Manufacture Plant	
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9	Research on environmental restrictions Production and plant size estimate	
10	Research on political restrictions Mass balance	
11	Economics study MSDA search	
12	Cost analysis: construction cost, operation and maintenance cost	
13	Report preparation	
14	Students' oral presentation	

* Students are requested to conduct literature search for the assigned homework

Student Reference Information:

1. Siting a Facility Using Hazardous Materials
2. "Raritan Quadrangle Maps" USGS Quadrangle map that contains the possible sites for consideration
3. "Soil Survey - Somerset County" Soil Conservation Service, US Department of Agriculture. Reserved in the NJIT library.
4. Assignments

Instructor Reference Information:

1. "Encyclopedia of Chemical Technology, 4th Ed.", Edited by J. I. Kroschwitz and M. Howe-Grant, Wiley, New York, 1991.
2. Sax, I. N. and Lewis, R. J., Sr., "Dangerous Properties of Industrial Materials, 7th Ed.", Van Nostrand Reinhold, New York, 1989..
3. Mann, C. C. and Plummer, M. L., "The Aspirin Wars", Harvard Business School Press, Boston, 1991.
4. Austin, G. T., "Shreve's Chemical Process Industries, 5th Ed.", McGraw-Hill, New York, 1984.
5. McKetta, J. J. "Encyclopedia of Chemical Processing and Design, Vol. 4", M. Dekker, New York, pp. 24 - 30, 1977.
6. Ullman, F. "Encyclopedia of Industrial Chemistry, 5th Ed., Vol. A23", Weinheim, Federal Republic of Germany, Deerfield Beach, FL., USA, pp. 477 - 483, 1985.
7. Chemical Engineering, 55, March 1948, pp. 136 - 139.
8. Chemical Engineering, 60, June 1953, pp. 116 - 120.
9. Chemical Reviews, 57, 1957, pp. 583 - 620.

Lecture 1

Introduction to the Course

SITING A FACILITY USING HAZARDOUS MATERIALS

INTRODUCTION

This engineering case study is designed for first year engineering students in an appropriate freshman engineering design course. The case study is in the environmental field and is appropriate for students in all engineering disciplines. The case study is designed to expose engineering students to the design process at an understandable level appropriate to their level of technical sophistication. In this particular study, the design process is illustrated through the siting of a facility. The facility in this study is a manufacturing facility using hazardous materials.

MANUFACTURING FACILITY USING HAZARDOUS MATERIALS

A number of industries use raw materials, employ chemical and physical processes, produce chemical products, and generate waste, if improperly managed can lead to environmental releases. Five principal types of industries which use or produce hazardous materials or wastes are:

1. Organic Manufacturing Industry

Organic manufacturing includes the production of oils, fats, and waxes; the sugar and starch industries, fermentation industries; food and food by-product industries; fragrances, flavors and food additives industries; the pesticide, herbicide and rodenticide manufacturing industries; and the surface coating industries.

2. Inorganic Manufacturing Industry

Inorganic manufacturing includes the ceramic industries; Portland cement and glass industries, chloro-alkali industries; electrolytic industries; phosphorus, potassium, nitrogen, sulfur and sulfuric acid industries, hydrochloric and miscellaneous inorganic chemicals industries; the metal plating industrial; and the photographic products industries.

3. Steel Industry

Steel manufacturing includes steel mills, rolling mills, scrap metal operations, iron foundries, smelting and associated coke ovens.

4. Utilities/Energy Generation

The utilities industry includes fossil fuel power plants; energy, fuels, air conditioning, and refrigeration industries; nuclear reactors and radioisotope production and disposal; and the explosive industries.

5. Petrochemical Industry

This category includes refineries; petroleum processing; petrochemicals industries; plastic and resins production; and cyclic intermediate and dye industries.

HAZARDOUS MATERIAL

Generally a hazardous chemical or waste is a material that is potentially dangerous to human health or the environment. Occupational Safety and Health Agency (OHSA) defines hazardous chemicals in terms of health hazards and physical hazards (Woodside 1993).

Health hazard is assessed as either chronic or acute. In addition to these two classifications, there are specific health hazards which include the followings:

- Carcinogens
- Toxic chemicals
- Reproductive toxins
- Irritants
- Hepatotoxins (liver)
- Corrosive chemicals
- Neurotoxins (nervous system)
- Sensitizers
- Nephrotoxins (kidney)
- Agents that damage the blood, lungs, eyes, or skin

A chemical is defined as physical hazard if there is scientific evidence that it is a combustible liquid flammable, explosive, pyrophoric, or unstable (reactive). Additionally, a chemical is deemed hazardous if it is a compressed gas, an organic peroxide, or an oxidizer.

LEGISLATION ASPECT

1. Toxic Substances Control Act of 1976 (TSCA)

TSCA was enacted to regulate the introduction and use of new hazardous chemicals. Under TSCA regulations, industry must furnish data on the anticipated production, usage, and health effects of all new chemical substances and mixtures before they are manufactured for commercial distribution. TSCA also regulates the manufacture, processing, use, and disposal of all chemical substances by requiring the testing of potential harmful chemicals.

2. Resource Conservation and Recovery Act of 1976 (RCRA)

RCRA was promulgated to protect the quality of groundwater, surface water, the air, and the land from contamination by solid waste. It established the federal regulatory program for controlling hazardous waste and provide grants and technical assistance to the states to help improve their waste management techniques. It sets standards for the handling of hazardous wastes within a cradle-to-grave framework that originates with the generator and through handling, transporting, and treatment, and final disposal.

3. Emergency Planning and Community Right to Know Act of 1986 (EPCRA)

EPCRA was designed to help communities to prepare to respond in the event of a chemical emergency, and to increase the public's knowledge of the presence and threat of hazardous chemicals. It established a four parts program to:

- define emergency planning structures at State and local levels and develop local emergency response plans;
- require emergency notification of chemical release;
- require notification of chemical use, storage, and production activities; and
- report annual emissions

4. Hazardous Materials Transportation Act (HMTA) of 1975

This act regulates the transportation of hazardous materials. It gives the Department of Transportation the responsibility of regulating the packaging, container handling, labeling, vehicle placarding, and other safety aspects.

DESCRIPTION OF THE STUDY

The students will be provided with the following information:

- USGS Quadrangle maps (Raritan Quadrangle),
- Soil Survey information prepared by Soil Conservation Service (Somerset County).
- Types and quantities of hazardous materials and hazardous wastes to be used and manufactured by the facility.
- The manufacturing processes and land requirement.

EXPECTED OUTCOMES OF THE STUDY BY THE STUDENTS

The responsibility of the student teams includes the followings:

Select a site within the area specified by the instructor for the industry described in this course. Student should recognize that there is no perfect solution:

- Minimize the resultant cost of the facility.
- Minimize the environmental consequences of the site selected.
- The site selected should match the land area.
- Consideration of access to facilities and impact of transportation of hazardous materials.
- Availability of public utilities (power sources, water supply, waste treatment, etc.) in the areas of facilities.
- Evaluate the risk if chemical leaks and reaches the residential community.
- Evaluate the possible paths of pollution migration.

Write a report justifying the recommended site selection and comparing to at least two other possible sites in the specified region.

Each team presents a report to entire class and faculty instructor(s) as well as other department faculty. Other teams should challenge the presenting team in a professional manner.

PROJECT ASSESSMENT

Select three possible sites in the area of the study to be evaluated for their appropriateness as locations for a hazardous material manufacturing facility

Review the packet distributed by the instructor on the manufacturing process for such hazardous material(s) as background for the study.

Technical Information

1. The manufacturer will produce/process _____ lb/day of _____ . The area required for this manufacturing process is _____ acres. The following chemicals will be used as raw materials and solvent in this process _____. The following hazardous waste will be generated during the production _____ and will be treated by _____ (technology).
2. Prepare a Hazardous Substance Fact Sheet for the material used in the process, which should include the following information for each of the toxic materials: Hazard summary, identification, workplace exposure limits, how to determine if you are being exposed, ways of reducing exposure (health hazard information, workplace control and practices, personal protection equipment, and handling and storage)

Economics

1. Minimize cost of facility construction and general maintenance.
2. Minimize cost of hazardous substances/wastes handling, transportation, storage, and treatment.

3. Cost comparison of the, three sites selected.

Social - Political Issues

1. Review the site under consideration by the team for historic and archeological values. A review of the literature and visit to the local/regional historic preservation societies can be helpful in this regard.
2. Determine the route(s) to be taken by the trucks in transporting raw materials /products/waste to and from the industry. Characterize the impacts the community along the route(s) to be used. This would include the proximity to school, parks, residences, sensitive receptors, etc.

Environmental Issues

1. Utilizing the literature, determine the area of influence of the selected industry with regard to air emission, odor, etc. Utilizing these values and prevalent wind direction and magnitude in your area, determine the residences and facilities that will be impacted for the three sites under your review.
2. Review the local literature (US Dept. of Agriculture - Soil Service Maps) to determine if the sites contain lands with high water tables. If so determine if this may impact site selection.
3. Determine if any of your sites are in close proximity to local floodplains or wetlands. Consult local Flood Insurance Studies and national Wetland Inventory Maps.
4. Review topography at the sites reviewed with respect to impact on the plant design and operation.
5. Review sites with regard to habitat for threatened and endangered species. State and federal fish and game agencies can be of help in providing information in this area.
6. Determine the impacts of the plant on the aesthetics of the site and suggest possible improvement.

SUPPLEMENT TO ASSIGNMENT SHEET

- 1: The students need to learn that there is no perfect or correct solution to a design project. All sites have positive and negative impacts associated with their selection. Some sites have impacts that are so severe that they automatically cause their immediate rejection, e.g. if the site is located in a floodplane.
2. Each team conducts a field recon of the project area and selects three sites for their detailed study. Along with the recon, a photographic-video record is made for discussion with the instructor.
3. Starting from the sixth week, the instructors will meet individually with each group to assess their progress. Their project schedule is measured according to their schedule. Work turned in from the previous week is evaluated and returned to the teams.
4. Each team turns in a written report and orally presents the results of their study. During the presentation, the other teams challenge the conclusions drawn in a professional manner.

5. Grading will be based on class attendance and participation, assignments, oral presentation, and written report.
6. The final engineering report shall include, but not limited, the following:

Title Page Table of Contents and List of Illustrations Narrative - including, but not limited to:

Scope

Design Criteria (site selection consideration in terms of environmental restrictions, political constrains, and economic aspects)

Conclusions and Recommendations

Appendices (supporting computations, documents, location map, soil map, etc.)

The report must present its technical contents in a clear, direct, organized, and understandable manner. Technical competency and completeness should be demonstrated, and the specific format and presentation should be selected to best convey to the reader what is being recommended, and how and why these decision were reached.

The report must be 8 1/2 x 11" in size. All plans must be folded to 8 1/2 x 11" size.

7. Students are encouraged to use computer application programs for computations and reports (Word, Excel, etc.). A diskette with all computations and reports should be handed in with the final report.
8. The work required to successfully to complete the course requirements is demanding and unlike other courses to which you have been exposed in the past. A balanced effort is required throughout the semester since it is impossible to perform the required work in one or two weeks.

Partial List References for the Case Study

1. "Environmental Law Handbook", 13th Ed., Government Institutes, Inc., 1995.
2. Noble, G., "Siting Landfills and other LULUS", Technomic Publishing Co., Inc., Lancaster, PA, 1986.
3. Wentz, C. A. "Hazardous Waste Management", McGraw Hill Book Company, New York, NY, 1989.
4. Williams, E. A. and Massa, A. K., "Siting of Major Facilities", McGraw Hill Book Company, New York, NY, 1988.
5. Woodside, Gayle, "Hazardous Materials and Hazardous Waste Management: A Technical Guide", John Wiley and Sons, Inc. New York, NY, 1993.
6. "Means Building Construction Cost Data - 1996", R. S. Means Company, Inc., Kingston, MA, 1996.
7. New Jersey Department of Health, "Hazardous Substance Fact Sheet."
8. "Material Safety Data Sheets", Genium Publishing Corporation, Schenectady, New Jersey, 1990.
9. US Department of Agruculture, "Soil Survey of Somerset County", Dec. 1976.

Information regarding hazardous materials can be obtained from the following internet addresses:

1. <http://www.epa.gov/epahome/students.htm>
2. <http://www.chem.uky.edu/resources>
3. <http://www.fema.gov/fema/hazmat.html>
4. <http://www.smsu.edu/admin/hazard.htm>
5. <http://www.ps.uga.edu/hazmat/manual>
6. [gopher://atlas.chem.utah.edu/70/1/MSDS](http://atlas.chem.utah.edu/70/1/MSDS)

FE 102-008 Homework:
Week 1

1. How do Code of Federal Regulations (CFR) define the following terms:
 - (1) Hazardous Material (49CFR100)
 - (2) Hazardous Chemical (29CFR1910.1200)
 - (3) Hazardous Waste (40CFR261)

2. What is Material Safety Data Sheets (MSDS)? What information can be found in MSDS? Give one example.

3. Hazardous materials can be found in the following locations within the home: kitchen, bathroom, garage, and utility/laundry room. Look at the labels of the following household chemicals and list the hazardous or toxic chemical components.
 - (1) Toilet bowl cleaners
 - (2) Batteries
 - (3) Paints & thinners
 - (4) Herbicides
 - (5) Pool chemicals
 - (6) Fluorescent bulbs
 - (7) Radiator fluid

Hazardous Manufacturing Facility

- Organic Industry
- Inorganic Industry
- Steel Industry
- Utilities/Energy Generation
- Petrochemical Industry

Transportation Incidents

Mode	Accidents	Death	Injuries
Air	1,220	0	153
Highway	41,781	79	1,569
Railway	7,886	1	423
Water	83	1	35
Other	29	0	2
Total	50,999	81	2,182

Health Hazard - Chronic/Acute

- Irritants
- Carcinogens and suspect carcinogens
- Mutagens
- Teratogens

Legislation Aspect

- Toxic Substances Control Act of 1976
- Resources Conservation Recovery Act of 1976
- Emergency Planning and Community Right to Know Act of 1986
- Hazardous Materials Transportation Act (HMTA) of 1975

Toxic Substances Control Act

- To regulate the introduction and use of new hazardous chemicals.
- To regulate the manufacture, processing, use, and disposal of all chemical substances by requiring the testing of potential harmful chemicals.

Resource Conservation and Recovery Act

- To protect the quality of groundwater, surface water, the air, and the land from contamination by solid waste.
- It sets standards for the handling of hazardous wastes that originates with the generator and through handling, transporting, and treatment, and final disposal.

Emergency Planning and Community Right-to-Know Act

- To help communities to prepare to respond in the event of a chemical emergency
- To increase the public's knowledge of the presence and threat of hazardous chemicals.

Hazardous Materials Transportation Act

- To regulate the transportation of hazardous materials.

Hazardous Waste Materials

- Hazardous by definition
- Hazardous characteristics: ignitibility, corrosivity, reactivity, or toxicity

Hazardous by Definition

- **F waste:** hazardous waste from non-specific source
- **K waste:** hazardous waste from specific source
- **U/P waste:** commercial chemical product

Hazardous Characteristics

- Ignitibility
- corrosivity
- Reactivity
- Toxicity

Identification of Hazardous Materials

- Materials Safety Data Sheets (MSDS)
- 40 CFR 261 (Code of Federal Regulations, Title 40, Section 261)
- Radioactive Materials (10 CFR 20)
- Others

FE 102-008

Homework: Week 1

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 - (7) Radiator fluid

Lecture 2

Siting a Facility

SITING A FACILITY USING HAZARDOUS MATERIALS

PLANNING

Design, construction, and operation a facility is an engineering project. For this to be successful and efficiently operated, proper planning along with the sound engineering principles is essential in every phase of the project. Most operational problems can be prevented in the initial development stages. This is easier and more economical than correcting the defects after they occur.

Feasibility

The first phase of planning for a facility project concerns feasibility. It can be safely assumed that this facility is technically and physical practicable today; so the question becomes that of the economical and political feasibility of selecting a suitable site and meeting all of the expenses and restrictions associated with operating the site.

One important issue that has to be taken into account in the feasibility analysis is public opposition. According to the environmental regulations, public hearings have to be held to address the concerns of the community. Often, a proposed developer will have problems with the site's neighbors. There often exists a "not in my backyard" (NIMBY) syndrome among the public. Citizens opposing the site will seek to prevent site implementation by testifying against the site at public hearings and by filing law suits directly seeking to overturn or prevent regulatory agency approvals.

Factors that most affect the economic feasibility of a project are:

1. the availability of a suitable site at reasonable cost,
2. the volume of raw materials and wastes produced,
3. the distance that materials or waste must be transported,
4. the cost of equipment and local labor wage rates,

Planning process for a new facility can be divided into the following steps:

1. Establish goals and gather political support.
2. Identify facility design basis and need.
3. Identify potential sites within the region
4. Select and evaluate in detail the most desirable sites.
5. Select best site for development.
6. Obtain regulatory approval of site.

Funding

The cost of developing a facility is quite high. Funds for the initial investigation, preparation of the report, construction, and so on must be obtained for planning purposes.

A proper estimate for each stage of the proposal preparation and the flow of necessary funds must be studied. Discussion regarding the availability of funds with the person(s) dealing with the budget is essential. Funding is a very critical issue for facilities owned publicly or by giant corporation.

SITE SELECTION CONSIDERATIONS

Proper selection of a suitable site is essential in order to avoid problems that may occur later. Site selection should consider the local geotechnical hydro-geological and the climatic conditions.

DATA COLLECTION

Usually, several sites may be considered for locating the facility. To aid in final selection, several maps and other information need to be studied to collect data within the search radius. The following information is needed: topographic maps, soil maps, land use plans, and transportation plans. Brief discussion of each of these items follows.

Topographic Maps

The topography of the area indicates low and high areas, natural surface water drainage pattern, streams, and wetlands. A topographic map will help find sites that are not on natural surface water drains or within a wetland. USGS Quadrangle maps will be useful for this purpose.

Soil maps

These maps, primarily meant for agricultural use, will show the types of soil near the surface. Although these maps are partly useful for siting of natural attenuation type facilities, they have very little use for containment type facilities. Type of soil will affect degree of attenuation and the need for liners. Surficial soils with lower permeability are preferable for siting. Soil Survey published by the US Department of Agriculture should be available in for local library.

Land Use Plans

These plans are useful in delineating areas with definite zoning restrictions. There may be restrictions on the use of agricultural land or on the use of forest land for wastewater treatment facility purposes. These maps are used to delineate possible sites that are sufficiently away from localities and to satisfy zoning criteria within the search area.

Transportation Maps

These maps, which indicate road and railways and locations of airports, are used to determine the transportation needs in developing a site. Allowable axle loads on roads leading to a potential site must be studied to find out whether any road improvement will be necessary.

Water Use Plan

Once potential areas are delineated the water use in those areas must be investigated. A plan indicating the following items should be developed: private and public wells indicating the capacity of each well, major and minor drinking water supply line(s), water intake jetty located on surface water bodies, and open wells.

Flood Plain Maps

These maps are used to delineate areas that are within a 100 year flood plain. Siting of facilities must be avoided with the flood plains of major rivers. A facility may be constructed near an intermittent stream if additional protection measures (e.g., levee) are implemented.

Geological Maps

These maps indicate geological features and are very important for glaciated regions. A general idea about soil type can be developed from a geologic map. These maps are also very helpful in identifying clay borrow sources. In nonglaciated regions the maps may be used to identify predominantly sandy or clay areas.

Aerial photographs

Aerial photographs may not exist for the entire search area. Once a list of potential site is developed aerial photographs or preferably a photogrammetric survey of each of the potential sites may prove to be extremely helpful. Surface feature such as small lakes, intermittent stream beds, and current land use, which may not have been identified in earlier map searches, can be easily identified using aerial photographs.

Seismic Hazard Maps

If the site is within a seismic impact zone, data regarding design earthquake ground motions such as maximum horizontal velocity and maximum horizontal acceleration have to be considered. Seismic hazard maps published by appropriate government organizations may provide the required information.

Considerations to Mitigate Environmental Damage

To prevent environmental damage, the following site conditions have to be avoided for selection as facility sites unless the suitability of the site can be adequately demonstrated.

Airport area

If new, expanding and existing units are located near airport runway, the owner and/or operator of the facility must show that the facility does not pose a bird hazard to aircraft. New, expanding and existing facilities must be located at least 10,000 feet (3048 m) from airport runways utilized by jet aircraft or at least 500 feet (1524 m) from airport runways used by piston/propeller aircraft, unless it can be demonstrated that a hazard from birds does not exist.

Wetlands

New units and expansions should not be located in wetlands unless the owner and/or operator can demonstrate that the proposed facility will not influence the environment, will not degrade the wetland, and an alternative is not practically acceptable, in which case suitable and prescribed mitigatory measures are undertaken.

Fault area

New units and expansions should not be located within 200 feet of a fault that has had displacement in Holocene time unless the owner or operator can prove that an alternative setback distance of less than 200 feet will prevent damage to the structural integrity of the wastewater treatment facility.

Seismic area

New units and expansion units should not be located in seismic impact zones which are defined as lithified areas having greater than 10% possibility of a maximum horizontal acceleration of 0.01g (where g refers to the natural gravitational acceleration of the earth) in 250 years, unless otherwise demonstrated to the state.

Floodplains

New units and expansions of waste disposal facilities must not be located in the 100 year flood plain, nor can they interfere with the 100 year flood event or pose a threat to human health and environment.

Lake, pond or river

In case if a facility is to be located within 300 feet (100 m) of any navigable lake, pond, river or stream, the owner/operator of the wastewater treatment facility may have to demonstrate to the regulatory agency that there will be no concerns regarding runoff

waste contact water. Otherwise, a surface water monitoring program may have to be established.

Highway or Public Parks

Siting of facilities within 300 feet (100 m) of a highway or a park may require special provisions such as use of trees or berms to screen the site and/or a high fence and a secure gate to restrict easy access.

