Chapter 1

Contingency Support

Topics

To hear audio, click on the box.

Overview

As a Seabee in the Naval Construction Force (NCF), your primary mission is to support the Navy and Marine Corps during contingency operations. This means you have to be knowledgeable about contingency operations. Remember, the primary reason Seabees exist is to provide construction support in any contingency operation and to train everyone accordingly.

As a Crew Leader, Crew Member, Project Manager, and Project Supervisor, your understanding of how the Advanced Base Functional Component ABFC system works and what types of field structures you will be dealing with is critical to contingency operations.

Objectives

When you have completed this chapter, you will be able to do the following:

1. Describe the purpose and components of the Advanced Base Functional Components (ABFC) program.

Prerequisites

None

This course map shows all of the chapters in Utilitiesman Advanced. The suggested training order begins at the bottom and proceeds up. Skill levels increase as you advance on the course map.

<table>
<tr><td>Air Conditioning and Refrigeration</td><td rowspan="10">↑</td><td rowspan="10">U
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Features of this Manual

This manual has several features which make it easy to use online.

- Figure and table numbers in the text are italicized. The Figure or table is either next to or below the text that refers to it.
- The first time a glossary term appears in the text, it is bold and italicized. When your cursor crosses over that word or phrase, a popup box displays with the appropriate definition.
- Audio and video clips are included in the text, with an italicized instruction telling you where to click to activate it.
- Review questions that apply to a section are listed under the Test Your Knowledge banner at the end of the section. Select the answer you choose. If the answer is correct, you will be taken to the next section heading. If the answer is incorrect, you will be taken to the area in the chapter where the information is for review. When you have completed your review, select anywhere in that area to return to the review question. Try to answer the question again.
- Review questions are included at the end of this chapter. Select the answer you choose. If the answer is correct, you will be taken to the next question. If the answer is incorrect, you will be taken to the area in the chapter where the information is for review. When you have completed your review, select anywhere in that area to return to the review question. Try to answer the question again.

1.1.1 ADVANCED BASE FUNCTIONAL COMPONENT SYSTEM

The Advanced Base Functional Component (***ABFC***) system provides support facilities to the constantly changing tactical and strategic situations using a modular or building block concept. Components were needed to incorporate personnel, materials, equipment, and facilities. These components were designed and developed to fulfill specific functions, no matter where the components were placed. The Navy ABFC system is based on early experiences in advanced base planning and shipment used in World War II. Additional improvements were adopted from experiences learned in Korea, Vietnam, and the Persian Gulf, as well as many other small conflicts.

ABFCs are normally complete entities. There are three basic groupings of the ABFC system:

- ***Component***, a complete unit, such as p-25 smart
- ***Facility***, a portion of a complete component, like a galley facility
- ***Assembly***, a portion of a facility for instance a field burner

ABFCs, though normally complete, may not be supplied with housing, messing, medical facilities, maintenance facilities, defensive ordnance, communication equipment, and utilities with each component. These service components or facilities are to be integrated into an overall base development or augmentation plan. The ABFC system consists of two resources. The first resource is the *Table of Advanced Base Functional Components with Abridged Initial Outfitting Lists,* OPNAV 41P3A, which is part of OPNAVINST 4042.1 The second resource is an online NAVFAC system, the Advanced Base Functional Component/Table of Allowances system, which replaces the *Facilities Planning Guide,* NAVFAC P-437.

To facilitate reference, ABFCs are assigned descriptive names to indicate their functions and alphanumeric designators. An abridged initial outfitting list (ABIOL) is an itemized line-item printout of the material in each ABFC. Each command or bureau of the system is responsible for maintaining a detailed listing of that part of the ABIOL assigned to it.

1.1.1 Advanced Base Functional Component/Table of Allowances System

When you are tasked to assist in planning the construction of an advanced base, consult the Advanced Base Functional Component/Table of Allowances online system, also referred to as the ABFC View Program. This online system, which identifies the structures and supporting utilities of the Navy ABFC system, was developed to make pre-engineered facility designs and corresponding material lists available to planners at all levels. While these designs relate primarily to the expected needs at advanced bases and to the Navy ABFC system, they also can be used to satisfy peacetime requirements. Facility, logistic, and construction planners will find the information required to select and document the materials necessary to construct facilities.

The ABFC/TOA system consists of multiple sections. The P437 Drawings section contains reproducible engineering drawings and is organized as follows:

- Component Site Plans are indexed by component and ABFC designation.
- Facility Drawings are indexed by facility number and DOD category code.

- Assembly Drawings contain assembly information and are indexed by assembly number.

Each drawing is a detailed construction drawing that describes and lists the facilities, the assemblies, or the line items required to complete it. A summary of logistic, construction, and cost data is provided for each component, facility, and assembly of the ABFC system. A component is defined as a grouping of personnel and material that has a specific function or mission at an advanced base. Whether it is located overseas or in CONUS, a component is supported by facilities and assemblies.

A construction network is included in each facility of the ABFC system as part of the design package, as shown in *Figure 1-1*.