Critical Habitat Area

No waste disposal facility may be constructed within a critical habitat area. A critical habitat area is defined as one in which one or more endangered species live. It is sometimes difficult to define a critical habitat area. If in doubt, the regulatory agency should be consulted.

Unstable Areas

New, expanding and existing units must not be placed in unstable areas, which are defined as areas of potential landslide. All components of the facility must remain intact and be protective of human health and environment.

Water Table

An important parameter to be looked at is water table. It is undesirable to have high groundwater table in a treatment facility.

PLANNING ASSOCIATED WITH SITE DEVELOPMENT

In order to ensure that the public has good reason for accepting a new facility, adequate engineering planning is required. The first step is to survey the proposed site with the assistance of competent professionals. Evaluation maps should be prepared based on the survey. The type of facility best suited for the particular location under examination should be selected. Recommendations should be offered as to construction and location of all-weather access roads. Depths of fill at various locations on the site should be tentatively determined. If on-site materials are not suitable for construction, off site sources have to be considered. By providing suitable culverts, proper drainage throughout the site can be ensured.

Administration buildings, utilities, water supply for fire and dust control should be planned. A logical sequence of operations should be developed by the engineer before the construction, and is to be updated along with site specifications at various stages of completion. This could be accomplished with the use of bar charts and CPM techniques. Contingency operations for equipment or weather problems should be prepared.

An ideal facility will meet the following requirement:

1. Conforms with the land use planning of the area
2. Easily accessible in any weather to vehicles during the operation of the wastewater treatment facility and
3. Safeguards against potential surface and ground-water pollution

Subsurface Investigations

A properly conducted subsurface exploration program is necessary for site selection. This will consist of a combination of borings, test pits, and other field testing methods, and laboratory tests. It is essential to obtain information regarding stratigraphic profiles of soils. Samples will have to be obtained from all soil types, especially the natural subbase soils, so that tests can be conducted to determine the strength, stability and settlement characteristics. Suitability of subsurface materials for construction has to be looked into also. The number of borings and the depth of each boring should be enough to accomplish the objective and hence will be site-specific.

Seismic Hazard Investigations

In sites located within the seismic impact zone, additional investigations to find seismic design parameters should be undertaken. The two mechanisms that can cause damage to a facility are: 1. strong ground motion and 2. displacement of the ground below or adjacent to the facility due to movement along a fault. The strong ground motion may cause liquefaction of subsoil leading to substantial settlement of the facility base.

It is recommended that investigations regarding the existence of faults below a proposed site should be undertaken for sites located within a seismic impact zone. Such investigations of the existence of faults are costly. A stepped approach may be used, which would eliminate unnecessary cost and time required for the investigation. The suggested steps are:

1. Review of the published seismic data.
2. Review of subsurface exploration data to determine if a fault exists.
3. A geologic reconnaissance survey of the area.
4. Review of the regional seismological and geological history.
5. Geophysical investigations utilizing one or more of the following: seismic refraction/reflection, gravimetric survey, and magnetic survey.
6. Angular borings. and
7. Test trenching to search for evidence of recent faulting.

Usually the first four of the above steps will provide adequate information regarding the possibility of the existence of a fault. Steps 5 through 7 are undertaken only when strong evidence regarding the existence of fault is found in the first four steps. Since it will

be very expensive to perform all these investigation, it is preferable to avoid locating wastewater treatment facilities in seismic impact zones.

Lecture 3
Aspirin Manufacturing Industry

Aspirin Manufacturing Industry

Aspirin is a non-prescription drug commonly used as an analgesic agent. Over 80 billion tablets were sold in the United States 1992 alone. The aspirin manufacturing industry is selected for the study. Site selection and development for such a manufacturing facility is considered for this engineering design course. This section outlines the background, history, and the chemical processes involved in the production of Aspirin.

I. Background

Other than being used as an analgesic agent, Aspirin is also used as a pain reliever; antipyretic, or fever reducer; and anti-inflammatory agent. Its activity is based on chemicals called salicylates, originally derived from willow and other plants. Modern aspirin- acetylsalicylic acid- was synthesized in a laboratory in the late nineteenth century and introduced into wide spread medical use in the United States in 1899.

Aspirin is most effective in relieving slight to moderately severe pain, particularly headaches, muscle aches, and joint pains. Because it suppresses inflammatory processes while relieving pain, it is still the treatment of choice for arthritis and related disorders. Aspirin reduces fever increasing blood flow to the surface, thereby promoting sweating and heat loss from the body. In recent years it has been used as a prevention against stroke and heart attacks because of its ability to thin blood.

Aspirin is considered a relatively safe drug. Its major drawback is its ability to irritate the lining of the stomach and cause bleeding. In large doses aspirin is toxic, causing kidney damage and in severe cases, death.

II. History

In 1886, two Alsatian interns, Drs. Kahn and Hepp ordered naphthalene, from a nearby pharmacist. This substance did not have the effect they were looking for, but it did lower the patient's fever. They soon found out that their order was mixed up. They had received acetanilid, a coal and tar derivative that was never given to humans before.

At the time there were only three compounds known to have the same fever reducing effect. They were salicylic acid, quinine, and antipyrine. Salicylic acid was a modern version of an herbal potion made from the bark of the white willow. Its properties were firmly established by the Reverend Edward Stone. The active ingredient in willow bark turned out to be a bitter-tasting yellow crystal now called salicin. French chemists later synthesized a simpler version, salicylic acid.

Quinine had been used to treat malaria since the seventeenth century. It was an excellent antipyretic but was extremely hard to synthesize. This drove its cost up to an unsatisfactory level.

The newest of the three was antiphrine. It was discovered by Ludwig Knorr in 1883. It was also the drug rediscovered by Kahn and Hepp. As a result, they were unable to patent acetanilid. So, they renamed it Antifebrin and began to promote the drug under its new name.

Carl Duisberg became the supervisor of Bayer's research facility the year of Antifebrin's introduction. When he saw its success he told his research staff to develop a process that would turn the waste para-nitrophenol into acetanilid. He called this new drug Phenacetin.

Duisberg's accomplishment was revolutionary. For the first time a drug had been conceived, developed, tested, and marketed by a private company. This was the beginning of the modern drug industry, the marriage of science and business.

By 1903 Bayer had grown enormously. As a result Carl Duisberg began looking for a site in America to build a new factory. The construction of this plant in Rensselaer, New York was the foundation for the "great aspirin wars."

Aspirin makers have been slugging it out over the same ground ever since. They have reasons for this, in America alone 2.7 billion dollars worth of aspirin were sold in 1990. This fierce competition has brought about many changes to aspirin. Some companies have added ingredients such as caffeine and antacids, while others have added special coatings. However, all of these companies still use the same active ingredient that was invented in 1897, acetylsalicylic acid. None of these new aspirins have been proven to be any more effective than the original.

III. Hazardous Materials in Manufacturing Processes

During the production of aspirin, a few raw materials can become a major threat to the health of those working with these chemicals. Phenol, salicylic acid, sodium hydroxide, sodium sulfate, sulfuric acid, toluene, acetic anhydride, and the final product of aspirin can all be considered a hazardous material. Student will be asked to look for their hazardous properties from Material Safety Data Sheets (MSDS). A sample of MSDS is shown in Appendix.

Phenol imposes a serious health hazard. It is moderately flammable, has a slight reactivity, and is very corrosive to contact with human touch. Upon contact it can cause severe burns. If swallowed, or inhaled it can cause death. It has a threshold limit value of 5 ppm, a short term exposure limit of 10 ppm, and a permissible exposure limit of 5 ppm. The major organs affected by phenol are the kidneys, liver and skin. Eye, skin, and breathing equipment should always be used when handling phenol.

Salicylic acid is a slight health hazard. It is slightly flammable, with a slight reactivity, and a moderate danger to contact. It causes irritation on contact, and is

salicylic acid. If overexposure occurs, blindness, nausea, and upper respiratory infection may occur. It targets the eyes and skin.

Sodium hydroxide is a severe health hazard. It is moderately reactive, with an extreme danger to contact. A vent hood, goggles, lab coat, and gloves should always be used when working with sodium hydroxide. It is classified as a poison, and causes severe burns. It has a threshold limit of less than 1 ppm, and a permissible exposure limit of less than 1 ppm. It targets the eyes, skin and respiratory systems. In case of ingestion, never induce vomiting.

Sodium sulfate only causes a slight problem when in contact with the skin. Safety glasses and a lab coat are always recommended for use while working with sodium sulfate. It only causes slight irritation of the skin.

Sulfuric acid is a severe health hazard. It is a severe reactive chemical, with an extreme hazard to contact. While working with sulfuric acid, a lab coat, goggles and shield, an apron, a vent hood, and gloves are always recommended. It is classified as a poison and can cause severe burns. Concentrated Sulfuric Acid reacts very violently with water. The threshold limit value is less than 1 ppm, with a permissible exposure limit of less than 1 ppm. It targets the skin, eyes, respiratory system and the teeth.

Toluene is a moderate health hazard. It is severely flammable, with a slight contact hazard. Safety glass, a lab coat, a vent hood, and a class b extinguisher are always recommended while working with toluene. Toluene causes irritation and may be fatal if swallowed. Toluene should be kept away from heat, fire, and sparks. Water may be ineffective in putting out the fire of toluene. Alcohol foam, carbon dioxide or a dry foam must be used. It has a threshold limit value of 100 ppm, with a short-term exposure limit of 150 ppm, with a permissible exposure limit of 200 ppm. Upon ingestion or inhalation it may cause a headache as well as nausea, vomiting and gastrointestinal irritation. It targets the central nervous system, liver, kidneys, and the skin.

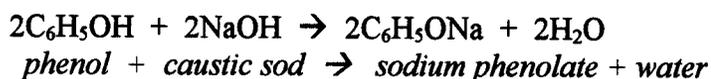
Acetic anhydride is a severe health hazard. It has a moderate flammability, a moderate reactivity, and a severe contact hazard. A lab coat, goggles, vent hood, proper gloves, and a class b extinguisher are needed while working with acetic anhydride. It is classified as a poison, is easily combustible, and causes severe burns. Water is ineffective against acetic anhydride. It has a threshold limit value of 5 ppm, a permissible exposure limit of 5 ppm. Upon contact will cause severe burns in the mouth and stomach. It will target the respiratory system, eyes, skin and teeth.

Finally, the finished product aspirin has a slight health hazard. It is slightly flammable with a slight contact hazard. A lab coat, and goggles are always recommended when working with aspirin because of possible skin irritation. It has a threshold limit value of less than 1 ppm. The dust may even irritate the eyes.

IV. Process of Manufacturing

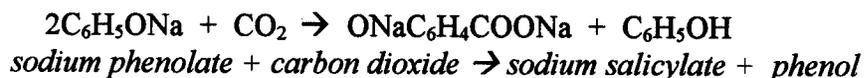
The chemical reaction to produce Aspirin (acetyl salicylic acid) is a result of a two step process involving numerous reactions of materials. The processes are shown in Figures 1 to 4. Figures 1 and 2 illustrate the raw materials used and chemicals produced. Figures 3 and 4 give the details of step-by-step manufacturing process. The equipment used and processes involved are described in the following paragraphs:

1. Mixer: The manufacturing of Aspirin begins when phenol is mixed with caustic soda (sodium hydroxide), sodium phenolate is the product in this process.

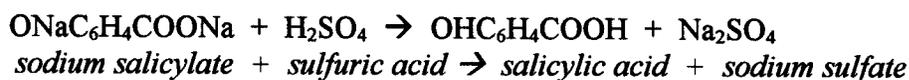


2. Autoclave: The sodium phenolate is dried in an autoclave to finely divided powder. The autoclave is a revolving, heated ball mill. It operates under a vacuum and a temperature of 130⁰ C. Water is removed from the process.

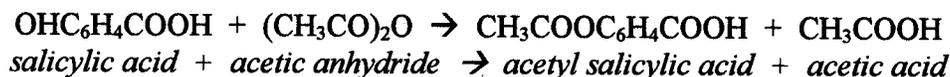
When drying the sodium phenolate is complete, carbon dioxide gas is introduced under a pressure of 700kPa and a temperature of 100⁰ C. Sodium phenol carbonate is formed and this in turn reacts to sodium salicylate. Phenol is regenerated and recovered for recycle.

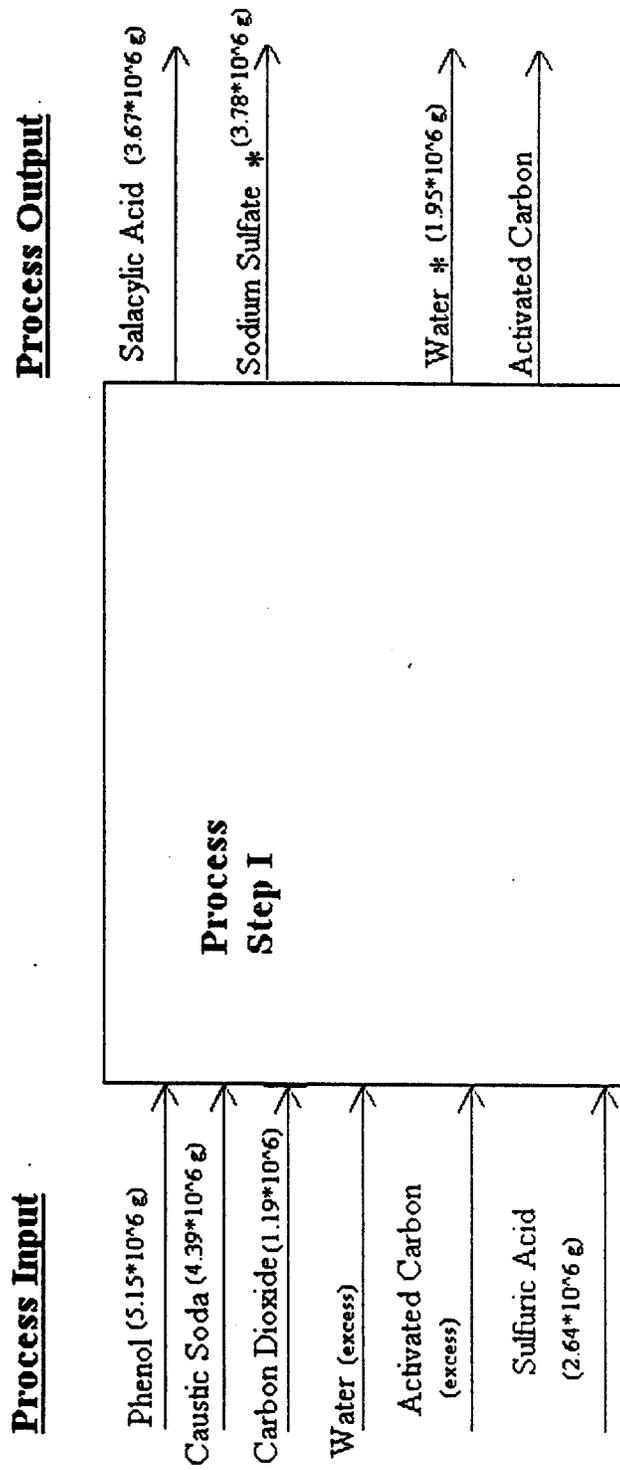


3. Dissolver: Water dissolves the sodium salicylate and activated carbon is added to remove color by absorption. The solid activated carbon is removed in a filter, reactivated and recycled. .
4. Precipitator: The sodium salicylate solution is mixed with sulfuric acid which precipitates the salicylic acid.



5. Centrifuges: The precipitated salicylic acid is removed from the sodium sulfate solution and sent to another drier.
6. Drier: The salicylic acid is purified by sublimation sent to packing and finally sold.
7. Reactor: The salicylic acid is mixed with toluene and acetic anhydride and refluxed at 88 - 92⁰C for approximately twenty hours.