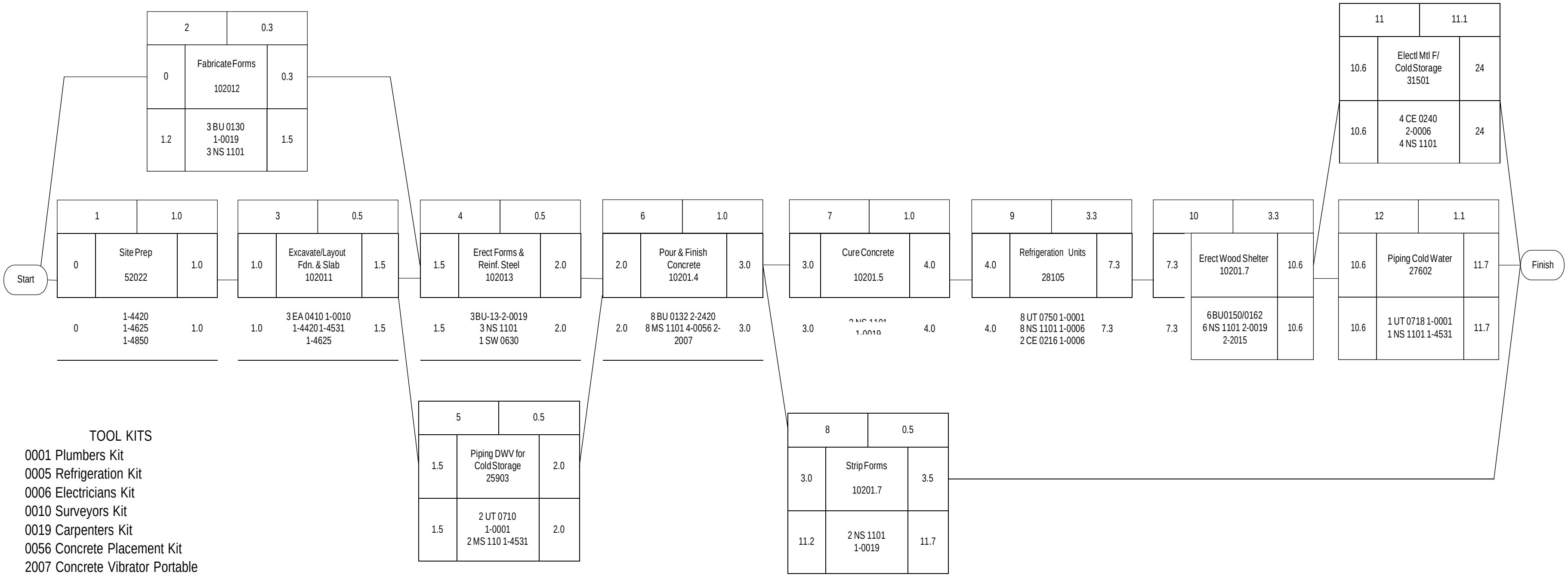


Figure 1-1 — Construction Network.

TOOL KITS

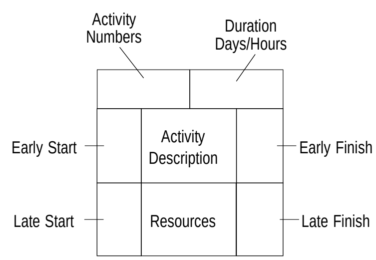
0001 Plumbers Kit
0005 Refrigeration Kit
0006 Electricians Kit
0010 Surveyors Kit
0019 Carpenters Kit
0056 Concrete Placement Kit
2007 Concrete Vibrator Portable
2015 Drill Portable ¾"

EQUIPMENT

2420 Transit Mixer
4420 Motor Grader
4531 Front End Loader
4625 Roller Vibrating
4850 Crawler Tractor

SKILLS

0130 BU Forming and Reinforcing
0132 BU Concrete Work
0150 BU Light Frame Construction
0162 BU Roofing
0216 CE Elec Motors & Control
0240 CE Interior Wiring
0410 EA Surveying
0630 SW Steel Reinforcing
0710 UT Plumbing
0760 UT Air Con & Refrigeration



NOTES
1. Equipment comes with the operator.
2. One manday equals ten manhours.
3. When this network is used in a CMS program[Ch5], it adds 0.9 day duration to the project.

Users of this drawing are requested to note discrepancies and recommended revisions on a blue print copy and mail to

Commanding Officer (Code 155)
Naval Construction Battalion Center
Port Hueneme, CA

The network includes information on tool kits, equipment, and skills required for each facility. You can save time and effort by using the construction networks that were developed for each facility in the ABFC system. To benefit from the construction networks, you must have an understanding of the basic principles and assumptions the networks are based on. Network analysis procedures for precedence diagramming are covered in Chapter 5 of the *Seabee Planner's and Estimator's Handbook,* NAVFAC P-405.

Separate sections of the ABFC/TOA system contain the detailed data display for each component, facility, and assembly. (Except for earthwork, material lists in the system are complete bills of material.) Sections are arranged as follows:

- Facility/Group lists and describes by DOD category code the facilities requirement for each component.
- Assembly lists and describes by assembly number the assembly requirement for each facility.
- Local National Stock Number (NSN)/Cage & Part Number lists line-item requirements by NSN for each assembly.

The ABFC/TOA system also contains other useful information for planners, such as crew sizes; man-hours by skill; land areas; amounts of fuel necessary to make a component, facility, or assembly operational; and information about predesigned facilities and assemblies that are not directly related to components shown in the ABFC table (OPNAV 41P3). These predesigned facilities and assemblies give the planner alternatives for satisfying contingency requirements when the callout of a complete component is not desired. To make the ABFC/TOA system compatible with DOD planning guides, a related publication, *Category Codes Facilities,* NAVFAC P-72, establishes the category codes, the nomenclature, and the required units of measure for identifying, classifying, and quantifying real property. These are the cardinal category codes:

100	Operations and Training
200	Maintenance and Production
300	Research, Development, and Evaluation
400	Supply
500	Hospital and Medical
600	Administrative
700	Housing and Community Support
800	Utilities and Ground Improvement
900	Real Estate

If a facility is required for enlisted personnel quarters, for example, it will be found in the 700 series (Housing and Community Support). The assemblies within each facility consist of a grouping of line items at the NSN level which, when assembled, will perform a specific function in support of the facility. An assembly is functionally grouped in such a way that the assembly number relates to the Occupational Field 13 skill required to install it. The groupings are numbered, as shown in *Table 1-1*.

Table 1-1 — Assembly Sequence Numbers.

Description	Number Start	Sequence Stop
Builder (BU) oriented	10,000	19,999
Utilitiesman (UT) oriented	20,000	29,999
Construction Electrician (CE) oriented	30,000	39,999
Steelworker (SW) oriented	40,000	49,999
Equipment Operator (EO) oriented	50,000	54,999
Waterfront equipment	55,000	57,999
Underwater construction and diving equipment	58,000	59,999
Operational supplies	60,000	62,499
Operating consumables	62,500	64,999
NBC warfare	65,000	67,499
Personnel-related supplies	67,500	69,999
Unassigned at present	70,000	79,999
Shop equipment including maintenance tools	80,000	80,999
Unique ABFC tool kits	81,000	81,999
Naval Construction Force (NCF) Table of Allowance (TOA) construction tools and kits (power tools)	82,000	82,099
NCF TOA construction tools and kits (electrical)	82,500	82,599
NCF TOA construction tools and kits (miscellaneous)	83,000	83,199
NCF TOA construction tools and kits (rigging)	84,000	84,099
Shop equipment (ABFC unique)	85,000	87,499

1.1.1 Tailoring Components and Facilities

When you use the ABFC system, remember to tailor it to your specific needs. Know your exact mission and its requirements. Choose the components, the facilities, or the assemblies that best fit or can be tailored to meet your desired goals. Develop modular elements to serve similar functions in various locations. The exact requirements for a specific base cannot be defined, economically designed, nor supported within the general system. However, the base development planner knows the specific location, mission, unit composition, and availability of other assets. The planner can then select from the ABFC system the components or facilities that satisfy these specific requirements. Tailor the preplanned ABFC assets to come up with what is needed.

Tailor components or facilities by one or both of these:

1. Deleting or adding facilities or assemblies
2. Specifying requirements for the Tropical or North Temperate Zone

Tropical temperate zone information is indicated by the abbreviation “Trop.” North Temperate Zone information is indicated by the word “North.”

1.1.2 Use and Application of the ABFC/TOA System

Although a listing in the ABFC/TOA system may help you order individual items in general supply, it does NOT replace stock lists of systems commands or bureaus, offices, single managers, or inventory control points. Stock numbers and descriptions can be verified through appropriate stock lists. You are responsible for verifying stock numbers when ordering a component, a facility, or an assembly. Navigate to the ABFC/TOA system on NAVFAC as follows:

Link to the ABFC/TOA system: https://abfcview.navfac.navy.mil/login.cfm.

You will be asked to verify your CAC code.

You will see the ABFC TOA Web Manager screen shown in *Figure 1-2*.

Figure 1-2 — ABFC login screen.

Click on 

.

You will see the About ABFC/TOA Planning Information screen shown in *Figure 1-3*.

Figure 1-3 — About ABFC/TOA planning information screen.

1.1.2.1 2.1 Component

There are a number of screens showing information on components. These screens are accessed as follows:

Click on 

.

You will see the ABFC/TOA component search screen shown in *Figure 1-4*.