* This product contributes to the waste stream

Figure 1 Manufacturing of Aspirin: Step I - Production of Salicylic Acid

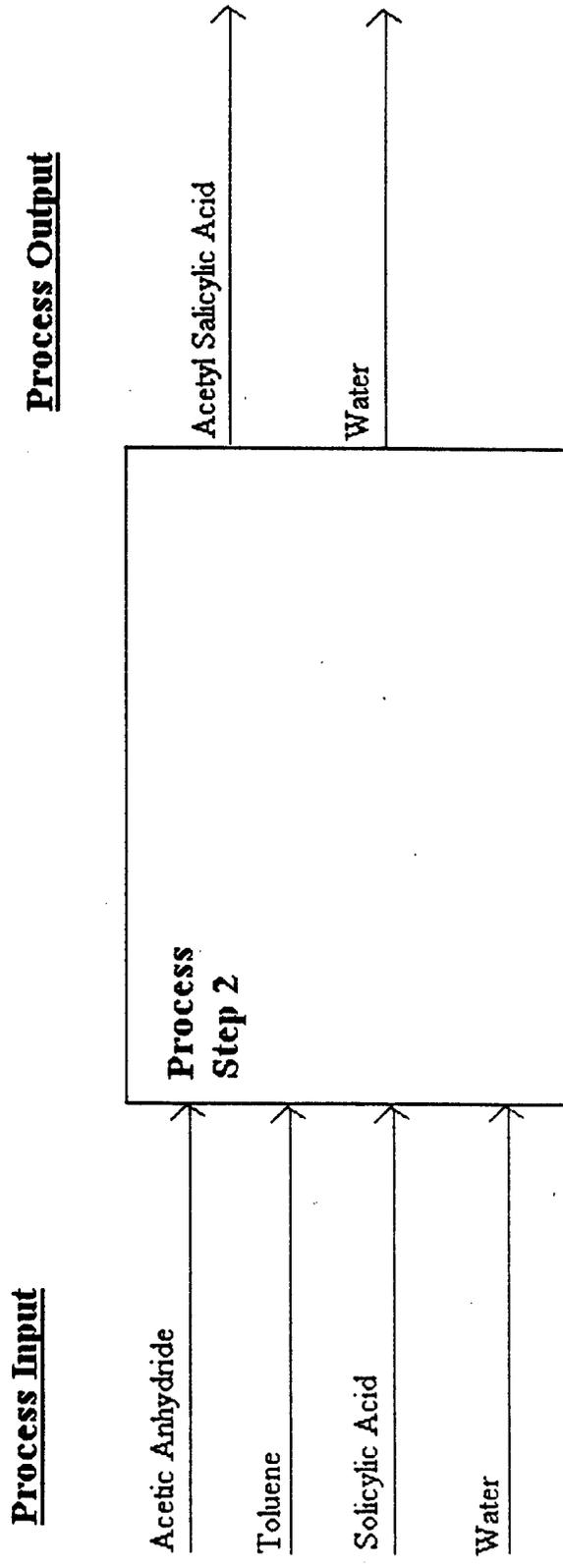


Figure 2 Manufacturing of Aspirin: Step II - Production of Acetylsalicylic Acid

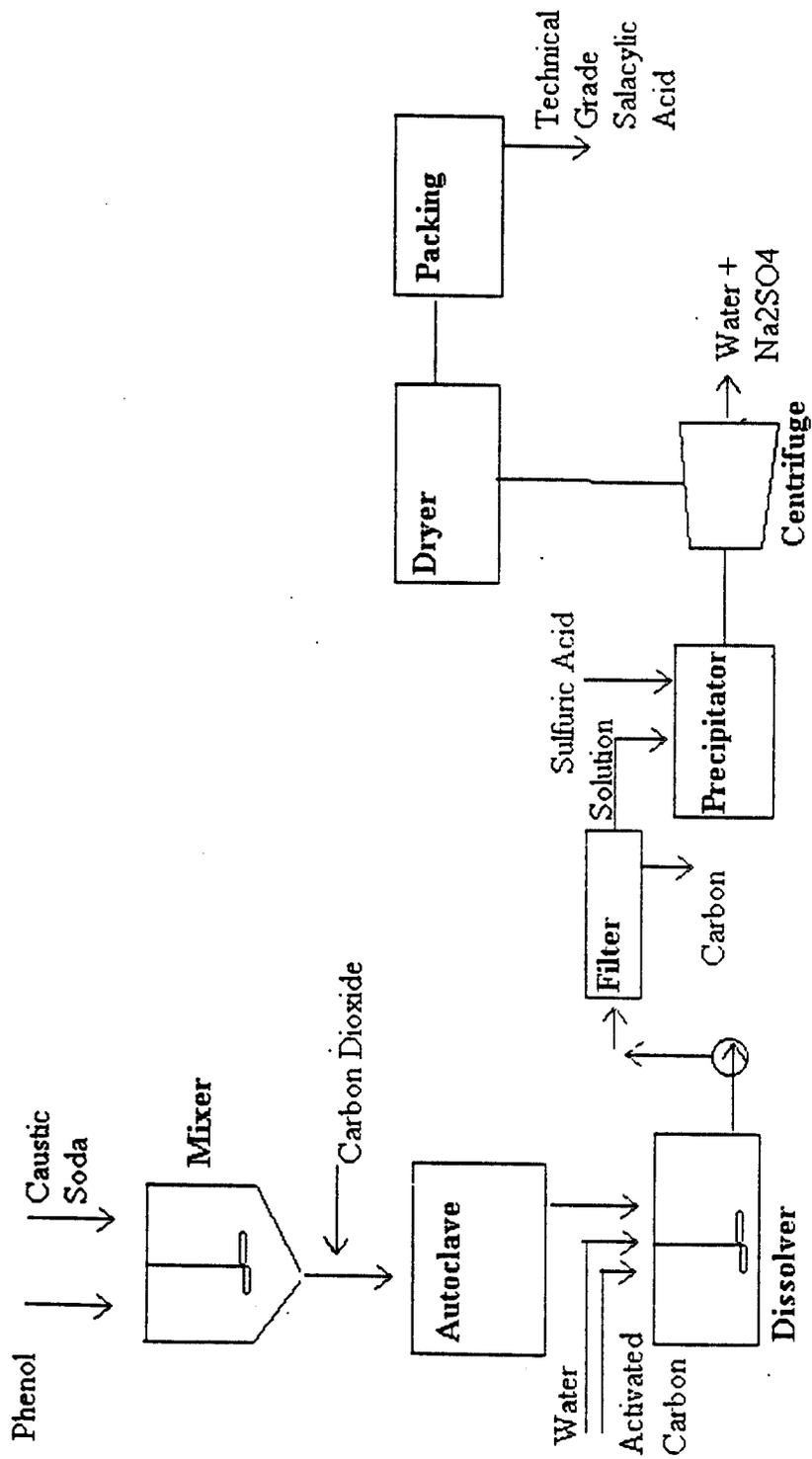
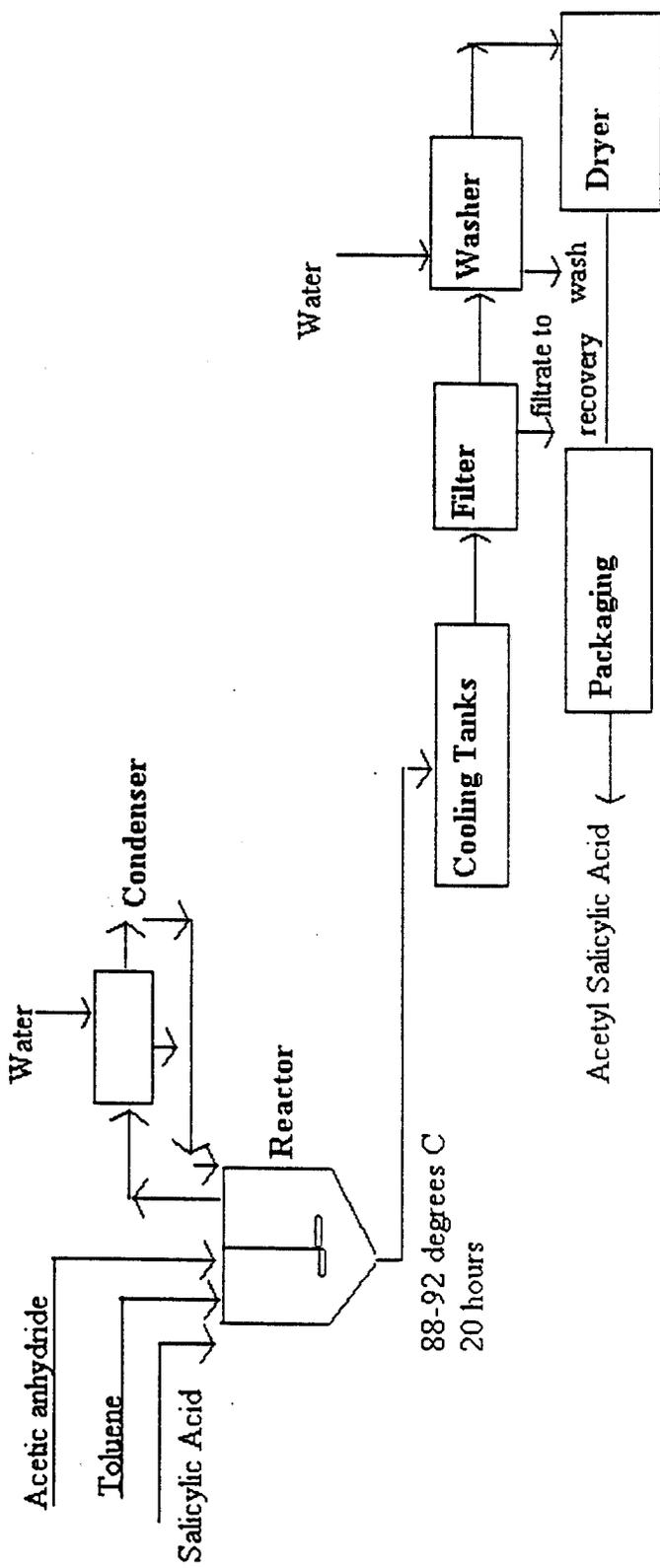


Figure 3 Manufacturing Process of Aspirin: Step 1 - Production of Salicylic Acid



**Figure 4 Manufacturing Process of Aspirin:
Step II - Production of Acetylsalicylic Acid**

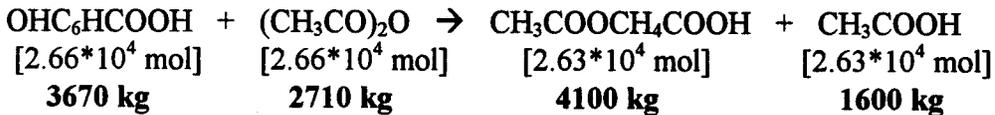
salicylic acid + acetic anhydride 4 acetylsalicylic acid + acetic acid

V. Material Balance

The rate of production for our facility is assumed to be 4100 kg of Aspirin. This figure was calculated by assuming that the company will have a 5% market share in the year 2007, which is based calculated U.S. and Aspirin demographics. The values were calculated by stoichiometry of the chemical equations involved in the process. The calculation starts by first calculating the moles of acetylsalicylic acid and it is assumed that $2.63 \cdot 10^4$ kg mol will be produced in one day. The calculation is then worked backwards through the chemical processes. We further assume that a 1 percent molar loss for each step in the two step process.

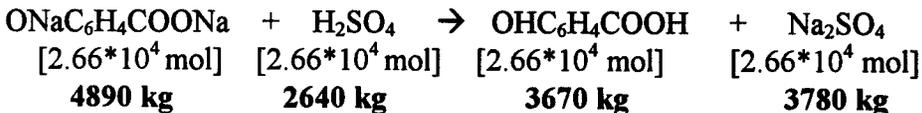
1. Step Two

Reaction:

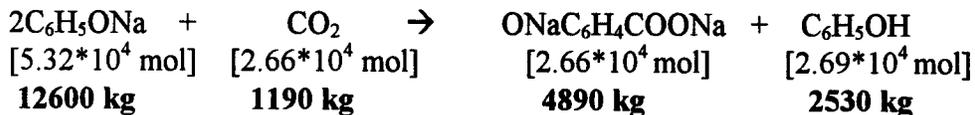


2. Step One

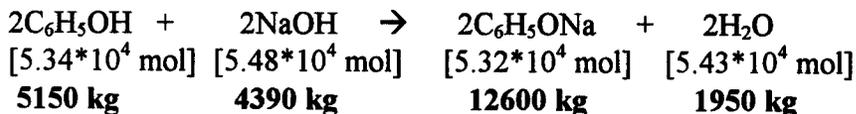
Reaction 3:



Reaction 2:



Reaction 1:



VI. Pollution Prevention and Treatment

There are wastes produced during the manufacturing processes that require attention.

Two waste products are produced in step I, activated carbon and sodium sulfate are produced. Activated carbon can be regenerated through heat treatment. Sodium sulfate can be collected and be sold. Phenol may also be present and it can be recovered and treated, or recycled. A wastewater treatment facility on site can be installed for the phenol wastewater treatment.

Problem

1. Develop Material Safety Data Sheets (MSDS) for all chemical reactants and products in the manufacture of Aspirin.
2. Determine the size of the production facility through the determination of growth of U. S. population, growth of U. S. Aspirin production, the need of Aspirin in year 2007, and the share of Aspirin market can be captured.
3. Determine the quantities of all raw materials needed and all by-products formed. Assume 100 percent conversion in each step and a process yield of 95% in each step.
4. Specify the waste streams, the quantities, and suggest a method of disposal.

References

1. Bureau of the Census, U. S. Department of Commerce, "Population 1900-1990; Center of Population", 1992, World Almanac.
2. "Endangered and Threatened Wildlife of New Jersey", 1996, New Jersey State Gov., Internet address: <http://www.state.nj.us>.
3. Flieger, K. "Americas 80 Billion Aspirin Habit", 1994, Medical Sciences Bulletin. Internet address: <http://phamiinfo.com/cgi-bin/>
4. Mann, Charles C. and Plummer, Mark L., "The Aspirin Wars", 1993, Harvard Business School Press, Boston, MA.
5. "Material Safety Data Sheets", 1996, University of Utah, Internet address: <gopher://gopher.chem.utah.edu/I1/MSDS>.

Lecture 4
Soil Conditions and Cost Estimate

Soil Conditions

I. Soil and Rock Investigations

The designer of a steel structure can not proceed without knowing the physical properties of the soil. The soil and rock formations under the structure are just as much a part of the structural system as the steel structure. However, whereas designers can control the character of the man-made materials, they have little control over the character of the soil and rock. Therefore, either the design must be adapted to the site conditions or else the site conditions must be improved. In either case it is imperative that these conditions be evaluated accurately.

A complete investigation of underground conditions includes the following points:

1. Nature of the deposits (geology, recent history of filling, excavation, and flooding)
2. Depth, thickness, lateral extent, elevations, and composition of each soil and rock stratum.
3. Groundwater elevations and their differences across the site.
4. The engineering properties of the soil and rock strata that affect the performance of the structure.

An investigation consists of three steps:

1. Reconnaissance: To determine the geology of the formations and to estimate the soil, rock, and water conditions through geologic study and site inspection,
2. Exploratory investigation: To determine the depth, thickness, and composition of the soils and rocks, the level of groundwater, and to estimate the engineering properties of the materials through soil boring and sampling.
3. Intensive investigation: To secure quantitative data on critical strata from which design computation can be made.

An examination of the site and the adjacent areas will reveal much valuable information. The topography, drainage pattern, erosion pattern, vegetation, and land use reflect the underground conditions, particularly the structure and texture of the soil and rock. Highway and railroad cuts and stream banks often disclose the cross section of the formations and indicate the depth of rock. Outcrops of rock or areas of gravel and boulders may indicate the presence of dikes and more resistant strata. Groundwater conditions are often reflected in the presence of seeps, springs, and the type of vegetation.

II. Use of Foundation

1. **Composition of Soil:** By definition, soils include all unconsolidated materials which are composed of many different ingredients in all three states - solids, liquid, and gases. The same applies to many rocks.
2. **Engineering Soil Classification:** Textural classifications group soils by their grain size characteristics. The gravel and large sizes are disregarded and the particles finer than 2 mm in diameter are divided into three groups, sand sizes, silt sizes, and clay sizes. The soils are then grouped by the percentage of each of these three components. Clayey soils are classified by plasticity characteristics which are based on the interaction of clay and water.
3. **Bearing Capacity** The bearing capacity of a soil is the ability of the soil to carry a load without failure within the soil. It is analogous to the ability of a beam to carry a load without breaking.

The foundation is the supporting part of a structure. The term is usually restricted to the structural member that transmits the superstructure load to the earth, but in a large sense it includes the soil and rock below. The design depends on the characteristics of both the structure and the soil and rock. There are two types of foundations:

1. **Shallow foundation:** Footing and mats are common used. A footing is an enlargement of a column or wall in order to reduce the pressure on the soil to maximum allowable. A-mat is a combined footing supporting multiple structural elements not located in the same line.
2. **Deep foundation:** Piles and Piers (Caisson) foundation are used. Piles are used in many ways. Bearing piles that support foundation loads by transferring the load of the structure through soft strata into stronger, incompressible soils or rock below. Friction piles transfer load to surrounding soil by friction or adhesion. Tension piles are used to resist upward forces. Laterally loaded piles support loads applied perpendicular to the axis of the pile in foundations subject to horizontal forces. The pier foundation is a relatively large, deep foundation. Its function is to transfer a foundation load through soft soil to hard soil or rock or to transfer a load through soils that may be scoured away by rivers or tidal currents.

III. Effect of Groundwater

Groundwater is a factor to be considered in several ways. First, excavation below the groundwater level is expensive and often hazardous because upward seepage loosens sands and tends to create a quick condition, and water standing over exposed clays softens them. Second, when the groundwater level is above the lowest level floor, seepage into the structure and hydrostatic uplift become serious problems. Third, changes in the elevation of the water table have caused much trouble such as building settlement and decreasing of soil strength.

IV. Hazardous Waste Contaminated Sites

There are over 100 New Jersey Superfund sites on the National Priorities List at the end of 1988. Remediation Investigation and Feasibility Studies were conducted on some of these sites. In addition, there are more small sites with less contamination and were not on the list. NJ Department of Environmental Protection has established an element of community relations activities which is called the Land Information Program. It provides information concerning hazardous waste sites to prospective home buyers, realtors, banks, and other public agencies. It can be reached by calling (609)633-2325.

References:

1. Sowers, George F., :Introductory Soil Mechanics and Foundations: Geotechnical Engineering, 4th Ed., MacMillan Publishing Co., Inc., New York, 1979.
2. "The BOCA Basic National Building Code/1984", 9th Ed., Building Official & Code Administrators International, Inc. Country Club Hills, Illinois, 1986.

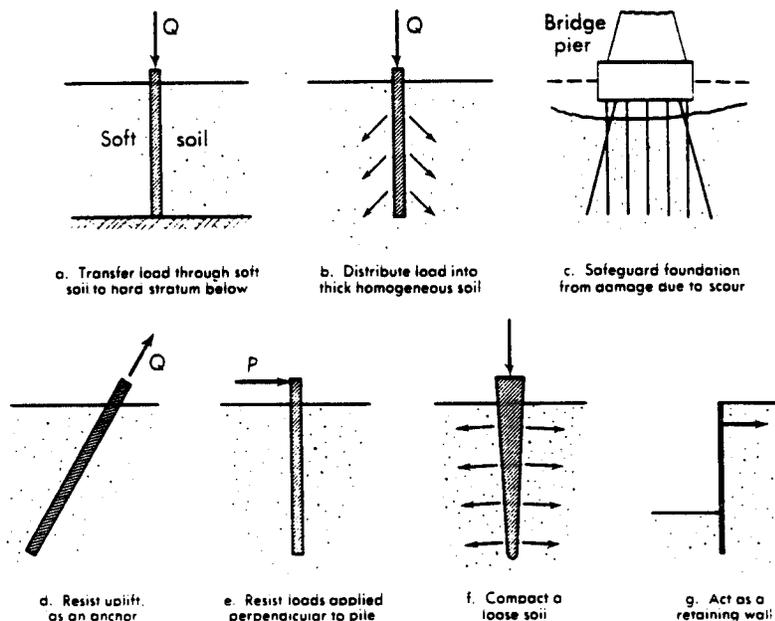


Figure 11.1 Uses of piles.

ARTICLE 10

FOUNDATION SYSTEMS

Table 1001
PRESUMPTIVE SURFACE BEARING VALUES OF FOUNDATION MATERIALS

Class of material	Tons per square foot
1. Massive crystalline bedrock including granite, diorite, gneiss, trap rock, hard limestone and dolomite	100
2. Foliated rock including bedded limestone, schist and slate in sound condition	40
3. Sedimentary rock including hard shales, sandstones, and thoroughly-cemented conglomerates	25
4. Soft or broken bedrock (excluding shale), and soft limestone	10
5. Compacted, partially cemented gravels, and sand and hardpan overlying rock	10
6. Gravel and sand gravel mixtures	6
7. Loose gravel, hard dry clay, compact coarse sand, and soft shales	4
8. Loose, coarse sand and sand-gravel mixtures and compact fine sand (confined)	3
9. Loose medium sand (confined), stiff clay	2
10. Soft broken shale, soft clay	1.5

Note a. 1 ton per square foot = 9765 kg/m².

SECTION 1000.0 GENERAL

1000.1 Scope: The provisions of this article shall control the foundation design and construction of all buildings and structures hereafter erected to insure adequate strength of all parts thereof for the safe support of all superimposed live and special loads, in addition to their own dead load, without exceeding the allowable stresses or design capabilities.

SECTION 1001.0 BEARING VALUE OF SOILS

1001.1 Soil analysis: All applications for permits for the construction of new buildings or structures, and for the alteration of permanent structures which require changes in foundation loads and distribution shall be accompanied by a statement describing the soil in the ultimate bearing strata, including sufficient records and data to establish its character, nature and loadbearing capacity. Such records shall be certified by a licensed professional engineer or a licensed architect.

1001.2 Satisfactory foundation materials: Satisfactory bearing materials for spread footings shall include ledge rock on its natural bed; natural deposits of sand, gravel or firm clay, or a combination of such materials, provided they do not overlie an appreciable amount of peat, organic silt, soft clay or other objectionable materials.

1001.3 Presumptive bearing values: Except when determined by field loading tests or as otherwise provided herein, the maximum allowable pressure on supporting soils under spread footings at or near the surface shall not exceed the values specified in Table 1001. Presumptive bearing values shall apply to all materials of similar physical characteristics and disposition. Surface values shall be adjusted for deep footings, and for the bearing strata under piles, as provided in this code. When foundation piles are driven to penetrate into sound rock, the allowable bearing values in Table 1001 may be increased as prescribed in Section 1021.0.

1001.4 Lightweight structures: Mud, organic silt, or unprepared fill shall be assumed not to have presumptive bearing capacity unless approved by test, except where the bearing capacity is deemed adequate by the building official for the support of lightweight and temporary structures.

SECTION 1002.0 FOUNDATION INVESTIGATIONS

1002.1 When required: In the absence of satisfactory data from immediately adjacent areas, the owner or applicant shall make borings, test pits, or other soil investigations at such locations and to sufficient depths of the bearing materials to the satisfaction of the building official. For all buildings which are more than three stories or 40 feet (12192 mm) in height, and whenever it is proposed to use float, mat or any type of deep foundation, there shall be at least one exploratory boring to rock or to an adequate depth below the loadbearing strata for every 2,500 square feet (232.5 m²) of built-over area, and such additional tests that the building official may direct. When the safe sustaining power of the soil is in doubt, or superior bearing value than specified in this code is claimed, the building official shall direct that the necessary borings or tests be made.

1002.2 Soil samples: Samples of the strata penetrated in test borings or test pits, representing the natural disposition and conditions at the site, shall be available for examination by the building official. Wash or bucket samples shall not be approved.

1002.3 Varying soil values: When test borings indicate nonuniformity of bearing materials, a sufficient number of additional borings shall be made to establish strata levels of equal bearing capacity.

1002.4 Cost of tests: Costs of soil investigations shall be at the expense of the owner.

Engineering Cost Estimate

1. Engineering Cost

The cost of an engineering project can be divided into three parts: initial investment, construction costs, operation and maintenance cost.

Initial investment is the costs spent from the point of the beginning of the plan of a new facility to the time the construction permit is received. It includes the following:

- Feasibility analysis
- Legal services
- Financial services
- Engineering investigation
- Environmental assessment
- Engineering design
- Land purchase and
- Other fees

Costs of some items can be expressed as percentages of total construction costs based on engineering experience: For instance, engineering investigation fees, environmental impact analyses and engineering design fees can be about 10% of construction costs. Some items may vary from case to case. For example, feasibility analysis is related to the size of the project and types of investigation conducted.

Construction costs usually include the following cost:

- Site preparation
- Building construction (superstructure structure and foundation)
- Equipment (elevators, equipment for manufacturing process)
- Plumbing
- Electric system
- HVAC
- Communication system (computer network, telephone)
- Waste treatment and disposal
- Landscaping
- Drainage
- Access roads
- Miscellaneous items such as fences, alarm system, monitoring devices.
- Interior decorations.
- Administration fees and overheads

These costs depend on the site conditions and engineering design. In the construction costs, the labor costs make up about 40-50 percent of the costs, the

equipment costs account for 30-40 percent, and the remaining 20 percent is administration fees and overheads.

Costs of site preparation and excavation include costs for site cleaning, excavation, grading, slope protection, and erosion control. The unit prices used in the estimates can be found on *National Construction Estimator Data* (Kiley, 1994) and *Means Site Work & Landscape Cost* (1996).

Total operation and maintenance is about 40-70 percent of the total project costs. Costs included in this part are:

- Transportation of raw materials and products
- Utilities
- Maintenance of roadways, structure, and equipment.
- Administration fees and overheads

2. Earthwork and Excavation

The selection of construction equipment for structural excavation and bulk excavation or for grading is determined by the following factors:

- Quantities of material
- Type of material
- Depth or height of cut
- Length of haul
- Condition of haul road
- Accessibility of site
- Moisture content and dewatering requirements
- Availability of excavating and hauling equipment

3. Use of Means Cost Data

Reference

"Means Building Construction Cost Data - 1996", R. S. Means Company, Inc., Kingston, MA, 1996.

"Means Site Work & Landscape Cost Data", 15th ed., Kingston, MA. Means Company, Inc. 1996..

Kiley, M. and N. K. Martin. 1994. "Construction Estimator" 42nd ed. Carlsbad, Calif: Craftsman Book Company.

20 ESTIMATING CONSTRUCTION COSTS

SAMPLE ESTIMATE

Item No.	Description	Calculations	No. units	Unit	Unit cost	Material cost	Equipment cost	Labor cost	Total cost
400	Furnish and drive 200 creosote-treated piles Drive piles to full penetration into normal soil. Length of piles, 50 ft. Size of piles, 14-in.-butt and 6-in.-tip diameters	205 piles × 50 ft	10,250	lin ft	2 00	20,500 00			20,500 00
10	Materials								
20	Equipment								
	Moving to and away from the job	200 piles ÷ 2½ per hr							
	Crane, 12-ton crawler type		80	hr	Lump sum	750 00			750 00
	Hammer, single-acting, 15,000 ft-lb		80	hr	12 60	1,008 00			1,008 00
	Boiler, water, fuel, etc.		80	hr	3 50	280 00			280 00
	Leads and sundry equipment		80	hr	4 25	340 00			340 00
30	Labor, add 16 hr to set up and take down equipment		80	hr	2 80	224 00			224 00
	Foreman	80 + 16	96	hr	8 25			792 00	792 00
	Fireman		96	hr	5 40			518 40	518 40
	Crane operator		96	hr	6 25			600 00	600 00
	Crane oiler		96	hr	4 80			460 80	460 80
	Men on hammer	2 × 96	192	hr	4 90			940 80	940 80
	Helpers	2 × 96	192	hr	4 75			911 00	911 00
	Subtotal, direct cost					20,500 00	2,602 00	4,223 00	27,325 00
50	Overhead	10% × \$27,325.00							2,732 50
60	Social security tax	5.85% × \$4,223.00							247 05
62	Workmen's compensation insurance	8.68% × \$4,223.00							366 56
64	Unemployment tax	3% × \$4,223.00							126 69
70	Subtotal cost								
80	Profit	10% × \$30,797.80							3,079 78
85	Subtotal cost								
									30,797 80
90	Performance bond	¾% × \$33,877.58							33,877 58
94	Total cost, amount of bid								254 10
95	Cost per lin ft.	\$34,131.68 ÷ 10,000 lin ft							34,131 68
									3 41

Fig. 1-1 Form used to estimate construction costs.