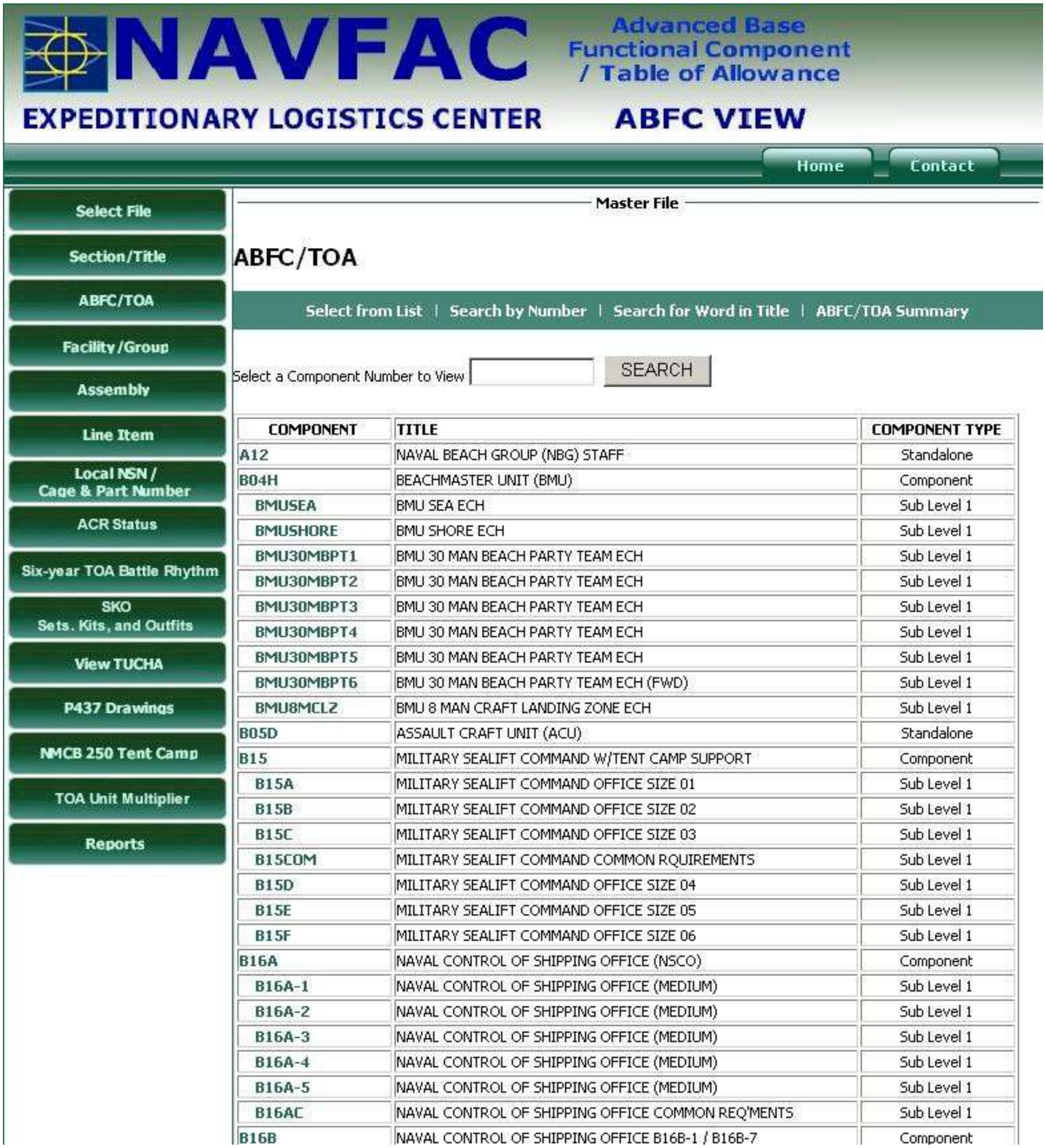


Figure 1-4 — ABFC/TOA component search screen.

Enter the number of the component you need, and then click on SEARCH. From the list, select the component you need. You will see the ABFC/TOA Component View screen shown in *Figure 1-5*.

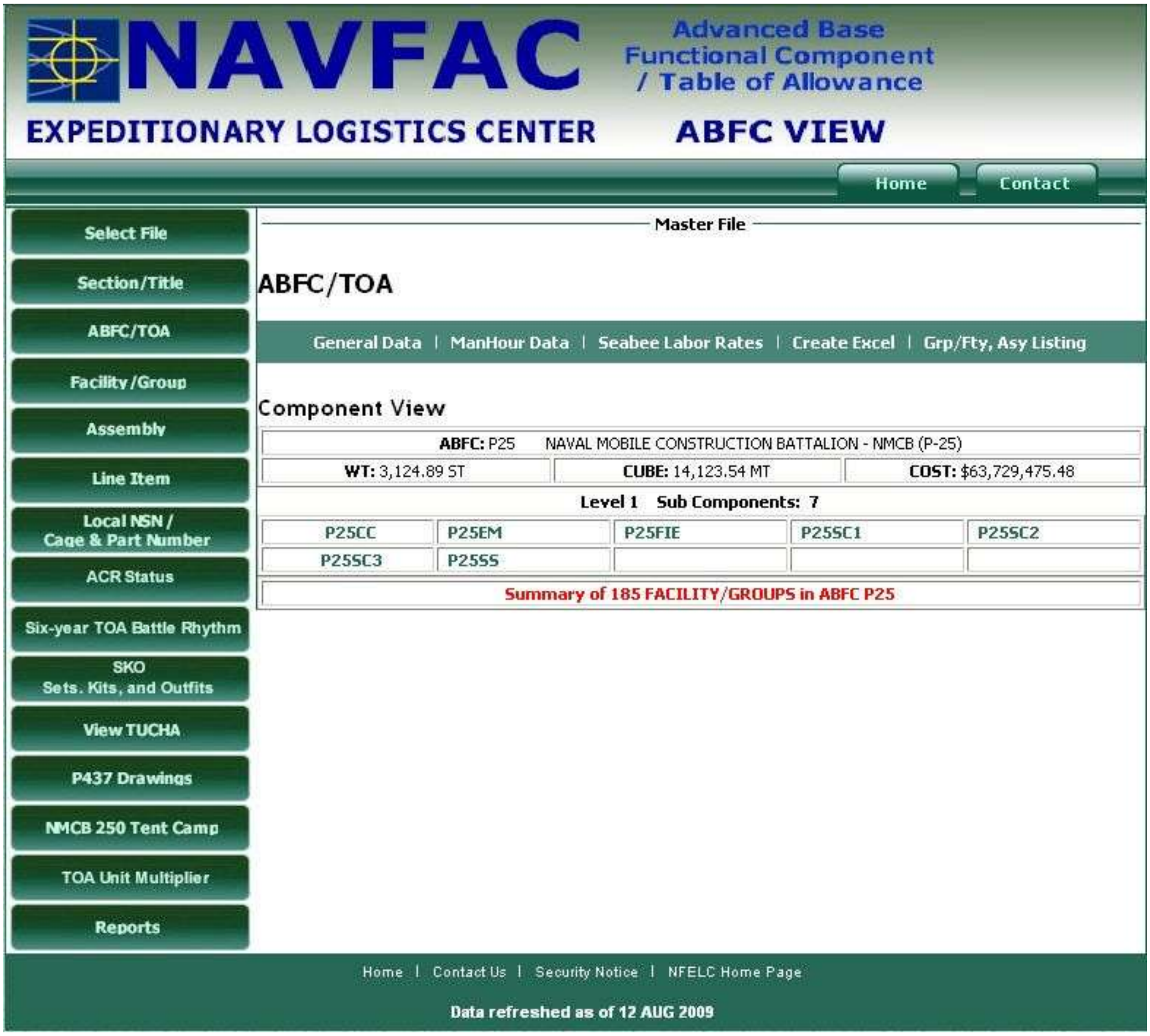
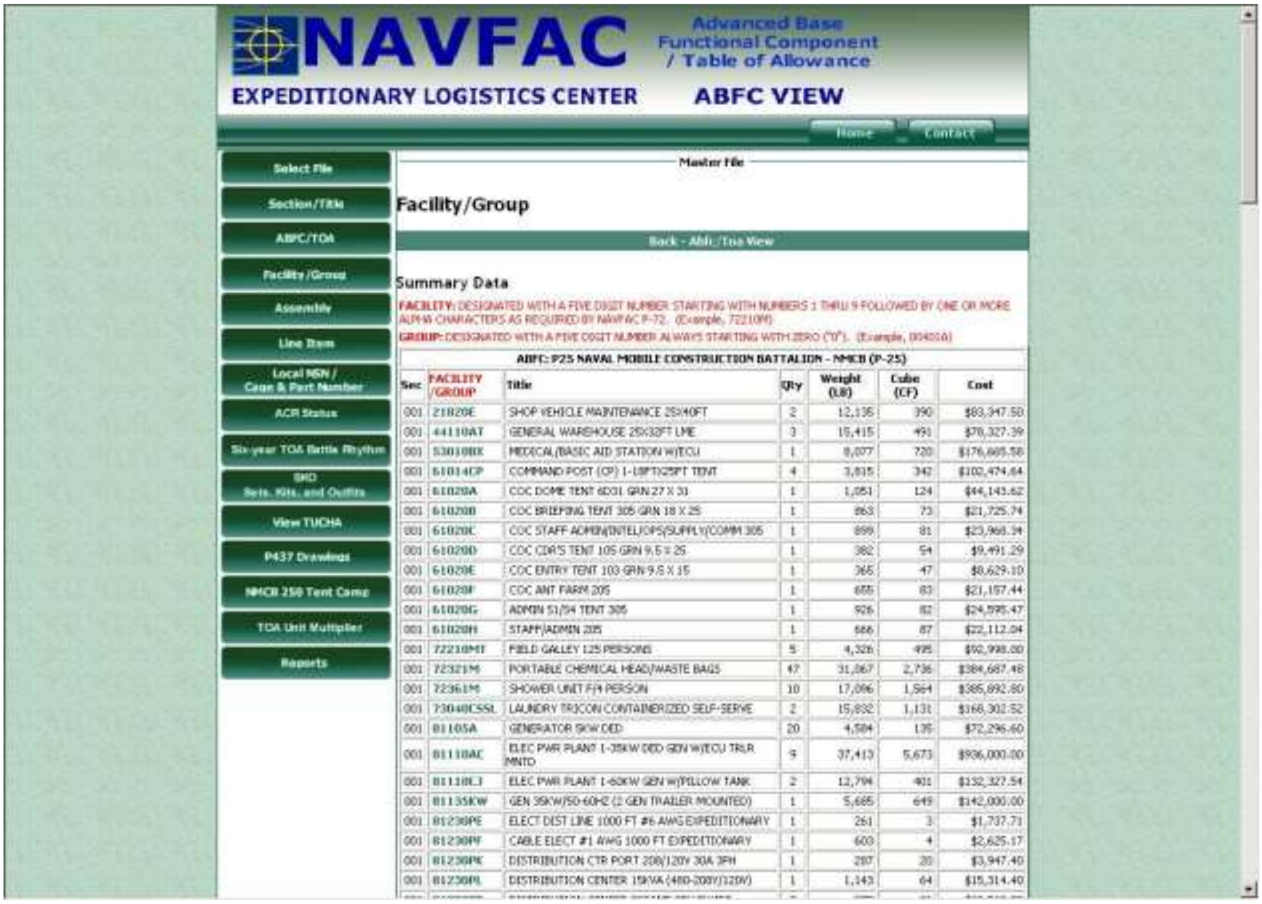


Figure 1-5 — ABFC/TOA component view screen.