HOW TO USE THE UNIT PRICE PAGES

The following is a detailed explanation of a sample entry in the Unit Price Section. Next to each bold number below is the item being described with appropriate component of the sample entry following in parenthesis. Some prices are listed as bare costs, others as costs that include overhead and profit of the installing contractor. In most cases, if the work is to be subcontracted, the general contractor will need to add an additional markup (R.S. Means suggests using 10%) to the figures in the column "Total Incl. O&P."

1 Division Number/Title (031/Concrete Formwork)

Use the Unit Price Section Table of Contents to locate specific items. The sections are classified according to the CSI MASTERFORMAT.

2 Line Numbers (031 158 5000)

Each unit price line item has been assigned a unique 10-digit code based on the 5-digit CSI MASTERFORMAT classification.

MASTERFORMAT Mediumscope
MASTERFORMAT Division

031 100
031 158 5000

Means Subdivision

Means Major Classification

Means Individual Line Number

3 Description (FORMS IN PLACE, etc.)

Each line item is described in detail. Sub-items and additional sizes are indented beneath the appropriate line items. The first line or two after the main item (in boldface) may contain descriptive information that pertains to all line items beneath this boldface listing.

4 Reference Number Information (R031-050)

You'll see reference numbers shown in bold squares at the beginning of some major classifications. These refer to related items in the Reference Section.

The relation may be: (1) an estimating procedure that should be read before estimating, (2) an alternate pricing method, or (3) technical information.

The "R" designates the Reference Section. The numbers refer to the MASTERFORMAT classification system.

It is strongly recommended that you review all reference numbers that appear within the major classification you are estimating.

Example: The square number above is directing you to refer to the reference number R031-050. This particular reference number shows how the unit price lines for forms in place were formulated and costs derived.

031 Concrete Formwork		031 100 Struct C.I.P. Formwork		CREW	DAILY OUTPUT	MAN-HOURS	UNIT	1993 BARE COSTS				TOTAL INCL O&P
								MAT.	LABOR	EQUIP.	TOTAL	
158	0010	FORMS IN PLACE, FOOTINGS Continuous wall, 1 use	R031-050	C-1	375	.085	SFCA	1.05	1.89	.07	3.01	4.19
	0050	2 use			440	.075		.97	1.80	.06	2.24	3.22
	4000	of hexagonal caps, 1 use			200	.080		1.64	3.00	.11	4.90	6.85
	4050				200	.080		.91	2.00	.09	3.53	5.05
	4100				200	.080		.69	2.00	.08	3.09	4.50
	4150				315	.102		.61	2.25	.08	2.94	4.29
	5000	Spread footings, 1 use			305	.105		1.07	2.32	.08	3.47	4.92
	5050	2 use			371	.086		.62	1.91	.07	2.60	3.75
	5100	3 use			401	.080		.47	1.77	.06	2.30	3.36
	5150	4 use			414	.077		.39	1.71	.06	2.16	3.22
	6000	Supports for dowels, plin... templates, 2' x 2'			25	1.280	Each	2.95	28.50	.99	32.44	45.88
	6050	4' x 4' footing			22	1.455		6.35	32	1.12	39.47	53.94
	6100	8' x 8' footing			20	1.600		12.90	35.50	1.25	49.65	67.50

5 Crew (C-1)

The "Crew" column designates the typical trade or crew used to install the item. If an installation can be accomplished by one trade and requires no power equipment, that trade and the number of workers are listed (for example, "2 Carp"). If an installation requires a composite crew, a crew code designation is listed (for example, "C-1"). You'll find full details on all composite crews in the Crew Listings.

- For a complete list of all trades utilized in this book and their abbreviations, see the inside back cover.

CREWS

Crew No.	Bare Costs		Incl. Subs O & P		Cost Per Man-Hour	
	Hr.	Daily	Hr.	Daily	Bare Costs	Incl. O&P
Crew C-1						
3 Carpenters	\$23.35	\$560.40	\$36.65	\$879.60	\$22.15	\$34.76
1 Building Laborer	18.55	148.40	29.10	232.80		
3 Power Tools		24.60		27.05	.77	.85
32 M.H. Daily Totals		\$733.40		\$1139.45	\$22.92	\$35.61

6 Productivity: Daily Output (3.05)/ Man-Hours (.105)

The "Daily Output" represents the typical number of units the designated crew will install in a normal 8-hour day. To find out the number of days the given crew would require to complete the installation, divide your quantity by the daily output. For example:

Quantity	÷	Daily Output	=	Duration
1000 SFCA	÷	305 SFCA/ Crew Day	=	3.28 Crew Days

The "Man-Hours" figure represents the number of man-hours required to install one unit of work. To find out the number of man-hours required for your particular task, multiply the quantity of the item times the number of man-hours shown. For example:

Quantity	x	Productivity Rate	=	Duration
1000 SFCA	x	.105 Man-Hours/ SFCA	=	105 Man-Hours

7 Unit (SFCA)

The abbreviated designation indicates the unit of measure upon which the price, production, and crew are based (SFCA = Square Foot Contact Area). For a complete listing of abbreviations refer to the Abbreviations Listing in the Reference Section of this book.

8 Bare Costs:

Mat. (Bare Material Cost) (1.07)

This figure for the unit material cost for the line item is the "bare" material cost with no overhead and profit allowances included. *Costs shown reflect national average material prices for January of the current year and include delivery to the job site. No sales taxes are included.*

Labor (2.32)

The unit labor cost is derived by multiplying bare man-hour costs for Crew C-1 by man-hour units. In this case, the bare man-hour cost is found in the Crew Section under C-1. (If a trade is listed, the hourly labor cost—the wage rate—is found on the inside back cover.)

Man-Hour Cost Crew C-1	x	Man-Hour Units	=	Labor
\$22.15	x	.105	=	\$2.32

Equip. (Equipment) (.08)

Equipment costs for each crew are listed in the description of each crew. The unit equipment cost is derived by multiplying the bare equipment hourly cost by the man-hour units.

Equipment Cost Crew C-1	x	Man-Hour Units	=	Equip.
\$0.77	x	.105	=	\$0.08

Total (3.47)

The total of the bare costs is the arithmetic total of the three previous columns: mat., labor, and equip.

Material	+	Labor	+	Equip.	=	Total
\$1.07	+	\$2.32	+	\$0.08	=	\$3.47

9 Total Costs Including O&P

The figure in this column is the sum of three components: the bare material cost plus 10%; the bare labor cost plus overhead and profit (per the labor rate table on the inside back cover or, if a crew is listed, from the crew listings); and the bare equipment cost plus 10%.

Material is Bare Material cost + 10% = \$1.07 + \$0.11	=	\$1.18
Labor for Crew C-1 = Man-Hour Cost (\$34.76) x Man-Hour Units (.105)	=	\$3.65
Equip. is Bare Equip. Cost + 10% = \$0.08 + \$0.01	=	\$0.09
Total	=	\$4.92

021 | Site Preparation and Excavation Support

021 620 Cribbing & Walers		CREW	DAILY OUTPUT	MAN-HOURS	UNIT	1993 BARE COSTS				TOTAL INCL O&P
						MAT.	LABOR	EQUIP.	TOTAL	
624	2350	B-46	400	.120	S.F.	1.25	2.56	.11	3.92	5.75
	2370		250	.192		1.88	4.10	.18	6.16	9.05
	2400	↓	1,736	.028	↓	.46	.59	.03	1.08	1.52
	2450		1,510	.032		.52	.68	.03	1.23	1.72
	2500								20%	20%
	2550								60%	60%
	2700	B-46	86.80	.553	L.F.	8.10	11.80	.52	20.42	29
	2750	↓	38.50	1.247	*	17.85	26.50	1.17	45.52	65
	3500	↓	2	24	Ea.	345	515	22.50	882.50	1,250
	3600		1.58	30.380		*	445	650	28.50	1,123.50
021 680 Slurry Wall										
684	0010									684
	0020									
	0050	C-7	333	.192	C.F.	3.07	3.86	2.39	9.32	12
	0100	↑	200	.320	*	5.55	6.40	3.97	15.92	20.50
	0200	↓	150	.427	S.F.	6.65	8.55	5.30	20.50	26.50
	0300		120	.533		9.15	10.70	6.60	26.45	34
	0500	B-48	177	.316	↓	4.12	6.55	9.95	20.62	25.50
	0600	*	69	.812		16.50	16.75	25.50	58.75	72
	0800	B-34B	99	.081	C.Y.		1.57	3.92	5.49	6.70
	0900	*	40	.200	*		3.89	9.70	13.59	16.60

SITE WORK 2

022 | Earthwork

022 100 Grading		CREW	DAILY OUTPUT	MAN-HOURS	UNIT	1993 BARE COSTS				TOTAL INCL O&P
						MAT.	LABOR	EQUIP.	TOTAL	
104	0010									104
	0020									
022 200 Excav, Backfill, Compact										
204	0010									204
	0100									
	0300									
	0400									
	0500									
	0600									
	0800									
	0900									
	1000									
	1100									
	1300									
	1400									
	1600									
	1700									
	1900									
	2000									
	2200									
	2300									
204	0010									212
	0020									

For expanded coverage of these items see Means Heavy Construction Cost Data 1993

022 | Earthwork

022 200 Excav./Backfill/Compact.		CREW	DAILY OUTPUT	LABOR HOURS	UNIT	1996 BARE COSTS				TOTAL INCL. O&P	
						MAT.	LABOR	EQUIP.	TOTAL		
242	6080 Clay	B-10V	550	.022	C.Y.		.52	5.20	5.72	6.55	242
246	0010 EXCAVATION, BULK, SCRAPERS	P022 -040									246
	0100 Elevating scraper 11 C.Y., sand & gravel 1500' haul	B-33F	690	.020	C.Y.		.49	1.35	1.84	2.24	
	0150 3000' haul		610	.023			.55	1.52	2.07	2.53	
	0200 5000' haul		505	.028			.67	1.84	2.51	3.06	
	0300 Common earth, 1500' haul		600	.023			.56	1.55	2.11	2.57	
	0350 3000' haul		530	.025			.63	1.75	2.38	2.91	
	0400 5000' haul		440	.032			.76	2.11	2.87	3.50	
	0500 Clay, 1500' haul		375	.037			.90	2.48	3.38	4.12	
	0550 3000' haul		330	.042			1.02	2.82	3.84	4.68	
	0600 5000' haul		275	.051			1.22	3.38	4.60	5.60	
	1000 Self propelled scraper, 14 C.Y. 1/4 push dozer, sand and gravel, 1500' haul	B-33D	920	.015	C.Y.		.37	2	2.37	2.77	
	1100 3000' haul		805	.017			.42	2.29	2.71	3.17	
	1200 5000' haul		645	.022			.52	2.86	3.38	3.95	
	1300 Common earth, 1500' haul		800	.017			.42	2.30	2.72	3.18	
	1350 3000' haul		700	.020			.48	2.63	3.11	3.63	
	1400 5000' haul		560	.025			.60	3.29	3.89	4.55	
	1500 Clay, 1500' haul		500	.028			.67	3.68	4.35	5.10	
	1550 3000' haul		440	.032			.76	4.19	4.95	5.80	
	1600 5000' haul		350	.040			.96	5.25	6.21	7.30	
	2000 21 C.Y., 1/4 push dozer, sand & gravel, 1500' haul	B-33E	1,180	.012			.28	1.82	2.10	2.44	
	2100 3000' haul		910	.015			.37	2.36	2.73	3.17	
	2200 5000' haul		750	.019			.45	2.86	3.31	3.85	
	2300 Common earth, 1500' haul		1,030	.014			.33	2.09	2.42	2.80	
	2350 3000' haul		790	.018			.43	2.72	3.15	3.65	
	2400 5000' haul		650	.022			.52	3.31	3.83	4.44	
	2500 Clay, 1500' haul		645	.022			.52	3.33	3.85	4.47	
	2550 3000' haul		495	.028			.68	4.34	5.02	5.80	
	2600 5000' haul		405	.035			.83	5.30	6.13	7.15	
	2700 Towed, 10 C.Y., 1/4 push dozer, sand & gravel, 1500' haul	B-33B	560	.025			.60	2.82	3.42	4.04	
	2720 3000' haul		450	.031			.75	3.51	4.26	5.05	
	2730 5000' haul		365	.038			.92	4.33	5.25	6.20	
	2750 Common earth, 1500' haul		420	.033			.80	3.77	4.57	5.40	
	2770 3000' haul		400	.035			.84	3.95	4.79	5.65	
	2780 5000' haul		310	.045			1.08	5.10	6.18	7.30	
	2800 Clay, 1500' haul		315	.044			1.07	5	6.07	7.15	
	2820 3000' haul		300	.047			1.12	5.25	6.37	7.55	
	2840 5000' haul		225	.062			1.49	7.05	8.54	10.05	
	2900 15 C.Y., 1/4 push dozer, sand & gravel, 1500' haul	B-33C	800	.017			.42	1.98	2.40	2.82	
	2920 3000' haul		640	.022			.53	2.47	3	3.53	
	2940 5000' haul		520	.027			.65	3.04	3.69	4.35	
	2960 Common earth, 1500' haul		600	.023			.56	2.64	3.20	3.77	
	2980 3000' haul		560	.025			.60	2.82	3.42	4.04	
	3000 5000' haul		440	.032			.76	3.59	4.35	5.15	
	3020 Clay, 1500' haul		450	.031			.75	3.51	4.26	5.05	
	3040 3000' haul		420	.033			.80	3.77	4.57	5.40	
	3060 5000' haul		320	.044			1.05	4.94	5.99	7.10	
250	0010 EXCAVATING, STRUCTURAL Hand, pits to 6' deep, sandy soil	1 Cab	8	1	C.Y.		19.80		19.80	31.50	250
	0100 Heavy soil or clay		4	2			39.50		39.50	63	
	0300 Pits 6' to 12' deep, sandy soil		5	1.600			31.50		31.50	50.50	
	0500 Heavy soil or clay		3	2.667			53		53	84.50	
	0700 Pits 12' to 18' deep, sandy soil		4	2			39.50		39.50	63	
	0900 Heavy soil or clay		2	4			79		79	126	

028 | Site Improvements

028 100 Irrigation Systems		CREW	DAILY OUTPUT	LABOR-HOURS	UNIT	1996 BARE COSTS				TOTAL INCL O&P
						MAT.	LABOR	EQUIP.	TOTAL	
0010	SPRINKLER IRRIGATION SYSTEM For lawns									
0100	Golf course with fully automatic system	C-17	.05	1,600	9 holes	74,000	42,200		116,200	149,000
0200	24' diam. head at 15' O.C incl. piping, minimum	B-20	70	.343	Head	16	7.70		23.70	30
0300	Maximum		40	.600		37	13.50		50.50	62
0500	60' diameter head, automatic operation, minimum		28	.857		50	19.30		69.30	86
0600	Maximum		23	1.043		135	23.50		158.50	187
0800	Residential system, custom, 1" supply		2,619	.009	S.F.	22	21		.43	.57
0900	1-1/2" supply		2,311	.010		20	23		.43	.59
028 200 Fountains										
0010	FOUNTAINS incl. fiberglass pools, pumps, piping and lights									
0200	4' diameter pool, 18" diameter spray ring	Q-1	2	8	Ea.	630	216		846	1,025
0300	6' diameter pool, 24" diameter spray ring		1.50	10.667		1,100	289		1,389	1,650
0400	7.5' diameter pool, 48" diameter spray ring		1	16		1,600	435		2,035	2,400
0500	Rain curtains, 3' rain bar, 2' x 4' x 1' pool		2	8		600	216		816	990
0600	7' rain bar, 2' x 8' x 1' pool		1	16		1,275	435		1,710	2,050
028 300 Fences & Gates										
0010	FENCE, CHAIN LINK INDUSTRIAL 6' high plus 3 strands									
0020	barbed wire, 2" line post @ 10' O.C., 1-5/8" top rail									
0200	9 ga. wire, galv. steel	B-80	250	.128	L.F.	5.65	2.77	1.85	10.27	12.60
0300	Aluminized steel		250	.128		7.10	2.77	1.85	11.72	14.25
0500	6 ga. wire, galv. steel		250	.128		8.95	2.77	1.85	13.57	16.25
0600	Aluminized steel		250	.128		10.35	2.77	1.85	14.97	17.80
0800	6 ga. wire, 6' high but omit barbed wire, galv. steel		260	.123		8.50	2.67	1.77	12.94	15.50
0900	Aluminized steel		260	.123		10.10	2.67	1.77	14.54	17.25
1100	Add for corner posts, 3" diam., galv. steel		40	.800	Ea.	46.50	17.35	11.55	75.40	90.50
1200	Aluminized steel		40	.800		56.50	17.35	11.55	85.40	102
1300	Add for braces, galv. steel		80	.400		12.45	8.65	5.75	26.85	33.50
1350	Aluminized steel		80	.400		15.40	8.65	5.75	29.80	37
1400	Gate for 6' high fence, 1-5/8" frame, 3' wide, galv. steel		10	3.200		65.50	69.50	46	181	232
1500	Aluminized steel		10	3.200		83	69.50	46	198.50	251
2000	5'-0" high fence, 9 ga., no barbed wire, 2" line post,									
2010	10' O.C., 1-5/8" top rail									
2100	Galvanized steel	B-80	315	.102	L.F.	5.05	2.20	1.46	8.71	10.60
2200	Aluminized steel		315	.102		6.15	2.20	1.46	9.81	11.80
2400	Gate, 4' wide, 5' high, 2" frame, galv. steel		10	3.200	Ea.	86	69.50	46	201.50	255
2500	Aluminized steel		10	3.200		93	69.50	46	208.50	262
2700	Motor operator for gates, not including gates or									
2710	electrical wiring, for swinging gate 15' wide	B-80	2	16	Oprg.	1,400	345	231	1,976	2,350
2800	For swinging gate up to 30' wide (pair)		2	16		2,500	345	231	3,076	3,550
2900	For sliding gate up to 45' long (pair)		2	16		2,575	345	231	3,151	3,650
3100	Overhead slide gate, chain link, 6' high, to 18' wide		38	.842	L.F.	50	18.25	12.15	80.40	97
3110	Cantilever type		48	.667		32	14.45	9.60	56.05	68
5000	Double swing gates, incl. posts & hardware									
5010	5' high, 12' opening	B-80	3.40	9.412	Oprg.	217	204	136	557	710
5020	20' opening		2.80	11.429		252	248	165	665	850
5060	6' high, 12' opening		3.20	10		247	217	144	608	770
5070	20' opening		2.60	12.308		305	267	177	749	950
5080	8' high, 12' opening		1.57	20.382		465	440	294	1,199	1,525
5090	20' opening		1.25	25.600		575	555	370	1,500	1,900
5100	10' high, 12' opening		1.31	24.427		550	530	350	1,430	1,825
5110	20' opening		1.03	31.068		695	675	450	1,820	2,300
5120	12' high, 12' opening		1.05	30.476		685	660	440	1,785	2,275
5130	20' opening		.85	37.647		865	815	545	2,225	2,825
5190	For aluminized steel add					20%				



171 | S.F., C.F. and % of Total Costs

171 000 S.F. & C.F. Costs		UNIT	UNIT COSTS			% OF TOTAL			
			1/4	MEDIAN	3/4	1/4	MEDIAN	3/4	
010	0010 APARTMENTS Low Rise (1 to 3 story)	R171 -100	S.F.	37.05	46.60	61.60			
	0020 Total project cost		C.F.	3.34	4.39	5.40			
	0100 Sitework	R171 -200	S.F.	3.10	4.48	7.15	6.40%	10.60%	14%
	0500 Masonry			.57	1.75	2.95	1.40%	4%	6.50%
	1500 Finishes			3.92	5	6.60	8.90%	10.60%	12.90%
	1800 Equipment			1.22	1.84	2.68	2.80%	4%	6.20%
	2720 Plumbing			2.90	3.79	4.74	6.70%	9%	10.10%
	2770 Heating, ventilating, air conditioning			1.85	2.28	3.31	4.20%	5.80%	7.70%
	2900 Electrical			2.15	2.87	3.96	5.20%	6.70%	8.60%
	3100 Total: Mechanical & Electrical			6.45	7.90	10.25	15.90%	18.30%	22.20%
9000 Per apartment unit, total cost		Apt.	29,100	43,100	64,900				
9500 Total: Mechanical & Electrical		*	5,350	7,850	11,200				
020	0010 APARTMENTS Mid Rise (4 to 7 story)		S.F.	47.45	58.35	71.80			
	0020 Total project costs		C.F.	3.84	5.25	7.30			
	0100 Sitework		S.F.	1.91	3.74	6.95	5.20%	6.70%	9.20%
	0500 Masonry			2.99	4.20	6.20	5.20%	7.50%	10.50%
	1500 Finishes			6.10	7.70	9.80	10.40%	11.90%	16.90%
	1800 Equipment			1.62	2.21	2.95	2.80%	3.50%	4.50%
	2500 Conveying equipment			1.12	1.37	1.64	2.10%	2.20%	2.60%
	2720 Plumbing			2.90	4.57	5	6.20%	7.40%	8.90%
	2900 Electrical			3.30	4.43	5.45	6.60%	7.20%	8.90%
	3100 Total: Mechanical & Electrical			9.10	11.45	14.15	17.90%	20.10%	22.30%
9000 Per apartment unit, total cost		Apt.	36,600	55,600	65,100				
9500 Total: Mechanical & Electrical		*	10,900	12,700	18,700				
030	0010 APARTMENTS High Rise (8 to 24 story)		S.F.	55.95	67.80	79.15			
	0020 Total project costs		C.F.	4.63	6.45	7.85			
	0100 Sitework		S.F.	1.72	3.29	4.61	2.50%	4.80%	6.10%
	0500 Masonry			3.18	5.75	7.25	4.70%	9.60%	10.70%
	1500 Finishes			6.10	7.80	8.90	9.30%	11.70%	13.50%
	1800 Equipment			1.75	2.20	2.85	2.50%	3.30%	4.20%
	2500 Conveying equipment			1.14	1.87	2.67	2.20%	2.70%	3.30%
	2720 Plumbing			3.59	4.87	6.15	6.70%	9.10%	10.60%
	2900 Electrical			3.86	4.95	6.60	6.40%	7.60%	8.80%
	3100 Total: Mechanical & Electrical			11.40	13.95	17.35	18.20%	22%	24.40%
9000 Per apartment unit, total cost		Apt.	51,700	61,000	66,700				
9500 Total: Mechanical & Electrical		*	12,600	14,400	15,600				
040	0010 AUDITORIUMS		S.F.	56.10	79.15	104			
	0020 Total project costs		C.F.	3.72	5.20	7.45			
	2720 Plumbing		S.F.	3.61	4.80	6.20	5.80%	6.90%	8.40%
	2770 Heating, ventilating, air conditioning			7.50	18.20	21.10	6.90%	16%	19.80%
	2900 Electrical			4.60	6.55	8.50	6.70%	8.80%	11%
	3100 Total: Mechanical & Electrical			9.55	12.65	22.10	14.70%	18.50%	23.80%
050	0010 AUTOMOTIVE SALES		S.F.	39.40	48.40	66.05			
	0020 Total project costs		C.F.	2.90	3.31	4.42			
	2720 Plumbing		S.F.	1.96	3.41	3.80	2.80%	6.20%	6.90%
	2770 Heating, ventilating, air conditioning			3.02	4.71	6.75	6.30%	10%	10.70%
	2900 Electrical			3.35	5.20	7.25	7.30%	8.70%	12.30%
3100 Total: Mechanical & Electrical			7.10	10.70	14.35	15.40%	19.10%	27%	
060	0010 BANKS		S.F.	85.15	106	138			
	0020 Total project costs		C.F.	6.05	8.20	10.85			
	0100 Sitework		S.F.	8.40	14.55	22.90	7%	13.40%	16.90%
	0500 Masonry			4.27	7.20	14.50	2.90%	6.10%	10%
	1500 Finishes			6.95	9.55	12.60	5.40%	7.60%	9.90%
	1800 Equipment			2.49	7	16.95	2.50%	7.90%	13.60%
	2720 Plumbing			2.75	3.92	5.80	2.80%	4%	4.90%
	2770 Heating, ventilating, air conditioning			5.25	7.05	9.40	5%	7.20%	8.60%

17 SQUARE FOOT

CREWS

Crew No.	Bare Costs		Incl. Subs O & P		Cost Per Man-Hour	
	Hr.	Daily	Hr.	Daily	Bare Costs	Incl. O&P
Crew B-5						
1 Labor Foreman (outside)	\$20.55	\$164.40	\$32.25	\$258.00	\$21.06	\$32.64
4 Building Laborers	18.55	593.60	29.10	931.20		
2 Equip. Oper. (med.)	24.10	385.60	36.75	588.00		
1 Mechanic	25.55	204.40	38.95	311.60		
1 Air Comp., 250 C.F.M.		102.80		113.10		
2 Air Tools & Accessories		29.60		32.55		
2-50 Ft. Air Hoses, 1.5" Dia.		12.80		14.10		
1 F.E. Loader, T.M., 2.5 C.Y.		764.00		840.40	14.21	15.63
64 M.H., Daily Totals		\$2257.20		\$3088.95	\$35.27	\$48.27
Crew B-6						
2 Building Laborers	\$18.55	\$296.80	\$29.10	\$465.60	\$20.07	\$31.15
1 Equip. Oper. (light)	23.10	184.80	35.25	282.00		
1 Backhoe Loader, 48 H.P.		200.60		220.65	8.36	9.19
24 M.H., Daily Totals		\$682.20		\$968.25	\$28.43	\$40.34
Crew B-7						
1 Labor Foreman (outside)	\$20.55	\$164.40	\$32.25	\$258.00	\$19.81	\$30.90
4 Building Laborers	18.55	593.60	29.10	931.20		
1 Equip. Oper. (med.)	24.10	192.80	36.75	294.00		
1 Chipping Machine		188.60		207.45		
1 F.E. Loader, T.M., 2.5 C.Y.		764.00		840.40		
2 Chain Saws		90.00		99.00	21.72	23.89
48 M.H., Daily Totals		\$1993.40		\$2630.05	\$41.53	\$54.79
Crew B-7A						
2 Laborers	\$18.55	\$296.80	\$29.10	\$465.60	\$20.07	\$31.15
1 Equip. Oper. (light)	23.10	184.80	35.25	282.00		
1 Reel w/Tractor		197.60		217.35		
2 Chain Saws		44.40		48.85	10.08	11.09
24 M.H., Daily Totals		\$723.60		\$1013.80	\$30.15	\$42.24
Crew B-8						
1 Labor Foreman (outside)	\$20.55	\$164.40	\$32.25	\$258.00	\$20.63	\$31.79
2 Building Laborers	18.55	296.80	29.10	465.60		
2 Equip. Oper. (med.)	24.10	385.60	36.75	588.00		
1 Equip. Oper. Older	20.25	162.00	30.90	247.20		
2 Truck Drivers (heavy)	19.45	311.20	29.75	476.00		
1 Hyd. Crane, 25 Ton		508.20		559.00		
1 F.E. Loader, T.M., 2.5 C.Y.		764.00		840.40		
2 Dump Trucks, 16 Ton		775.60		853.15	32.00	35.20
64 M.H., Daily Totals		\$3367.80		\$4287.35	\$52.63	\$66.99
Crew B-9						
1 Labor Foreman (outside)	\$20.55	\$164.40	\$32.25	\$258.00	\$18.95	\$29.73
4 Building Laborers	18.55	593.60	29.10	931.20		
1 Air Comp., 250 C.F.M.		102.80		113.10		
2 Air Tools & Accessories		29.60		32.55		
2-50 Ft. Air Hoses, 1.5" Dia.		12.80		14.10	3.63	3.99
40 M.H., Daily Totals		\$903.20		\$1348.95	\$22.58	\$33.72
Crew B-10						
1 Equip. Oper. (med.)	\$24.10	\$192.80	\$36.75	\$294.00	\$22.25	\$34.20
.5 Building Laborer	18.55	74.20	29.10	116.40		
12 M.H., Daily Totals		\$267.00		\$410.40	\$22.25	\$34.20
Crew B-10A						
1 Equip. Oper. (med.)	\$24.10	\$192.80	\$36.75	\$294.00	\$22.25	\$34.20
.5 Building Laborer	18.55	74.20	29.10	116.40		
1 Roll. Compact, 2K Lbs.		79.20		87.10	6.60	7.26
12 M.H., Daily Totals		\$346.20		\$497.50	\$28.85	\$41.46

Crew No.	Bare Costs		Incl. Subs O & P		Cost Per Man-Hour	
	Hr.	Daily	Hr.	Daily	Bare Costs	Incl. O&P
Crew B-10B						
1 Equip. Oper. (med.)	\$24.10	\$192.80	\$36.75	\$294.00	\$22.25	\$34.20
.5 Building Laborer	18.55	74.20	29.10	116.40		
1 Dozer, 200 H.P.		832.00		915.20	69.33	76.87
12 M.H., Daily Totals		\$1099.00		\$1325.60	\$91.58	\$110.07
Crew B-10C						
1 Equip. Oper. (med.)	\$24.10	\$192.80	\$36.75	\$294.00	\$22.25	\$34.20
.5 Building Laborer	18.55	74.20	29.10	116.40		
1 Dozer, 200 H.P.		832.00		915.20		
1 Vibratory Roller, Towed		95.00		105.60	77.33	85.87
12 M.H., Daily Totals		\$1195.00		\$1431.20	\$99.58	\$118.27
Crew B-10D						
1 Equip. Oper. (med.)	\$24.10	\$192.80	\$36.75	\$294.00	\$22.25	\$34.20
.5 Building Laborer	18.55	74.20	29.10	116.40		
1 Dozer, 200 H.P.		832.00		915.20		
1 Sheepsfoot Roller, Towed		107.40		118.15	78.28	86.11
12 M.H., Daily Totals		\$1206.40		\$1443.75	\$100.53	\$120.31
Crew B-10E						
1 Equip. Oper. (med.)	\$24.10	\$192.80	\$36.75	\$294.00	\$22.25	\$34.20
.5 Building Laborer	18.55	74.20	29.10	116.40		
1 Tandem Roller, 5 Ton		122.80		135.10	10.23	11.26
12 M.H., Daily Totals		\$389.80		\$545.50	\$32.48	\$45.46
Crew B-10F						
1 Equip. Oper. (med.)	\$24.10	\$192.80	\$36.75	\$294.00	\$22.25	\$34.20
.5 Building Laborer	18.55	74.20	29.10	116.40		
1 Tandem Roller, 10 Ton		223.80		246.20	18.65	20.52
12 M.H., Daily Totals		\$490.80		\$656.60	\$40.90	\$54.72
Crew B-10G						
1 Equip. Oper. (med.)	\$24.10	\$192.80	\$36.75	\$294.00	\$22.25	\$34.20
.5 Building Laborer	18.55	74.20	29.10	116.40		
1 Sheepsfoot Roll., 130 H.P.		512.00		563.20	42.67	46.93
12 M.H., Daily Totals		\$779.00		\$973.60	\$64.92	\$81.13
Crew B-10H						
1 Equip. Oper. (med.)	\$24.10	\$192.80	\$36.75	\$294.00	\$22.25	\$34.20
.5 Building Laborer	18.55	74.20	29.10	116.40		
1 Diaphr. Water Pump, 2"		19.00		20.90		
1-20 Ft. Suction Hose, 2"		4.40		4.85		
2-50 Ft. Disch. Hoses, 2"		6.80		7.50	2.52	2.77
12 M.H., Daily Totals		\$297.20		\$443.65	\$24.77	\$36.97
Crew B-10I						
1 Equip. Oper. (med.)	\$24.10	\$192.80	\$36.75	\$294.00	\$22.25	\$34.20
.5 Building Laborer	18.55	74.20	29.10	116.40		
1 Diaphr. Water Pump, 4"		54.00		59.40		
1-20 Ft. Suction Hose, 4"		11.40		12.55		
2-50 Ft. Disch. Hoses, 4"		12.80		14.10	6.52	7.17
12 M.H., Daily Totals		\$345.20		\$496.45	\$28.77	\$41.37
Crew B-10J						
1 Equip. Oper. (med.)	\$24.10	\$192.80	\$36.75	\$294.00	\$22.25	\$34.20
.5 Building Laborer	18.55	74.20	29.10	116.40		
1 Centr. Water Pump, 3"		28.40		31.25		
1-20 Ft. Suction Hose, 3"		7.40		8.15		
2-50 Ft. Disch. Hoses, 3"		8.80		9.70	3.72	4.09
12 M.H., Daily Totals		\$311.60		\$459.50	\$25.97	\$38.29

CITY COST INDEXES

DIVISION	NEW JERSEY						NEW MEXICO			NEW YORK								
	PATERSON			TRENTON			ALBUQUERQUE			ALBANY			BINGHAMTON			BUFFALO		
	MAT.	INST.	TOTAL	MAT.	INST.	TOTAL	MAT.	INST.	TOTAL	MAT.	INST.	TOTAL	MAT.	INST.	TOTAL	MAT.	INST.	TOTAL
2	116.3	107.5	112.3	107.0	106.2	106.7	108.6	90.8	100.6	103.2	103.3	103.3	92.6	88.0	90.5	99.5	99.8	99.6
3.1	109.9	131.1	126.3	124.8	128.1	127.3	126.1	70.5	83.2	118.0	99.1	103.5	112.7	84.2	90.7	123.1	123.6	123.5
3.2	108.8	143.4	123.4	109.2	101.1	105.8	117.7	71.7	98.3	80.1	92.8	85.5	80.1	88.5	83.6	96.2	110.5	102.2
3.3	102.2	102.8	102.6	89.1	100.7	96.3	101.8	99.6	100.5	77.6	101.2	92.2	91.1	98.0	95.3	108.7	101.5	104.2
3	105.3	117.6	113.2	101.0	111.5	107.7	110.4	85.6	94.5	86.6	99.6	94.9	93.1	91.7	92.2	108.9	111.0	110.3
4	109.9	138.1	131.6	105.2	124.5	120.1	102.8	69.0	76.8	87.8	99.9	97.1	100.3	87.4	90.3	99.3	116.1	112.2
5	96.1	128.2	107.8	98.1	102.3	99.6	107.4	82.1	98.2	97.1	96.5	96.9	99.2	90.3	95.9	104.4	106.7	105.2
6	117.6	133.5	126.2	120.2	134.9	128.2	100.4	72.2	85.1	96.8	97.9	97.4	103.8	80.2	91.0	112.4	125.2	119.4
7	114.3	124.7	117.7	102.8	130.0	111.6	97.4	62.3	86.1	105.8	101.2	104.3	97.5	86.1	93.8	100.8	112.3	104.5
8	98.6	131.3	115.6	104.8	127.1	116.4	99.2	68.7	83.4	103.7	91.7	97.5	99.3	77.6	88.0	96.0	112.6	104.6
9.2	99.6	101.7	101.2	115.3	98.6	102.7	119.1	70.2	82.0	106.0	101.0	102.2	109.0	81.0	87.8	110.9	115.2	114.2
9.2	113.2	119.8	116.2	109.6	119.8	114.3	85.6	71.4	79.0	105.5	98.1	102.1	113.6	79.8	97.9	123.6	126.8	125.1
9.5	100.6	134.6	119.1	96.9	134.6	117.4	92.1	71.2	80.8	111.3	97.9	104.0	110.6	79.5	93.7	114.7	126.5	121.1
9.6	90.5	140.2	103.9	101.1	128.2	108.4	103.9	63.8	93.0	86.1	93.9	88.3	99.7	87.9	96.5	104.5	118.1	108.2
9.9	100.0	129.6	123.4	96.4	129.6	122.7	110.1	65.4	74.7	116.9	90.1	95.7	103.4	82.8	87.1	112.4	114.1	113.7
9	105.6	124.7	115.7	105.5	123.7	115.2	93.3	68.7	80.3	102.9	95.2	98.8	109.2	81.4	94.5	117.3	121.1	119.3
10-14	100.0	114.7	104.3	100.0	117.2	105.0	100.0	79.5	93.9	100.0	94.3	98.3	100.0	88.6	96.6	100.0	102.1	100.6
15	99.9	113.0	106.5	99.9	115.1	107.5	100.3	81.9	91.2	96.2	93.9	95.1	100.1	81.1	90.6	97.4	94.3	95.9
16	96.7	122.2	114.4	94.8	135.1	122.8	95.0	77.0	82.5	92.5	99.8	97.6	92.2	92.4	92.4	99.0	102.0	101.1
1-16	103.4	122.1	113.5	101.7	119.6	111.3	101.6	77.8	88.8	97.0	97.6	97.3	98.8	86.7	92.3	102.6	107.7	105.4

DIVISION	NEW YORK												NORTH CAROLINA					
	NEW YORK			ROCHESTER			SYRACUSE			UTICA			YONKERS			CHARLOTTE		
	MAT.	INST.	TOTAL	MAT.	INST.	TOTAL	MAT.	INST.	TOTAL	MAT.	INST.	TOTAL	MAT.	INST.	TOTAL	MAT.	INST.	TOTAL
2	118.1	129.1	123.1	107.9	94.3	101.8	96.8	96.5	96.7	116.5	93.9	106.3	123.4	121.8	122.7	115.4	82.1	100.4
3.1	111.2	170.4	156.8	108.5	108.3	108.3	111.1	95.1	98.8	114.3	69.9	80.1	116.1	153.2	144.7	109.4	56.2	68.4
3.2	100.6	186.7	137.0	106.4	104.5	105.6	106.4	98.8	103.2	106.4	86.4	98.0	80.1	132.9	102.4	87.7	59.2	75.7
3.3	152.3	116.0	129.9	126.7	98.5	109.3	103.0	78.9	88.2	84.0	96.2	91.5	116.4	113.6	114.7	110.7	92.9	99.7
3	132.3	143.8	139.7	118.4	102.9	108.5	105.5	87.1	93.7	95.3	85.0	88.7	108.3	130.9	122.8	105.3	75.4	86.2
4	105.1	166.1	152.2	102.1	112.6	110.2	102.1	96.5	97.8	100.1	92.1	93.9	122.5	151.5	144.9	89.9	45.1	55.3
5	104.5	159.2	124.4	102.0	100.6	101.5	103.1	92.0	99.1	103.8	91.7	99.4	97.5	156.1	118.9	100.2	73.9	90.6
6	111.8	169.3	143.0	98.2	110.3	104.8	107.2	93.8	99.9	112.6	68.8	88.8	103.5	150.2	128.8	105.0	58.7	79.9
7	110.1	165.3	127.9	97.4	117.8	104.0	96.6	105.0	99.3	97.5	98.8	98.0	105.6	155.3	121.7	88.8	42.8	73.9
8	98.9	171.0	136.3	96.8	105.8	101.5	97.8	90.4	93.9	104.0	71.6	87.2	104.8	162.0	134.5	96.0	55.5	75.0
9.2	87.9	160.6	143.0	107.6	115.6	113.6	106.1	95.0	97.7	109.3	76.7	84.6	93.6	135.3	125.2	100.0	49.2	61.5
9.2	119.8	172.3	144.2	94.1	111.1	102.0	108.6	93.8	101.7	110.2	67.9	90.6	97.5	141.0	117.6	87.9	57.4	73.8
9.5	102.6	172.0	140.2	115.7	110.8	113.1	98.7	93.6	95.9	115.7	67.7	89.7	115.7	151.8	135.3	92.1	57.3	73.2
9.6	98.4	155.8	114.0	93.6	111.2	98.4	86.4	90.4	87.5	88.0	85.6	87.3	101.8	136.8	111.3	90.8	44.0	78.1
9.9	118.2	149.1	142.7	98.1	114.4	111.0	103.2	90.9	93.4	108.6	90.9	94.6	107.6	139.3	132.7	96.8	57.5	65.7
9	112.9	162.4	139.2	96.4	112.5	104.9	102.3	92.6	97.2	105.6	77.6	90.7	100.8	140.7	122.0	90.1	56.0	72.0
10-14	100.0	133.3	109.8	100.0	102.8	100.8	100.0	94.9	98.5	100.0	92.4	97.7	100.0	134.9	110.2	100.0	72.9	92.0
15	99.5	162.3	130.8	97.3	97.0	97.2	100.7	96.6	98.7	99.3	90.1	94.7	96.8	136.6	116.6	97.2	59.1	78.2
16	95.6	150.8	133.9	98.3	99.4	99.1	98.6	94.8	95.9	95.8	90.5	92.1	104.0	137.1	126.9	98.1	54.9	68.1
1-16	108.0	155.2	133.4	101.9	103.9	103.0	101.0	93.5	97.0	101.1	87.3	93.7	103.9	140.3	123.5	98.5	61.4	78.5

DIVISION	NORTH CAROLINA						OHIO											
	GREENSBORO			RALEIGH			AKRON			CANTON			CINCINNATI			CLEVELAND		
	MAT.	INST.	TOTAL	MAT.	INST.	TOTAL	MAT.	INST.	TOTAL	MAT.	INST.	TOTAL	MAT.	INST.	TOTAL	MAT.	INST.	TOTAL
2	90.4	86.5	88.6	99.2	89.8	95.0	117.0	98.0	108.4	105.1	97.0	101.5	92.5	101.0	96.3	122.2	106.8	115.3
3.1	100.4	56.3	66.4	105.1	56.2	67.4	112.4	102.9	105.1	111.2	93.7	97.7	100.2	95.7	96.7	121.5	117.0	118.0
3.2	82.2	61.4	73.4	93.8	61.4	80.1	98.2	110.2	103.3	98.2	84.2	92.3	105.7	94.7	101.0	84.8	110.2	95.6
3.3	99.4	90.6	94.0	107.2	95.5	99.9	89.6	99.2	95.5	89.6	99.7	95.8	87.4	97.0	93.3	93.9	111.2	104.6
3	95.8	74.5	82.1	103.8	76.9	86.6	96.3	101.6	99.7	96.0	95.9	96.0	94.1	96.2	95.5	97.6	113.4	107.7
4	102.7	45.1	58.3	89.2	45.1	55.2	93.6	105.4	102.7	107.5	90.8	94.6	74.9	91.8	87.9	96.4	110.8	107.5
5	91.2	74.4	85.1	91.2	76.0	85.6	98.9	105.1	101.2	98.9	89.2	95.4	98.5	95.8	97.5	104.8	109.1	106.4
6	91.8	58.7	73.8	95.0	58.7	75.3	104.7	104.3	104.5	103.3	92.8	97.6	109.3	93.9	101.0	142.5	115.0	127.6
7	86.7	42.8	72.5	87.2	42.8	72.8	99.0	98.8	98.9	99.1	97.4	98.5	96.0	100.3	97.4	108.5	119.1	111.9
8	91.4	56.9	73.5	85.5	56.9	70.7	101.3	107.2	104.4	88.4	82.1	85.2	96.6	90.5	93.5	94.0	114.0	104.4
9.2	97.8	59.5	68.8	106.6	53.6	66.4	115.9	100.4	104.1	112.1	84.4	91.1	102.9	94.7	96.7	104.7	113.0	111.0
9.2	85.7	57.4	72.6	95.4	57.4	77.8	112.5	104.7	108.9	110.7	90.0	101.1	97.8	93.3	95.7	101.2	115.6	107.9
9.5	97.6	57.3	75.7	108.8	57.3	80.8	82.6	104.4	94.4	101.5	92.6	96.6	96.9	93.8	95.2	98.3	115.3	107.6
9.6	89.9	44.0	77.4	101.6	44.0	86.0	82.4	93.6	85.4	114.2	86.0	106.5	91.0	92.3	91.4	85.2	111.5	92.3
9.9	91.0	57.5	64.5	90.4	57.5	64.3	107.7	106.4	106.7	101.4	90.1	92.5	103.0	90.3	92.9	104.5	118.8	115.8
9	88.4	56.6	71.5	97.5	56.2	75.6	103.1	104.2	103.7	109.8	89.6	99.1	96.9	92.3	94.5	97.9	116.2	107.6
10-14	100.0	73.1																

Historical and City Cost Indexes

Historical Cost Indexes

The table below lists both the Means City Cost Index based on Jan. 1, 1975 = 100 as well as the computed value of an index based on Jan. 1, 1993 costs. Since the Jan. 1, 1993 figure is estimated, space is left to write in the actual index figures as they become available through either the quarterly "Means Construction

Cost Indexes" or as printed in the "Engineering News-Record." To compute the actual index based on Jan. 1, 1993 = 100, divide the Quarterly City Cost Index for a particular year by the actual Jan. 1, 1993 Quarterly City Cost Index. Space has been left to advance the index figures as the year progresses.