This is the main screen for component P25. It displays the weight, cubic feet, and cost of the component. It also lists the sub components included in this component. To view the subcomponents, click on the red Summary option. You will see the ABFC/TOA Summary Data screen, as shown in *Figure 1-6*, which shows a typical component breakdown of the P-25.



ABFC: P25 NAVAL MOBILE CONSTRUCTION BATTALION - NMCB (P-25)						
Sec	FACILITY /GROUP	Title	Qty	Weight (LB)	Cube (CF)	Cost
001	21820E	SHOP VEHICLE MAINTENANCE 25X40FT	2	12,136	390	$83,347.50
001	44110AT	GENERAL WAREHOUSE 25X32FT LME	3	15,415	491	$78,327.39
001	53010BX	MEDICAL/BASIC AID STATION W/ECU	1	8,077	720	$176,685.58
001	61014CP	COMMAND POST (CP) 1-18FTX25FT TENT	4	3,815	342	$102,474.64
001	61020A	COC DOME TENT 6D01 GRN 27 X 31	1	1,051	124	$44,143.62
001	61020B	COC BRIEFING TENT 305 GRN 18 X 25	1	863	73	$21,725.74
001	61020C	COC STAFF ADMIN/INTEL/OPS/SUPPLY/COMM 305	1	899	81	$23,968.34
001	61020D	COC CDR'S TENT 105 GRN 9.5 X 25	1	382	54	$9,491.29
001	61020E	COC ENTRY TENT 103 GRN 9.5 X 15	1	365	47	$8,629.10
001	61020F	COC ANT FARM 205	1	655	83	$21,157.44
001	61020G	ADMIN 51/54 TENT 305	1	926	82	$24,595.47
001	61020H	STAFF/ADMIN 205	1	666	87	$22,112.04
001	72210MT	FIELD GALLEY 125 PERSONS	5	4,326	495	$92,998.00
001	72321M	PORTABLE CHEMICAL HEAD/WASTE BAGS	47	31,067	2,736	$384,687.48
001	72361M	SHOWER UNIT F/4 PERSON	10	17,096	1,564	$385,892.80
001	73040CSSL	LAUNDRY TRICON CONTAINERIZED SELF-SERVE	2	15,832	1,131	$168,302.52
001	81105A	GENERATOR 5KW DED	20	4,584	135	$72,296.60
001	81110AC	ELEC PWR PLANT 1-35KW DED GEN W/ECU TRLR MNTD	9	37,413	5,673	$936,000.00
001	81110EJ	ELEC PWR PLANT 1-60KW GEN W/PILLOW TANK	2	12,794	401	$132,327.54
001	81135KW	GEN 35KW/50-60HZ (2 GEN TRAILER MOUNTED)	1	5,685	649	$142,000.00
001	81230PE	ELECT DIST LINE 1000 FT #6 AWG EXPEDITIONARY	1	261	3	$1,737.71
001	81230PF	CABLE ELECT #1 AWG 1000 FT EXPEDITIONARY	1	603	4	$2,625.17
001	81230PK	DISTRIBUTION CTR PORT 208/120V 30A 3PH	1	287	20	$3,947.40
001	81230PL	DISTRIBUTION CENTER 15KVA (480-208Y/120V)	1	1,143	64	$15,314.40

Figure 1-6 — ABFC/TOA component summary data screen.

The facilities required to make the component operative are listed in numerical sequence by DOD category code. The alpha suffix for each facility designator indicates differences between sizes, types, or layouts of facilities with the same functional purpose. Facility capacity is expressed in terms of the units of measure used in the *Category Codes Facilities,* NAVFAC P-72. The component capacity is figured by multiplying the facility capacity and the quantity. Weight and cube are measured in normal units for export packing.

Access general data about the component by first returning to the ABFC/TOA Component View screen. Select Back – ABFC/TOA View from the banner, and then select General Data.

Figure 1-7 shows the general data for the P-25. In this screen, notice that the Weight, Cube, and Cost are shown for both Tropical and North temperate zones. The site plan pertaining to each component is shown by a NAVFAC drawing number. The word *NONE* appears for components that have no site plans.