Year	Quarterly City Cost Index Jan. 1, 1975 = 100		Current Index Based on Jan. 1, 1993 = 100		Year	Quarterly City Cost Index Jan. 1, 1975 = 100		Current Index Based on Jan. 1, 1993 = 100		Year	Quarterly City Cost Index Jan. 1, 1975 = 100		Current Index Based on Jan. 1, 1993 = 100	
	Est.	Actual	Est.	Actual		Actual	Est.	Actual	Actual		Est.	Actual		
Oct 1993					July 1978	122.4	53.2			July 1960	45.0	19.6		
July 1993					1977	113.3	49.2			1959	44.2	19.2		
April 1993					1976	107.3	46.6			1958	43.0	18.7		
Jan 1993	230.1		100.0	100.0	1975	102.6	44.6			1957	42.2	18.3		
July 1992		227.6	98.9		1974	94.7	41.2			1956	40.4	17.6		
1991		221.6	96.3		1973	86.3	37.5			1955	38.1	16.6		
1990		215.9	93.8		1972	79.7	34.6			1954	36.7	15.9		
1989		210.9	91.7		1971	73.5	31.9			1953	36.2	15.7		
1988		205.7	89.4		1970	65.8	28.6			1952	35.3	15.3		
1987		200.7	87.2		1969	61.6	26.8			1951	34.4	15.0		
1986		192.8	83.8		1968	56.9	24.7			1950	31.4	13.6		
1985		189.1	82.2		1967	53.9	23.4			1949	30.4	13.2		
1984		187.6	81.5		1966	51.9	22.6			1948	30.4	13.2		
1983		183.5	79.7		1965	49.7	21.6			1947	27.6	12.0		
1982		174.3	75.7		1964	48.6	21.1			1946	23.2	10.1		
1981		160.2	69.6		1963	47.3	20.6			1945	20.2	8.8		
1980		144.0	62.6		1962	46.2	20.1			1944	19.3	8.4		
1979		132.3	57.5		1961	45.4	19.7			1943	18.6	8.1		

City Costs Indexes

Tabulated on the following pages are average construction cost indexes for 162 major U.S. and Canadian cities. Index figures for both material and installation are based on the 30 major city average of 100 and represent the cost relationship as of July 1, 1992. The index for each division is computed from representative material and labor quantities for that division. The weighted average for each city is a weighted total of the components listed above it, but does not include relative productivity between trades or cities.

The material index for the weighted average includes about 100 basic construction materials with appropriate quantities of each material to represent typical "average" building construction projects.

The installation index for the weighted average includes the distribution of about 24 construction trades with their representative man-days in proportion to the material items installed. Also included

in the installation costs are the representative equipment costs for those items requiring equipment.

Since each division of the book contains many different items, any particular item multiplied by the particular city index may give incorrect results. However, when all the book costs for a particular division are summarized and then factored, the result should be very close to the actual costs for that particular division for that city.

If a project has a preponderance of materials from any particular division (say structural steel), then the weighted average index should be adjusted in proportion to the value of the factor for that division.

Note: For listing of the 30 major cities see reference number R033-060

Adjustments to Costs

Time Adjustment using the Historical Cost Indexes:

$$\frac{\text{Index for Year A}}{\text{Index for Year B}} \times \text{Cost in Year B} = \text{Cost in Year A}$$

Location Adjustment using the City Cost Indexes:

$$\frac{\text{Index for City A}}{\text{Index for City B}} \times \text{Cost in City B} = \text{Cost in City A}$$

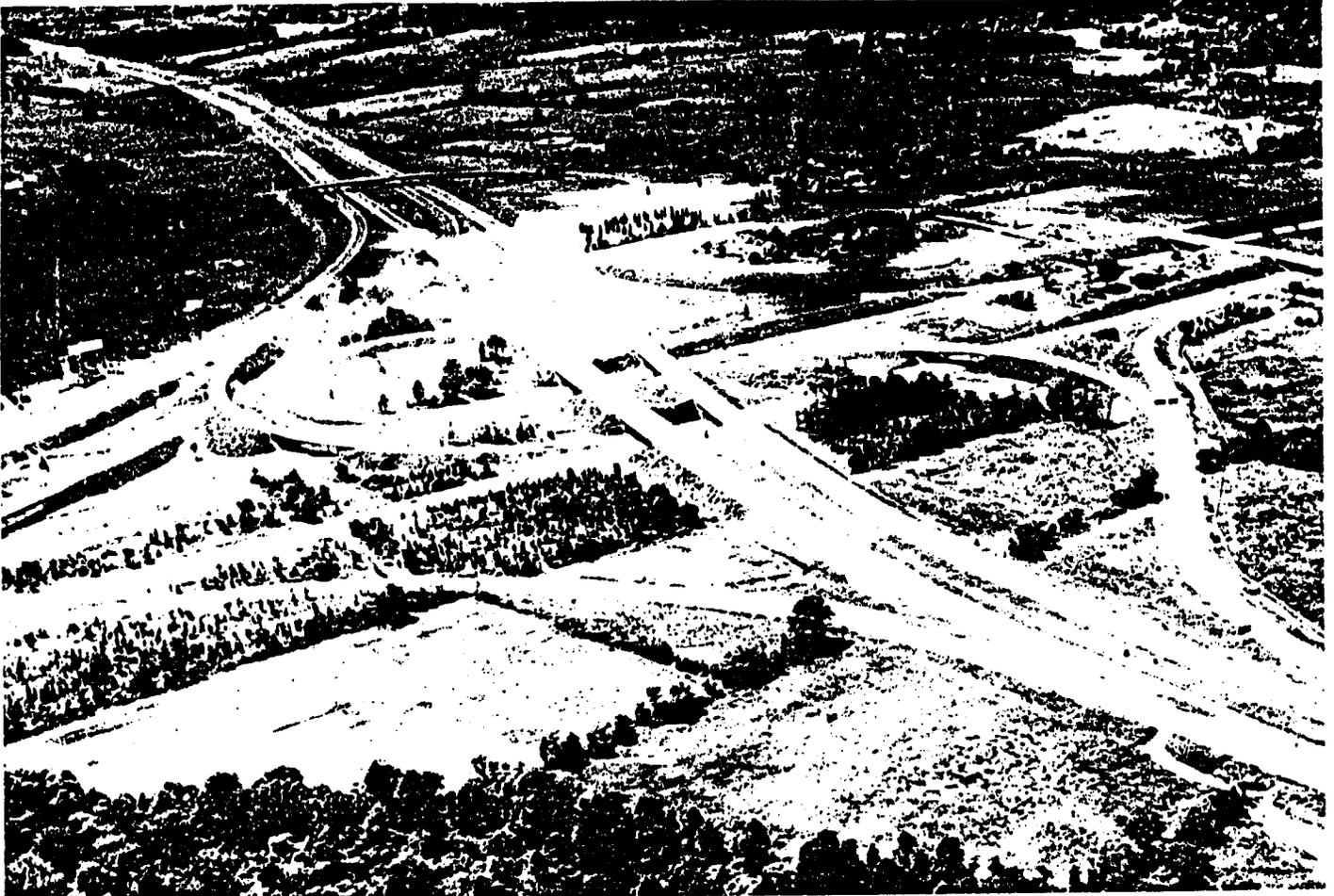
Adjustment from the National Average:

$$\text{National Average Cost} \times \frac{\text{Index for City A}}{100} = \text{Cost in City A}$$

The City Cost Indexes for Canada can be used to convert U.S. National averages to local costs in Canadian dollars.

SOIL SURVEY OF

Somerset County, New Jersey



United States Department of Agriculture Soil Conservation Service In cooperation with New Jersey Agricultural Experiment Station Cook College, Rutgers, The State University and the New Jersey Department of Agriculture State Soil Conservation Committee

2



TABLE 10.—Degree and kind of limitations

Soil series and map symbols	Foundations for dwellings—		Septic-tank absorption fields	Sewage lagoons	Sanitary landfills ¹
	With basements	Without basements			
Abbottstown: AbA, AbB.	Severe: seasonal high water table perched at a depth of $\frac{1}{2}$ foot to $1\frac{1}{2}$ feet.	Severe: seasonal high water table perched at a depth of $\frac{1}{2}$ foot to $1\frac{1}{2}$ feet.	Severe: seasonal high water table perched at a depth of $\frac{1}{2}$ foot to $1\frac{1}{2}$ feet; slow permeability in subsoil; bedrock at a depth of $3\frac{1}{2}$ to $4\frac{1}{2}$ feet.	Moderate: bedrock at a depth of $3\frac{1}{2}$ to $4\frac{1}{2}$ feet; AbB is gently sloping.	Severe: seasonal high water table perched at a depth of $\frac{1}{2}$ foot to $1\frac{1}{2}$ feet; rippable bedrock at a depth of $3\frac{1}{2}$ to $4\frac{1}{2}$ feet.
Amwell: AmB, AnB.....	Severe: seasonal high water table perched at a depth of 1 foot to 4 feet.	Severe: seasonal high water table perched at a depth of 1 foot to 4 feet.	Severe: seasonal high water table perched at a depth of 1 foot to 4 feet; slow permeability in fragipan; hard bedrock at a depth of $3\frac{1}{2}$ to more than 5 feet in places.	Moderate: gently sloping; hard bedrock at a depth of $3\frac{1}{2}$ to more than 5 feet in places.	Severe: seasonal high water table perched at a depth of 1 foot to 4 feet; hard bedrock at a depth of $3\frac{1}{2}$ to more than 5 feet in places.
AmC, AnC.....	Severe: seasonal high water table perched at a depth of 1 foot to 4 feet.	Severe: seasonal high water table perched at a depth of 1 foot to 4 feet.	Severe: seasonal high water table perched at a depth of 1 foot to 4 feet; slow permeability in fragipan; hard bedrock at a depth of $3\frac{1}{2}$ to more than 5 feet in places.	Severe: strongly sloping.	Severe: seasonal high water table perched at a depth of 1 foot to 4 feet; hard bedrock at a depth of $3\frac{1}{2}$ to more than 5 feet in places.
Arendtsville: ArB, ArC.....	Slight.....	Moderate: frost action potential.	Slight: hazard of ground-water pollution.	Severe: moderately rapid permeability in substratum.	Severe: moderately rapid permeability in substratum creates hazard of ground-water pollution.
Bartley: BaC.....	Moderate: seasonal high water table perched over fragipan at a depth of 2 to 4 feet.	Moderate: seasonal high water table perched at a depth of 2 to 4 feet.	Severe: seasonal high water table perched over fragipan at a depth of 2 to 4 feet; moderately slow permeability.	Severe: strongly sloping.	Severe: seasonal high water table perched at a depth of 2 to 4 feet; hazard of ground-water pollution in fractured limestone bedrock.
Birdsboro: BdA.....	Slight.....	Moderate: frost action potential.	Slight: hazard of ground-water pollution.	Severe: moderate to rapid permeability.	Severe: rapid permeability in substratum creates hazard of ground-water pollution.
BdB.....	Slight.....	Moderate: frost action potential.	Slight: hazard of ground-water pollution.	Severe: moderate to rapid permeability.	Severe: rapid permeability in substratum creates hazard of ground-water pollution.
BdC.....	Moderate: strongly sloping.	Moderate: strongly sloping; frost action potential.	Moderate: strongly sloping; hazard of ground-water pollution.	Severe: moderate to rapid permeability; strongly sloping.	Severe: rapid permeability in substratum creates hazard of ground-water pollution.

of soils used for community development

Local roads and streets	Lawns, landscaping, and golf fairways	Athletic fields	Picnic and play areas	Campsites for trailers and tents	Paths and trails
Severe: seasonal high water table perched at a depth of ½ foot to 1½ feet; high potential frost action.	Moderate: seasonal high water table at a depth of ½ foot to 1½ feet.	Severe: seasonal high water table at a depth of ½ foot to 1½ feet.	Moderate: water table above a depth of 20 inches for short period during season of use.	Moderate: water table below a depth of 20 inches during season of use.	Moderate: water table below a depth of 20 inches during season of use.
Severe: seasonal high water table perched at a depth of 1 foot to 4 feet; high potential frost action.	Moderate: seasonal high water table perched at a depth of 1 foot to 4 feet.	Severe: seasonal high water table perched at a depth of 1 foot to 4 feet.	Slight: water table below a depth of 20 inches during season of use.	Moderate: water table below a depth of 20 inches during season of use.	Slight: water table below a depth of 20 inches during season of use.
Severe: seasonal high water table perched at a depth of 1 foot to 4 feet; high potential frost action.	Moderate: seasonal high water table perched at a depth of 1 foot to 4 feet.	Severe: seasonal high water table perched at a depth of 1 foot to 4 feet; strongly sloping.	Moderate: strongly sloping.	Moderate: water table below a depth of 20 inches during season of use.	Slight: water table below a depth of 20 inches during season of use.
Moderate: potential frost action.	Moderate: high gravel content.	Severe: high gravel content.	Moderate: moderate gravel content on surface.	Moderate: moderate gravel content on surface.	Moderate: moderate gravel content on surface.
Severe: seasonal high water table perched at a depth of 2 to 4 feet; high potential frost action.	Moderate: strongly sloping.	Severe: strongly sloping.	Moderate: strongly sloping.	Moderate: strongly sloping.	Slight.
Moderate: high potential frost action.	Slight.....	Slight.....	Slight.....	Slight.....	Slight.
Moderate: high potential frost action.	Slight.....	Moderate: gently sloping.	Slight.....	Slight.....	Slight.
Moderate: potential frost action.	Moderate: strongly sloping.	Severe: strongly sloping.	Moderate: strongly sloping.	Moderate: strongly sloping.	Slight.

TABLE 7.—Estimated soil properties

[An asterisk in the first column indicates that at least one mapping unit in this series is made up of two or more kinds of soil. The soils in such other series that appear in the first column of this table. Absence of data indicates that soil is too vari-

Soil series and map symbols	Depth to—		Depth from surface	USDA texture	Classification		Coarse fraction greater than 3 inches
	Bedrock	Seasonal high water table			Unified	AASHTO	
Abbottstown: AbA, AbB.....	Feet 3½-4½	Feet ½-1½	Inches 0-9 9-19 19-35 35-48	Silt loam..... Silt loam, silty clay loam..... Silt loam..... Shaly silt loam.....	ML or CL ML or CL ML or CL ML, CL, SM, or SC	A-4 or A-6 A-4 or A-6 A-4 or A-6 A-4 or A-6	Percent 0-2 0-2 0-2 0-5
			48	Red shale bedrock.			
Amwell: AmB, AmC, AnB, AnC.	3½->5	1-4	0-14 14-21 21-36	Gravelly loam..... Clay loam..... Loam.....	ML or CL ML or CL ML, CL, GM, or GC	A-4 or A-6 A-4 or A-6 A-4 or A-6	0-10 0-10 0-10
			36-60	Fine sandy loam.....	SM, SC, ML, CL, GM, or GC	A-4	0-10
Arendtsville: ArB, ArC.....	>5	>4	0-15 15-43	Gravelly loam..... Gravelly loam, gravelly sandy clay loam.	ML, CL, SM, or SC ML or CL	A-4 or A-6 A-4, A-5, A-6, or A-7	0-5 0-5
			43-60	Gravelly sandy loam.....	GM or SM	A-2 or A-4	5-10
Bartley: BaC.....	>4	2-4	0-15 15-25 25-43	Loam..... Loam..... Clay loam.....	ML or CL ML or CL ML, CL, SM, or SC	A-4 or A-6 A-4 or A-6 A-4 or A-6	0-5 0-5 0-10
			43-50	Loam.....	SM or SC	A-2, A-4, or A-5	0-5
			50	Limestone bedrock.			
Birdsboro: BdA, BdB, BdC...	>5	>4	0-12 12-38 38-56 56-70	Silt loam..... Silt loam, silty clay loam..... Sandy loam..... Stratified sand and gravel.....	ML or CL ML or CL SM or SC SM, GM, SC, or GC	A-4 or A-6 A-4 or A-6 A-2 or A-4 A-2	0-2 0-2 0-2 0-1
Bowmansville: Bt.....	3½->5	0-1 (Very fre- quently flooded.)	0-17 17-47 47-60	Silt loam..... Clay loam, sandy clay loam, fine sandy loam. Stratified sand and gravel.....	ML or CL ML, CL, SM, or SC SM, GM, SC, GC, GW-SM, GP-GM, SP-SM, or SW-SM	A-4 or A-6 A-4 or A-6 A-1 or A-2	0-5 0-5 0-5
Bucks: BuB, BuC2.....	3½->5	>4	0-25 25-35 35-44	Silt loam..... Silt loam..... Shaly silt loam.....	ML or CL ML or CL GM, SM, ML, or CL	A-4 A-4 A-2 or A-4	----- ----- 5-15
			44	Shale bedrock.			
Califon: CaB, CcB.....	>5	½-2½	0-11 11-22	Gravelly loam..... Loam.....	ML or CL ML, CL, SC, or SM	A-4 or A-6 A-4 or A-6	0-10 0-10
			22-52	Loam.....	SM, SC, ML, or CL	A-4 or A-6	0-10
			52-65	Gravelly sandy loam.....	SM, SC, ML, or CL	A-2 or A-4	0-10
Chalfont: CdB, CdC, CeB, CeC, CeE.	3½->5	½-1½	0-15 15-40 40-50 50	Silt loam..... Silt loam..... Silt loam..... Argillite bedrock.	ML or CL ML or CL ML or CL	A-4 or A-6 A-4 or A-6 A-4	0-5 0-5 0-10

significant to engineering

mapping units may have different properties and limitations, and for this reason it is necessary to follow carefully the instructions for referring to able to be rated or that no estimate was made. The symbol > means greater than; < means less than

Percentage less than 3 inches passing sieve—				Liquid limit ¹	Plasticity index ²	Permeability	Available water capacity	Reaction ³	Shrink-swell potential
No. 4 (4.7 mm)	No. 10 (2.0 mm)	No. 40 (0.42 mm)	No. 200 (0.074 mm)						
95-100	90-100	80-95	70-90	20-35	5-15	<i>Inches per hour</i> 0.0-2.0	<i>Inches per inch of soil</i> 0.18-0.22	pH 4.5-5.0	Low.
95-100	90-100	85-95	70-85	20-35	5-15	0.2-0.6	0.18-0.22	4.5-5.0	Low.
95-100	80-90	70-90	60-80	20-35	5-15	<0.2	0.10-0.14	5.1-6.0	Low.
80-100	70-90	60-80	45-70	20-35	5-15	0.2-0.6	0.10-0.14	5.1-6.0	Low.
85-95	75-85	60-80	50-80	20-35	8-12	0.2-2.0	0.14-0.17	5.1-6.0	Low.
75-95	75-85	70-80	55-80	25-35	8-12	0.2-2.0	0.13-0.17	5.1-6.0	Low to moderate.
65-95	50-80	40-80	35-60	25-35	5-15	<0.2	0.08-0.12	5.1-6.5	Low.
65-95	65-80	40-80	35-55	20-30	5-10	2.0-6.0	0.08-0.12	5.1-6.5	Low.
75-95	70-90	55-80	45-70	20-35	5-15	2.0-6.0	0.13-0.17	<4.5-5.5	Low.
85-95	80-90	65-80	50-75	20-50	5-25	0.6-6.0	0.13-0.17	4.5-5.5	Low.
60-75	40-75	40-70	30-50	10-20	NP-5	2.0-6.0	0.05-0.10	4.5-5.5	Low.
95-100	85-95	75-95	60-90	30-50	5-20	0.6-2.0	*0.16-0.20	6.1-6.5	Moderate.
95-100	85-95	80-90	65-75	25-45	5-20	0.6-2.0	0.14-0.18	6.1-6.5	Moderate.
90-100	85-95	65-75	40-55	20-40	5-20	0.2-0.6	0.08-0.12	6.6-7.3	Low.
95-100	85-95	70-80	30-50	25-45	5-10	0.6-2.0	0.08-0.12	6.6-7.3	Low.
95-100	85-100	85-100	50-90	25-35	5-12	0.6-2.0	0.20-0.26	4.5-5.5	Low.
90-100	85-100	80-100	50-95	25-35	5-15	0.6-2.0	0.14-0.20	4.5-5.5	Low.
90-100	85-100	80-90	30-50	20-30	5-10	0.6-6.0	0.10-0.14	4.5-5.5	Low.
50-100	50-80	30-70	10-30	NI-10	NP-5	2.0->6.0	0.06-0.10	4.5-5.5	Low.
95-100	90-100	90-100	75-95	20-30	NP-10	0.6-2.0	*0.20-0.26	4.5-5.5	Low.
95-100	90-100	80-100	35-95	25-35	5-15	0.2-0.6	0.20-0.24	4.5-6.0	Low.
40-100	40-100	40-80	5-30	10-20	NP-10	2.0->6.0	0.03-0.10	4.5-6.0	Low.
95-100	95-100	90-100	60-90	25-35	4-10	0.2-2.0	0.18-0.24	4.5-5.5	Low.
80-100	70-100	70-100	60-95	25-35	4-10	0.2-2.0	0.18-0.24	4.5-5.5	Low.
60-90	60-80	20-80	15-70	20-30	2-10	0.2-2.0	0.08-0.16	4.5-5.5	Low.
80-100	75-90	70-80	50-70	20-30	8-12	0.6-2.0	*0.13-0.17	4.5-5.5	Low.
85-100	75-90	65-80	45-80	25-35	5-12	0.6-2.0	0.13-0.17	4.5-5.5	Moderate.
85-100	75-90	60-80	40-80	20-30	5-12	<0.2	0.06-0.10	4.5-5.5	Low.
85-95	75-90	60-90	30-70	15-25	5-10	0.6-2.0	0.06-0.10	4.5-5.5	Low.
90-100	90-100	75-100	70-95	25-40	5-15	0.2-2.0	*0.20-0.24	4.5-5.5	Low.
90-100	90-100	80-100	70-95	25-40	5-15	<0.2	0.08-0.12	4.5-5.5	Low.
80-100	70-90	70-80	60-80	25-35	5-10	0.2-2.0	0.08-0.12	4.5-5.5	Low.