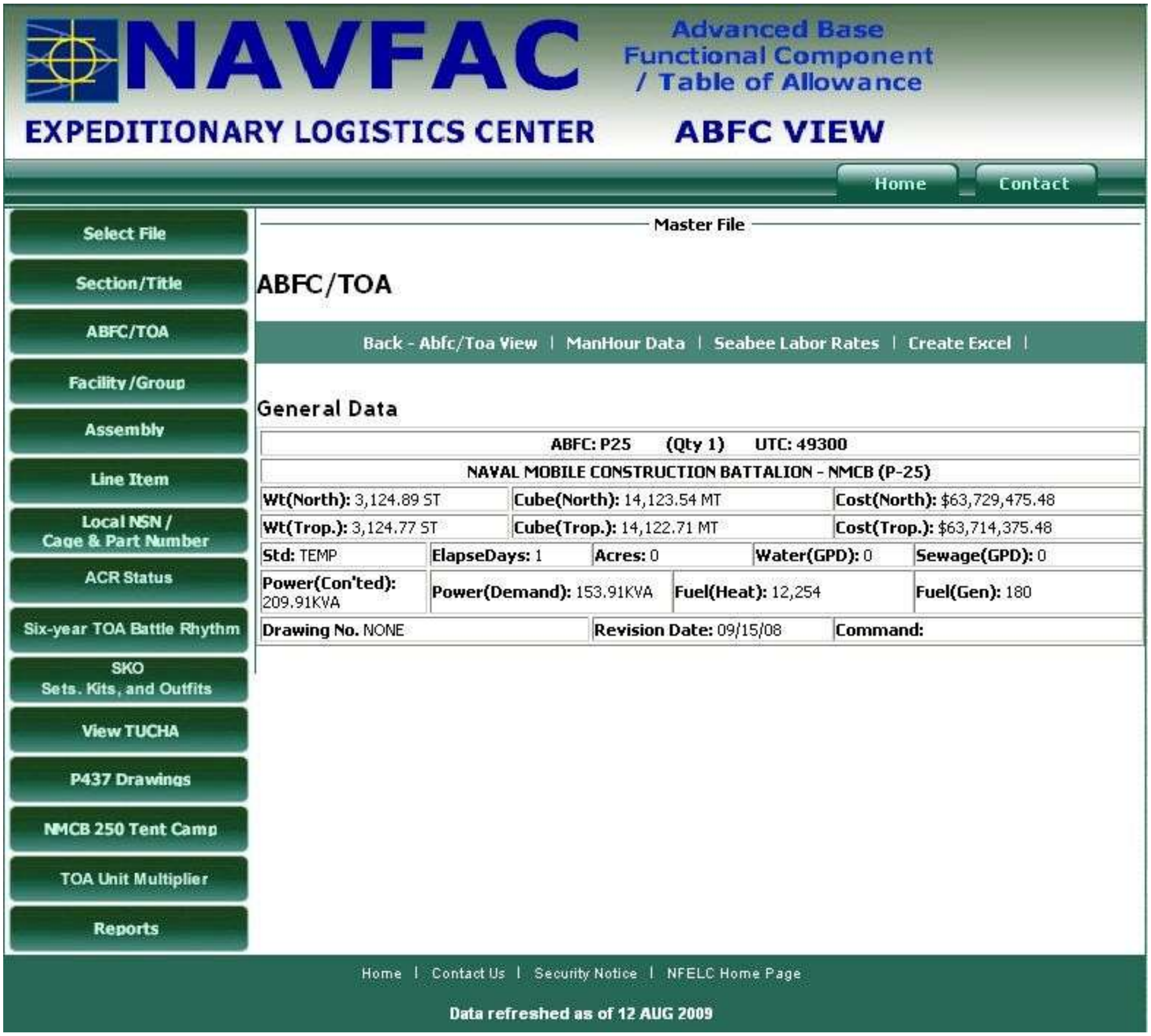


Figure 1-7 — ABFC/TOA component general data screen.