Appendix A
Material Safety and Data Sheet Sample

SECTION 1 CHEMICAL PRODUCT AND COMPANY IDENTIFICATION

MATHESON GAS PRODUCTS
30 SEAVIEW DRIVE
SECAUCUS, NEW JERSEY 07096
(201) 867-4100

EMERGENCY CONTACT:
CHEMTREC 1-800-424-9300

CAS NUMBER: 7664-41-7
RTECS NUMBER: BO0875000

SUBSTANCE: AMMONIA, ANHYDROUS

TRADE NAMES/SYNONYMS:

ANHYDROUS AMMONIA; AMMONIA GAS; AMMONIA; NITRO-SIL; R 717;
SPIRIT OF HARTSHORN; STCC 4904210; UN 1005; H3N; MAT01050

CHEMICAL FAMILY:

Inorganic gas

CREATION DATE: 01/24/89

REVISION DATE: 12/07/94

SECTION 2 COMPOSITION, INFORMATION ON INGREDIENTS

COMPONENT : AMMONIA, ANHYDROUS
CAS NUMBER: 7664-41-7
PERCENTAGE: 100.0

OTHER CONTAMINANTS: NONE

SECTION 3 HAZARDS IDENTIFICATION

CERCLA RATINGS (SCALE 0-3): HEALTH=3 FIRE=1 REACTIVITY=0 PERSISTENCE=0
NFPA RATINGS (SCALE 0-4): HEALTH=3 FIRE=1 REACTIVITY=0

EMERGENCY OVERVIEW:

Colorless gas with an extremely pungent odor.

Causes severe burns to mucous membranes. Causes respiratory tract, skin and eye irritation, possibly severe.

Container may rupture in heat of fire.

Do not breathe gas. Do not get in eyes, on skin, or on clothing. Keep away from heat and flame. Do not puncture container. Keep container tightly closed. Wash thoroughly after handling. Use only with adequate ventilation. Handle with caution.

POTENTIAL HEALTH EFFECTS:

INHALATION:

SHORT TERM EFFECTS: May cause irritation, possibly severe. May cause effects as reported in short term exp as reported in short term exposure. Additional sense of smell, nausea, vomiting, difficulty speaking, chest pain, difficulty breathing, high blood pressure, headache and lung damage.

LONG TERM EFFECTS: May cause effects as in short term exposure. Additional effects may include digestive disorders.

SKIN CONTACT:

SHORT TERM EFFECTS: May cause irritation, possibly severe. Additional

effects may include blisters, frostbite and numbness.

LONG TERM EFFECTS: Same effects as short term exposure.

EYE CONTACT:

SHORT TERM EFFECTS: May cause irritation, possibly severe. Additional effects may include frostbite, tearing, blindness and glaucoma.

LONG TERM EFFECTS: Same effects as short term exposure.

INGESTION:

SHORT TERM EFFECTS: May cause burns. Additional effects may include frostbite, fever, difficulty breathing, low blood pressure, kidney damage and shock.

LONG TERM EFFECTS: Same effects as short term exposure.

CARCINOGEN STATUS:

OSHA: N

NTP: N

IARC: N

SECTION 4

FIRST AID MEASURES

INHALATION:

FIRST AID- Remove from exposure area to fresh air immediately. Perform artificial respiration if necessary. Maintain airway, blood pressure and respiration. Keep warm and at rest. Treat symptomatically and supportively. Get medical attention immediately. Qualified medical personnel should consider administering oxygen.

SKIN CONTACT:

FIRST AID- Remove contaminated clothing and shoes immediately. Wash with soap or mild detergent and large amounts of water until no evidence of chemical remains (at least 15-20 minutes). If burns occur, proceed with the following: Cover affected area securely with sterile, dry, loose-fitting dressing. Treat symptomatically and supportively. Get medical attention immediately.

EYE CONTACT:

FIRST AID- Wash eyes immediately with large amounts of water, occasionally lifting upper and lower lids, until no evidence of chemical remains (at least 15-20 minutes). Continue irrigating with normal saline until the pH has returned to normal (30-60 minutes). Cover with sterile bandages. Get medical attention immediately.

INGESTION:

FIRST AID- Give large amounts of water or milk immediately. Allow vomiting to occur. Do not perform gastric lavage or induce emesis. Esophagoscopy is the only way to exclude the possibility of corrosion in the upper gastrointestinal tract; if corrosion is suspected, esophagoscopy should usually be performed within 24 hours. (Dreisbach & Robertson; Handbook of Poisoning; 12th Ed.). Do not give anything by mouth if person is unconscious or otherwise unable to swallow. If vomiting occurs, keep head lower than hips to help prevent aspiration. Maintain airway and respiration. Treat symptomatically and supportively. Get medical attention immediately.

NOTE TO PHYSICIAN

ANTIDOTE:

No specific antidote. Treat symptomatically and supportively.

SECTION 5

FIRE FIGHTING MEASURES

FIRE AND EXPLOSION HAZARD:

Slight fire hazard when exposed to heat or flame.

Moderate explosion hazard when exposed to heat or flame.

EXTINGUISHING MEDIA:

Dry chemical or carbon dioxide
(1993 Emergency Response Guidebook, RSPA P 5800.6).

For larger fires, use water spray, fog or regular foam
(1993 Emergency Response Guidebook, RSPA P 5800.6).

FIREFIGHTING:

Do not get water inside container. Move container from fire area if you can do it without risk. Apply cooling water to sides of containers that are exposed to flames until well after fire is out. Stay away from ends of tanks. Isolate area until gas has dispersed (1993 Emergency Response Guidebook, RSPA P 5800.6, Guide Page 15).

Extinguish using agents indicated. Cool containers with flooding amounts of water from as far a distance as possible. Use water spray to absorb corrosive vapors. Avoid breathing corrosive vapors; keep upwind. Consider evacuation of downwind area if material is leaking.

Stop flow of gas (NFPA 325M, Fire Hazard Properties of Flammable Liquids, Gases, and Volatile Solids, 1991).

FLASH POINT: no data available

LOWER FLAMMABLE LIMIT: 15%

UPPER FLAMMABLE LIMIT: 28%

AUTOIGNITION: 1204 F (651 C)

HAZARDOUS COMBUSTION PRODUCTS/HAZARDOUS COMBUSTION PRODUCTS:

Thermal decomposition may release corrosive fumes of ammonia and toxic oxides of nitrogen.

SECTION 6

ACCIDENTAL RELEASE MEASURES

OCCUPATIONAL SPILL:

Stop leak if you can do it without risk. Use water spray to reduce vapors; do not put water directly on leak or spill area. Do not get water inside container. Isolate area until gas has dispersed. For small spills, flush area with flooding amounts of water. For larger spills, dike far ahead of spill for later disposal. Keep unnecessary people away; isolate hazard area and deny entry. Stay upwind, out of low areas, and ventilate closed spaces before entering. Isolate the leak or spill area immediately for at least 150 feet in all directions.

Reportable Quantity (RQ): 100 pounds

The Superfund Amendments and Reauthorization Act (SARA) Section 304 requires that a release equal to or greater than the reportable quantity for this substance be immediately reported to the local emergency planning committee and the state emergency response commission (40 CFR 355.40). If the release of this substance is reportable under CERCLA Section 103, the National Response

Center must be notified immediately at (800) 424-8802 or (202) 426-2675 in the metropolitan Washington, D.C. area (40 CFR 302.6).

SOIL SPILL:

Dig a holding area such as a pit, pond or lagoon to contain spill and dike surface flow using barrier of soil, sandbags, foamed polyurethane or foamed concrete. Absorb liquid mass with fly ash or cement powder.

Add dilute acid to neutralize.

AIR SPILL:

Apply water spray to knock down and reduce vapors. Knock-down water is corrosive and toxic and should be diked for containment.

WATER SPILL:

Neutralize with vinegar or other dilute acid.

Use mechanical dredges or lifts to extract immobilized masses of pollution and precipitates.

SECTION 7

HANDLING AND STORAGE

T

Observe all federal, state and local regulations when storing this substance.

Store in accordance with 29 CFR 1910.111.

Protect against physical damage. Outside or detached storage is preferred. Inside storage should be in a cool, well-ventilated, noncombustible location, away from all possible sources of ignition. Separate from other chemicals, particularly oxidizing gases, chlorine, bromine, iodine, and acids (NFPA 49, Hazardous Chemicals Data, 1975).

Store away from incompatible substances.

Store in a cool, dry, well ventilated area.

Threshold Planning Quantity (TPQ):

The Superfund Amendments and Reauthorization Act (SARA) Section 302 requires that each facility where any extremely hazardous substance is present in a quantity equal to or greater than the TPQ established for that substance notify the state emergency response commission for the state in which it is located. Section 303 of SARA requires these facilities to participate in local emergency response planning (40 CFR 355.30).

Threshold quantity (TQ): 10,000 pounds

The Occupational Safety and Health Administration (OSHA) Process Safety Management (PSM) standard requires that facilities utilizing a process which involves a chemical at or above its specified threshold quantity comply with the provisions of 29 CFR 1910.119, Process Safety Management of highly hazardous chemicals.

SECTION 8 EXPOSURE CONTROLS, PERSONAL PROTECTION

EXPOSURE LIMITS:

AMMONIA, ANHYDROUS:

35 ppm (27 mg/m3) OSHA STEL
25 ppm (18 mg/m3) ACGIH TWA; 35 ppm (27 mg/m3) ACGIH STEL
25 ppm (18 mg/m3) NIOSH recommended TWA;
35 ppm (27 mg/m3) NIOSH recommended STEL
50 ppm (35 mg/m3) DFG MAK TWA;
100 ppm (70 mg/m3) DFG MAK 5 minute peak, momentary value, 8 times/shift

Measurement method: Passive sampler; none; ion chromatography;
(NIOSH Vol. III # 6701).

500 pounds SARA Section 302 Threshold Planning Quantity
100 pounds SARA Section 304 Reportable Quantity
100 pounds CERCLA Section 103 Reportable Quantity
10,000 pounds OSHA Process Safety Management Threshold Quantity
Subject to SARA Section 313 Annual Toxic Chemical Release Reporting

**OSHA revoked the final rule limits of January 19, 1989 in response to the
11th Circuit Court of Appeals decision (AFL-CIO v. OSHA) effective
June 30, 1993. See 29 CFR 1910.1000 (58 FR 35338)**

VENTILATION:

Provide local exhaust ventilation and/or general dilution ventilation to meet
published exposure limits.

EYE PROTECTION:

Employee must wear splash-proof or dust-resistant safety goggles and a
faceshield to prevent contact with this substance.

Emergency wash facilities:

Where there is any possibility that an employee's eyes and/or skin may be
exposed to this substance, the employer should provide an eye wash fountain
and quick drench shower within the immediate work area for emergency use.

CLOTHING:

Employee must wear appropriate protective (impervious) clothing and equipment
to prevent any possibility of skin contact with this substance.

GLOVES:

Employee must wear appropriate protective gloves to prevent contact with this
substance.

RESPIRATOR:

The following respirators and maximum use concentrations are recommendations
by the U.S. Department of Health and Human Services, NIOSH Pocket Guide to
Chemical Hazards; NIOSH criteria documents or by the U.S. Department of
Labor, 29 CFR 1910 Subpart Z.
The specific respirator selected must be based on contamination levels found
in the work place, must not exceed the working limits of the respirator and
be jointly approved by the National Institute for Occupational Safety and
Health and the Mine Safety and Health Administration (NIOSH-MSHA).

AMMONIA:

- 250 ppm- Any chemical cartridge respirator with cartridge(s) providing protection against ammonia.
Any supplied-air respirator.
Any self-contained breathing apparatus.
- 500 ppm- Any powered, air-purifying respirator with cartridge(s) providing protection against ammonia.
Any self-contained breathing apparatus with a full face-piece.
Any supplied-air respirator with a full face-piece.
Any air-purifying, chin-style, front- or back-mounted canister providing protection against ammonia. Any air-purifying, full-facepiece respirator.
Any chemical cartridge respirator with a full facepiece and cartridge(s) providing protection against ammonia.
Any supplied-air respirator operated in a continuous-flow mode.
- Escape- Any air-purifying, full-facepiece respirator (gas mask) with a chin-style, front- or back-mounted canister providing protection against ammonia.

FOR FIREFIGHTING AND OTHER IMMEDIATELY DANGEROUS TO LIFE OR HEALTH CONDITIONS:

Any self-contained breathing apparatus that has a full facepiece and is operated in a pressure-demand or other positive-pressure mode.

Any supplied-air respirator that has a full facepiece and is operated in a pressure-demand or other positive-pressure mode in combination with an auxiliary self-contained breathing apparatus operated in pressure-demand or other positive-pressure mode.

SECTION 9

PHYSICAL AND CHEMICAL PROPERTIES

DESCRIPTION: Colorless gas with an extremely pungent odor.
MOLECULAR WEIGHT: 17.03
MOLECULAR FORMULA: N-H₃
BOILING POINT: -27 F (-33 C)
FREEZING POINT: -108 F (-78 C)
VAPOR PRESSURE: 6658 mmHg @ 21 C
VAPOR DENSITY: 0.5967
SPECIFIC GRAVITY: 0.7067 g/L @ 25 C
WATER SOLUBILITY: 38% @ 20 C
PH: 11.6 @ 1.0 N soln
ODOR THRESHOLD: 1-5 ppm
EVAPORATION RATE: not applicable
SOLVENT SOLUBILITY: Soluble in methanol, ethanol, chloroform, ether, and other organic solvents.

SECTION 10

STABILITY AND REACTIVITY

REACTIVITY:
Stable under normal temperatures and pressures.

CONDITIONS TO AVOID:
Material is extremely poisonous; avoid inhalation of vapors or contact with skin. Contents may be under pressure; containers may rupture violently and travel a considerable distance.

INCOMPATIBILITIES:

AMMONIA, ANHYDROUS:

ACIDS: Violent reaction.

ALDEHYDES: May undergo violent exothermic condensation.

ALKYLENE OXIDES: May undergo violent exothermic condensation.

ALUMINUM: May be corrosive.

AMIDES: Possible violent reaction.

BORON: Incandescent reaction with release of hydrogen gas when heated.

BORON HALIDES: Violent reaction.

CALCIUM: Exothermic reaction which may become incandescent.

CHLORIC ACID: Formation of explosive compound.

CHLORINE AZIDE: Formation of explosive compound.

CHLORINE MONOXIDE: Explosive mixture.

CHLORITES: Forms shock-sensitive compound.

CHLOROFORMAMIDINIUM NITRATE: Violent reaction.

1-CHLORO-2,4-DINITROBENZENE: Violent reaction with possible explosion.

2-CHLORONITROBENZENE: Violent reaction.

CHLOROSILANE: May form spontaneously flammable compound.

CHROMIUM TRIOXIDE (CHROMIC ANHYDRIDE): Exothermic oxidation with possible incandescence.

CHROMYL CHLORIDE: Incandescent reaction with possible ignition.

COPPER: May be corrosive.

DIAMMINEBORONIUM HEPTAHYDROTETRABORATE: Violent decomposition.

DIBORANE: Ignition.

1,2-DICHLOROETHANE: May explode on contact with the liquified gas.

DIMETHYL SULFATE: Violent reaction.

GERMANIUM DERIVATIVES: Possible explosion.

HALOGENS: Violent reaction with possible formation of explosive compound.

HEAVY METALS AND COMPOUNDS (SILVER, GOLD, MERCURY, THALLIUM): May form compounds which are explosive when dry.

HEXACHLOROMELAMINE: Fire and explosion hazard.

HYDRAZINE AND ALKALI METALS: Forms explosive metal hydrazides.

HYDROGEN BROMIDE: Vigorous reaction.

HYPOCHLOROUS ACID: Explodes on contact.

INTERHALOGENS: Violent reaction with possible formation of explosive compound.

LEAD: May be corrosive.

MAGNESIUM PERCHLORATE: Exothermic reaction followed by explosion.

NITRIC ACID: Ignition.

NITROGEN TETROXIDE: Violent or explosive reaction.

NITROGEN HALIDES: Explosive reaction.

NITRYL CHLORIDE: Violent reaction even at -75 C.

OXIDIZERS (STRONG): Fire and explosion hazard.

OXYGEN: Possible explosion.

OXYGEN DIFLUORIDE: Immediate reaction producing white fumes.

PENTABORANE: Spontaneous ignition.

PERCHLORATES: Violent reaction.

PHOSPHORUS OXIDES: Violent reaction with possible ignition.

PICRIC ACID: Forms explosive salts.

PLASTICS, RUBBER, COATINGS: May be attacked.

POTASSIUM AND ARSINE: Vigorous reaction with the liquid.

POTASSIUM AND PHOSPHINE: Produces spontaneously flammable solid.

POTASSIUM AND SODIUM NITRITE: Produces explosive, reactive solid.

POTASSIUM CHLORATE: Hazardous reaction.

POTASSIUM FERRICYANIDE: Explosive reaction.

POTASSIUM MERCURICYANIDE: Explosive reaction.

POTASSIUM PERMANGANATE: Incandescent oxidation.

SODIUM AND CARBON MONOXIDE: Forms explosive product with the liquid.
 STIBINE: Explosion on heating.
 SULFUR AND COMPOUNDS: May form explosive product.
 TELLURIUM HALIDES: Forms explosive compound.
 TETRAMETHYLAMMONIUM AMIDE: Explosive decomposition.
 THIOCARBONYL AZIDE THIOCYANATE: Explosive reaction.
 THIONYL CHLORIDE (SULFINYL CHLORIDE): Formation of explosive compound.
 THIOTRITHIAZYL CHLORIDE: Explosive reaction.
 TIN: May be corrosive.
 TRICHLOROMELAMINE: Fire and explosion hazard.
 VINYL COMPOUNDS: May initiate violent, exothermic polymerization.

HAZARDOUS DECOMPOSITION:

Thermal decomposition may release corrosive fumes of ammonia and toxic oxides of nitrogen.

POLYMERIZATION:

Hazardous polymerization has not been reported to occur under normal temperatures and pressures.

SECTION 11**TOXICOLOGICAL INFORMATION**
 -----**AMMONIA, ANHYDROUS:**

TOXICITY DATA: 20 ppm inhalation-human TCLO; 5000 ppm/5 minutes inhalation-human LCLO; 2000 ppm/4 hours inhalation-rat LC50; 300 ppm/6 hours/5 days-intermittent inhalation-rat TCLO; 455 mg/m³/8 hours/90 days-intermittent inhalation-rat TCLO; 960 mg/m³/4 hours/17 weeks-intermittent inhalation-rat TCLO; 4230 ppm/1 hour inhalation-mouse LC50; 7 gm/m³/1 hour inhalation-cat LC50; 7 gm/m³/1 hour inhalation-rabbit LC50; 470 mg/m³/8 hours/90 days-intermittent inhalation-rabbit TCLO; 470 mg/m³/8 hours/90 days-intermittent inhalation-dog TCLO; 145 ppm/5 weeks-continuous inhalation-pig TCLO; 470 mg/m³/8 hours/90 days-intermittent inhalation-guinea pig TCLO; 5000 ppm/5 minutes inhalation-mammal LCLO; 15 uL/kg oral-man TDLo; 132 mg/kg unreported-man LDLo; mutagenic data (RTECS).

CARCINOGEN STATUS: None.

LOCAL EFFECTS: Corrosive- inhalation, skin, eye, ingestion.

ACUTE TOXICITY LEVEL: Moderately toxic by inhalation.

TARGET EFFECTS: Poisoning may affect the central nervous system.

AT INCREASED RISK FROM EXPOSURE: Persons with pre-existing eye, skin, and respiratory tract disorders.

HEALTH EFFECTS**INHALATION:****AMMONIA, ANHYDROUS:**

CORROSIVE. 500 ppm Immediately CORROSIVE. 500 ppm Immediately Dangerous to Life or ACUTE EXPOSURE- Concentrations of 5 ppm may cause minimal irritation; 9-50 ppm may cause nasal dryness, olfactory fatigue, and moderate irritation; 125-137 ppm may cause definite nose, throat, and chest irritation; and 150 ppm may cause laryngeal spasm. Exposure to 500 ppm for 30 minutes may cause cyclic hyperpnea, increased blood pressure and pulse rate, and upper respiratory tract irritation, sometimes persisting for 24 hours; 700 ppm may cause immediate irritation; 1500-10,000 ppm may cause dyspnea, convulsive coughing, chest pain, respiratory spasm, pink frothy sputum, rapid asphyxia, and delayed pulmonary edema which may be fatal. Other effects may include runny nose, swelling of the lips, restlessness, headache, salivation, nausea,

vomiting, glottal edema, pharyngitis, tracheitis, and difficulty in speaking. Death may result from bronchopneumonia or asphyxiation due to spasms, inflammation, or edema of the larynx. Residual effects from acute exposures may include hoarseness, productive cough, decreased respiratory function, chronic airway dysfunction, alveolar disease, bronchiolitis, bronchiectasis, emphysema, and anxiety neuroses.

CHRONIC EXPOSURE- Depending on the concentration and duration of exposure, repeated or prolonged exposure may cause inflammatory and ulcerative changes in the mouth, possible bronchial and gastrointestinal disturbances, and effects similar to acute exposure. Tolerance to usually irritating concentrations may be acquired by adaptation. In animals, continuous or repeated exposure to sublethal concentrations have produced adverse effects on the respiratory tract, liver, kidneys and spleen.

SKIN CONTACT:

AMMONIA, ANHYDROUS:

CORROSIVE.

ACUTE EXPOSURE- Exposure to 10,000 ppm may cause mild irritation to moist skin. Direct contact with solutions or high vapor concentrations (>30,000 ppm) may cause severe pain, a stinging sensation, severe burns and vesiculation, and possibly brownish stains. The corroded areas are soft, gelatinous, and necrotic, and the tissue destruction may be deep. If burns are extensive, death may occur. Rarely, vapor exposure may result in urticaria. Due to rapid evaporation, the liquid may cause frostbite with redness, tingling, and pain, or numbness. In more severe cases, the skin may become hard and white and blisters may develop.

CHRONIC EXPOSURE- Effects depend on the concentration and duration of exposure. Repeated or prolonged contact may cause dermatitis or effects similar to acute exposure.

EYE CONTACT:

AMMONIA, ANHYDROUS:

CORROSIVE.

ACUTE EXPOSURE- Exposure to 140 ppm caused slight irritation to human eyes; 700 ppm caused immediate irritation. Direct contact with solutions or high vapor concentrations (>2500 ppm) may cause severe irritation, swelling of the eyelids, lacrimation, blepharospasm, palpebral edema, increased intraocular pressure, oval semidilated fixed pupils, corneal ulceration, possibly severe ulceration, possibly severe, and temporary bl depends on the concentration and duration of contact. There may be destruction of epithelium, corneal and lenticular opacification, and iritis, accompanied by hypopyon or hemorrhages and possibly extensive loss of pigment from the posterior pigment layer of the iris. When damage is less than excessive, these symptoms tend to ameliorate. In severe burns, the extent of the injury may not be immediately apparent. Late complications may include persistent edema, vascularization and scarring of the cornea, permanent opacity, acute-angle glaucoma, staphyloma, cataract, atrophy of the retina and iris, and symblepharon. Due to rapid evaporation, the liquid may cause frostbite with pain, redness, and blurred vision.

CHRONIC EXPOSURE- Effects depend on concentration and duration of exposure. Repeated or prolonged contact may result in conjunctivitis or effects as in acute exposure. Exposure for several weeks to 675 ppm caused irritation of the eyes of dogs and rabbits and opacity over one-fourth to one-half of the cornea in rabbits.

INGESTION:
 AMMONIA, ANHYDROUS:
 CORROSIVE.

ACUTE EXPOSURE- Ingestion of solutions may cause immediate pain and circumoral burns and corrosion of the mucous membranes which at first turn white and soapy and then become brown, edematous, and ulcerated. There may be profuse salivation. Swallowing and speech may be difficult at first and then almost impossible. Even when there is no evidence of oral burns, the esophagus and stomach may be involved with burning pain, vomiting, and diarrhea. The vomitus may be thick and slimy with mucous, and later contain blood and shreds of mucous membrane. Epiglottal edema may result in respiratory distress and possibly asphyxia. Shock with marked hypotension, weak and rapid pulse, shallow respiration, and clammy skin may occur. Circulatory collapse may ensue, and if uncorrected, lead to renal failure. In severe cases, esophageal or gastric perforation are possible and may be accompanied by mediastinitis, substernal pain, peritonitis, abdominal rigidity, and fever. Esophageal, and possibly gastric or pyloric stricture may occur within a few weeks, but may be delayed for months or even years. Death may result within a short time from asphyxia, circulatory collapse, or aspiration of even minute amounts. Later, death may be due to the complications of perforation, pneumonia, or the effects of stricture formation. Ingestion of a gas is unlikely. If liquid is swallowed, frostbite damage to the lips, mouth and mucous membranes may occur.

CHRONIC EXPOSURE- Depending on the concentration, repeated ingestion may result in inflammatory and ulcerative effects on the oral mucous membranes and other effects as with acute ingestion. Ingestion of 80-130 mg/L for 17 months resulted in chronic acidosis and tissue changes in rabbits.

 ⌈ SECTION 12

ECOLOGICAL INFORMATION

⌋

ENVIRONMENTAL IMPACT RATING (0-4): no data available

ACUTE AQUATIC TOXICITY: no data available

DEGRADABILITY: no data available

LOG BIOCONCENTRATION FACTOR (BCF): no data available

LOG OCTANOL/WATER PARTITION COEFFICIENT: no data available

 ⌈ SECTION 13

DISPOSAL CONSIDERATIONS

⌋

Observe all federal, state and local regulations when disposing of this substance.

 ⌈ SECTION 14

TRANSPORT INFORMATION

⌋

FOR DOMESTIC SHIPMENTS:

U.S. DEPARTMENT OF TRANSPORTATION SHIPPING NAME-ID NUMBER, 49 CFR 172.101:
 Ammonia, anhydrous, liquified-UN 1005

U.S. DEPARTMENT OF TRANSPORTATION HAZARD CLASS OR DIVISION, 49 CFR 172.101:
 2.2 - Non-flammable compressed gas

Appendix B
Written and Oral Communication

VI. Written and Oral Communication

The net result of any experimentation and measurements is to convey the facts from the investigator's mind to that of interested readers (6). Hence, good communication abilities, both written and oral, are paramount and are probably the most important part of the investigations. Most of the time the ability to communicate effectively both in written form and oral form will determine the level of promotion of an individual. Good writing and good speaking abilities are very important and are a life-time endeavor. We never reach perfection as long as we live-but we must always try to reach perfection as long as we live.

We will consider reports

- Written
- Oral

A. Written Reports .

1. Generally speaking, we will consider only three types of written reports. These are:

- Research
- Memo
- Letter

A research report is a very detailed, lengthy report on an investigation. A memo report is less detailed than a research report but has sufficient detail for the reader. A letter report usually is an executive summary of the study and gives the reader the key significant facts, results, conclusions and recommendations. Often,

" . . . the real ability of a technical man remains unrecognized because the results of his work are poorly presented." Fre' Hoffman Rhodes, "Technical Report Writing" 1941 (6).

a) The purpose of a written report is to convey a set of facts from the mind of the writer to that of the reader. The report must be written with

- Clarity
- Precision
- and Completeness

b) The literary prose used in ordinary, nontechnical writing is

- Effective without being precise,
- Suggests rather than defines, and
- Implies rather than states.

c) Technical prose, on the other hand, must focus on

- Essentials
- Being clear and definite

For technical prose,

- (1) The writer must understand the material that he/she is trying to present
- (2) The material must be complete and organized
- (3) The results must be presented in logical order, for example,

- (a) experimental method.
- (b) experimental results
- (c) conclusions

The report must be written in good language (English in the U.S.) and must have good sentence structure. Good formatting with proper paragraphing is essential. The report must be complete yet it must be concise because a concise report is easier to follow.

d) **The requirements of a good report are:**

- Clearness
- Completeness
- Proper organization of material
- Correctness of presentation

2. The steps in report writing are:

- Collect data
- Assemble data
- Analyze data
- Outline the report
 - the organization and order in which various topics are to be discussed with
 - Divisions
 - Subdivisions

It is very important to first prepare a detailed outline of what is to be discussed prior to any writing.

3. *After the report is written,*

Ask yourself,

- Is the discussion clear?
- Is the discussion complete?
- Is the material logically arranged?
- Have all unnecessary words and statements been eliminated?
- Are there any errors in grammar, punctuation, or spelling?

4. *All tables and graphs should be near the point of discussion not all in the back of the report.*

5. *Correct styles, conventions and correct usage of words is essential.*

Technical reports are usually written in impersonal style.
For example,

Do not write:

I opened the valve.

We measured the distillate flow.

Instead, write:

The valve was opened.

The distillate flow was measured.

a) Sentences should be properly structured.

A good sentence length averages about 17 words because short sentences are too choppy and long sentences are too hard to follow.

Example:

A vertical kettle was used. It was cylindrical and made of steel. The kettle was three feet in diameter. It was six feet high. Both the top and the bottom were dished. It was provided with a steam jacket.

This paragraph can be better stated in one sentence:

The kettle was a vertical, steam jacketed, steel cylinder, three feet in diameter and six feet high, with dished heads.

**b) The selection of words is very important.
For example, the word obtained is used as:**

- Temperatures are obtained
- Samples are obtained

The word obtained is used instead of the words

collected, drawn, taken, removed, read, computed, calculated, estimated, derived, or measured.

The word *undoubtedly* means certainly. Therefore, do not use *probably* when you mean undoubtedly.

6. *Colloquial expressions are never used.*

For example, to write, "the agreement is not too good" is a colloquial usage.

It is better to write, "The agreement is rather poor".

The use of symbols instead of words is to be avoided.

Hence, do not say that the $\frac{dV}{d\theta}$'s vary as the 0.51 of the ΔP 's,

but rather say, the rate of flow varies as the 0.51 power of the difference in pressure.

B. *Organization of a Report (Formal)*

As stated, report forms discussed are:

- Formal (research)
- Memo
- Letter

The formal or research report is the most detailed. The structure of a research report is as follows:

1. *Title:* The title must be brief, but clear. For example,

"BATCH FILTRATION OF DIATOMACEOUS EARTH IN A PLATE AND FRAME FILTER."

and

"DISTILLATION OF METHANOL-WATER IN A SIEVE TRAY COLUMN."

Do not use titles such as:

FILTRATION
or
DISTILLATION

2. *Table Of Contents*

3. *Abstract*

The abstract should state:

- what you did
- what the results are
- what the conclusions are
- what the recommendations are

The abstract must, in very short paragraph form, give the reader a complete overview of the study. To learn how to write good abstracts, study abstracts written in good technical journals.

4. *Introduction*

The writer should include somewhere in the report, the

- Purpose of work

Why. is filtration of slurries in a plate and frame press important?

- Previous work in literature
- Theory - if significant

The writer must separate and discuss only the theory pertinent to the study.

5. Apparatus

A clear and complete sketch of the apparatus must be presented. The narrative accompanying the sketch must be complete.

Example

In the study of heat transfer, for a heat exchanger, describe the number and order of passes, number of tubes in each pass, and the ID, OD or BIG of each tube, the length of tubes, the material, the shell diameter, and the number and type of baffles, etc.

In the first paragraph of the narrative, which accompanies the sketch, give the overview of the equipment.

In succeeding paragraphs give more details.

6. Procedure

In the first paragraph of the procedure section, give an overview.

In the succeeding paragraphs give many more specific details.

Present a flow sheet of the system and always assume that the reader has intelligence and will understand. For example, don't say:

"The steam was turned on by opening the valve in the steam line."

The reader knows that steam is turned on by opening a steam valve.

From the written report, the reader must be able to operate the system to reproduce the data that were measured, if necessary.

7. *Experimental data*

Experimental data is presented in tables, graphs, charts, etc. Tables and graphs must be complete and detailed.

8. *Discussion*

In writing a discussion, refer to the detailed outline of the study that was prepared. This procedure will insure that the report is written in logical order and is complete.

First, introduce with what was done, then discuss results in logical order from the outline, with the proper conclusions at each point of discussion.

Errors should also be presented in the discussion.

9. *Conclusions*

Conclusions are presented in terse form. For example,

The conclusions of this study are:

- 1.
- 2.
- 3.

There is *no* discussion in this section of the report.

10. *Recommendations*

Recommendations are presented in terse form also. For example,

The recommendations of this study are:

- 1.
- 2.
- 3.

There is no discussion in this section of the report. This section gives what you, as the investigator, feel is necessary for further studies.

11. *Bibliography*

The bibliography or reference section should be clear.

It is wise to check textbooks, journal articles, etc. for proper form. For example,

Book

Felder, R. M. and Rousseau, R W. "Elementary Principles Of Chemical Processes", Second Ed., p.351, John Wiley & Sons, New York, 1986

Journal Articles

Ronald, M.C., "Investigation of the Teaching of English in Technical Schools" J. Eng. Educ. 43-, L17 (1941)

Patents

Carlin, G. B. and C. U. Laytor, US Patent 1, 475, 236 (Aug. 12, 1971)

12. *The Nomenclature used must be clearly defined.*

13. *The Appendix contains all important but not necessarily high priority data. For example,*

- Sample calculations
- Unimportant calibration graphs
- Data charts from recorders

Equations in a report must be properly written. For example,

“the empirical equation for the orifice is:

$$\frac{dw}{d\theta} = 4280 \Delta p^{0.5},$$

where $\frac{dw}{d\theta}$ = rate of flow of water, gal per minute

and Δp = drop in pressure across the orifice, pounds per square inch”

The definition of the terms in the equations can be presented with the equation in the main body of the report (as above), or one can place the definition of terms in the nomenclature section.

All **units** in technical reports, especially technical publications, are in SI units. Certain corporations in the U.S. may prefer the English system of units.

C. *Oral Reports*

The ability of an investigator to speak before a large or small audience is paramount. It is an invaluable asset which the investigator must develop. This development, like writing, is a life long process of trying to achieve perfection. Each presentation made should be better than the preceding one.

In making oral presentations,

- everyone must strive to be an effective speaker and
- we must all remember that everyone is nervous at first.

1. *Poor presentations are usually the result of*

- Lack of practice and
- Lack of skill in speaking

We do not read a paper before an audience and we must avoid "aaah" "S" Or "uh's".

We do not speak to the blackboard, and not only to the key people in the audience, but always to the entire audience.

Our speaking style should be conversational and not monotonous and, hence, boring.

2. *A good presentation can be assured if we:*

- Prepare good audio-visual material which is not cluttered
- Practice the presentation
- Overcome the nervousness of the first few minutes of the presentation
- Speak to the audience, the entire audience and not only to key people
- Have the material well organized such that it is logical and easy to follow

3. *In your presentation, tell the listeners:*

- What you will tell them
- Then tell them
- Then tell them what you have told them

In other words, always

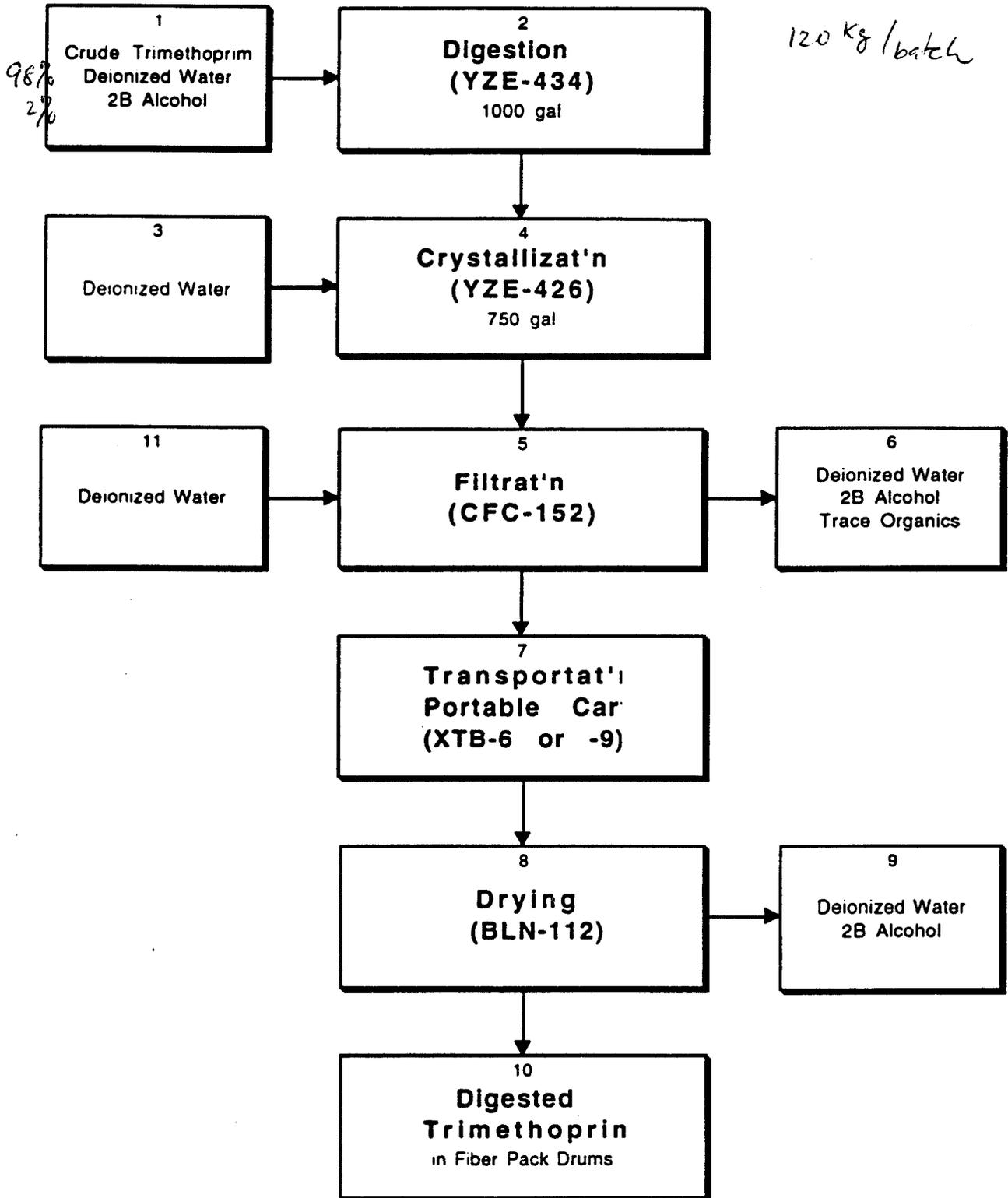
1. Introduce the main points that you will be discussing, then
2. Explain each point in detail, and finally,
3. Review and summarize the points that you have discussed.

References

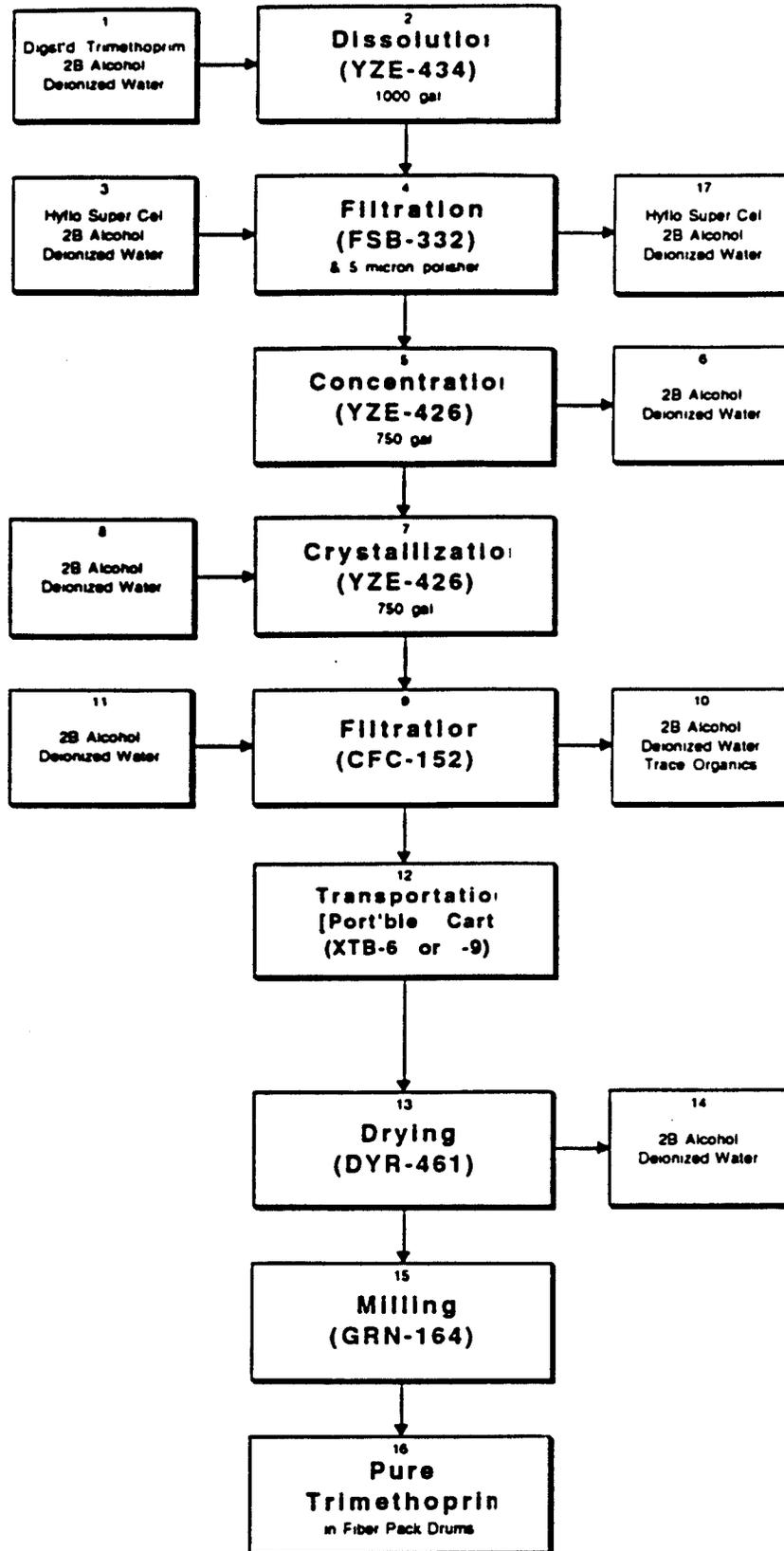
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Appendix C
Field Trip: Hoffmann LaRoche
Pharmaceutical Manufacture Plant

Trimethoprim(51310):
Digestion



Trimethoprim (51310)
Recrystallization



Bldg 44 Pure Water System: Prep'n of DI Water