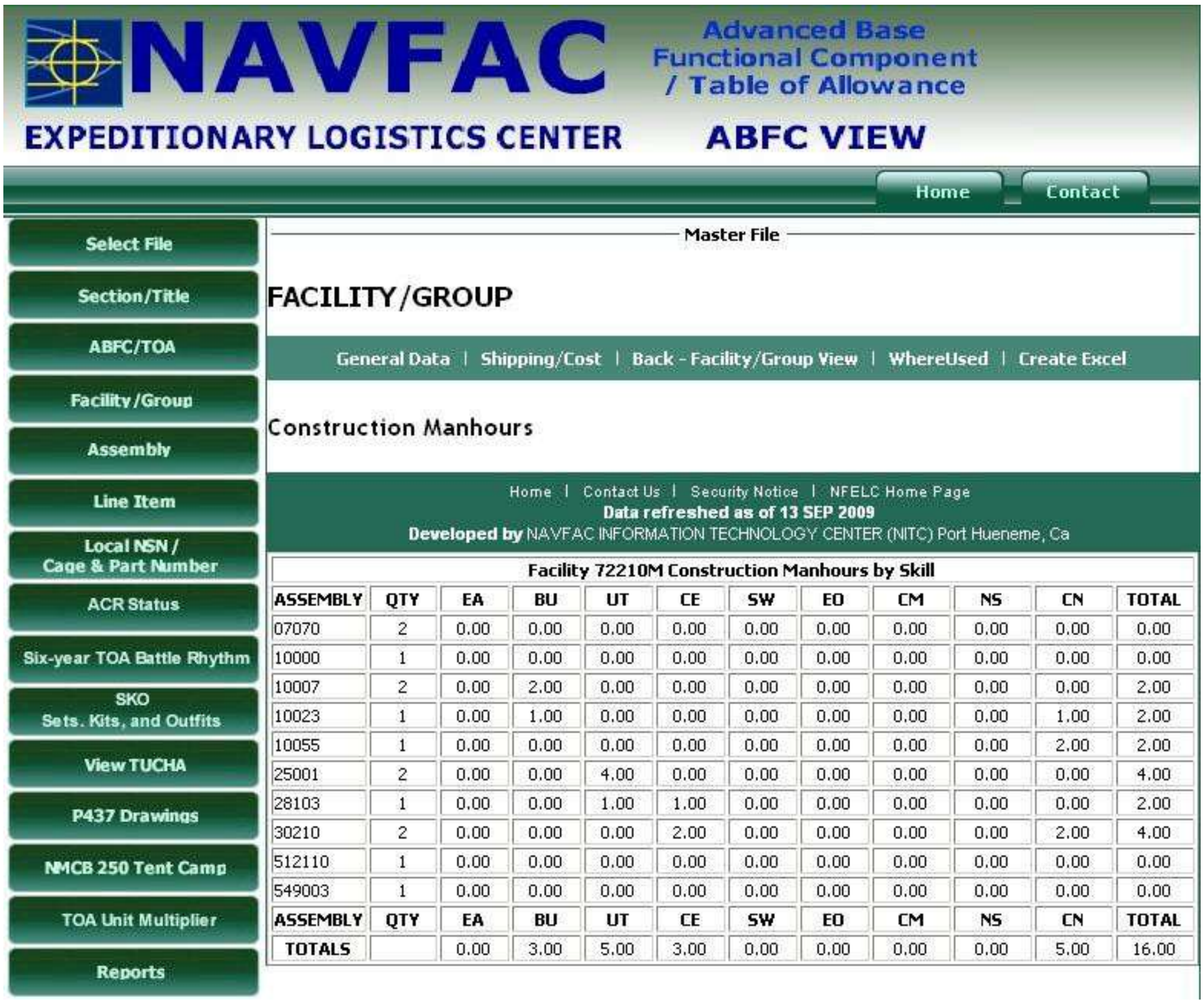
Summary data, located below the Weight, Cube, and Cost, provides information on the following:

1. Construction standards (Std), taken from *Joint Chiefs of Staff (JCS),* publication 3, are grouped into two classifications: Initial and Temporary. Initial (INIT) is a duration requirement of less than 6 months Temporary (TEMP) is a duration requirement of 6 to 60 months.
2. Days of construction duration (ElapseDays) are based on job requirements, optimum construction crew size, and full-material availability.
3. Often the land requirements (Acres), based on the assumed plot plan, will not be followed exactly because of terrain or existing buildings. The idealized plot plan was developed to design supporting utility systems. The information contained in the utility facilities has been increased to allow for variation in terrain.
4. Water and sewage (GPD) are based on ABIOL or TOA contents and the utility systems designed to these criteria.

5. The connected electrical load [Power (Con'ted)] has been computed based on knowledge of ABIOL or TOA contents. A load diversity factor has been applied to compute the kVA demand [Power (Demand)].

6. Fuel usage is computed on 30-day requirements for installed fuel-fired [Fuel (Heat)] or engine-driven [Fuel (Gen)] equipment only. No allowance for automotive, construction, weight handling, and other jobsite support equipment fuel is included. Fuel is not provided when facilities or assemblies are shipped. POL sustainment needs to be coordinated with area and local commander during your planning process. NAVSUP provides fuel as a contribution when whole components are shipped.

Access the skill requirements by selecting ManHour Data from the banner. *Figure 1-8* shows the Construction Manhours screen.



Facility 72210M Construction Manhours by Skill

ASSEMBLY	QTY	EA	BU	UT	CE	SW	EO	CM	NS	CN	TOTAL
07070	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10000	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10007	2	0.00	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.00
10023	1	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	2.00
10055	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.00	2.00
25001	2	0.00	0.00	4.00	0.00	0.00	0.00	0.00	0.00	0.00	4.00
28103	1	0.00	0.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	2.00
30210	2	0.00	0.00	0.00	2.00	0.00	0.00	0.00	0.00	2.00	4.00
512110	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
549003	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ASSEMBLY	QTY	EA	BU	UT	CE	SW	EO	CM	NS	CN	TOTAL
TOTALS		0.00	3.00	5.00	3.00	0.00	0.00	0.00	0.00	5.00	16.00

Figure 1-8 — ABFC/TOA screen.

The skill requirements are designated by Seabee (OF- 13) ratings and are expressed in man-hours, as computed for each assembly. The total man-hours are also shown for the component.

1.1.2.2 Facility

Access the Facility/Group View screen by clicking on 

.

Figure 1-9 shows a typical facility/group view--in this example, facility #72361M, the 4 person shower unit. The header shows the facility number and briefly describes the basic capability of the facility.

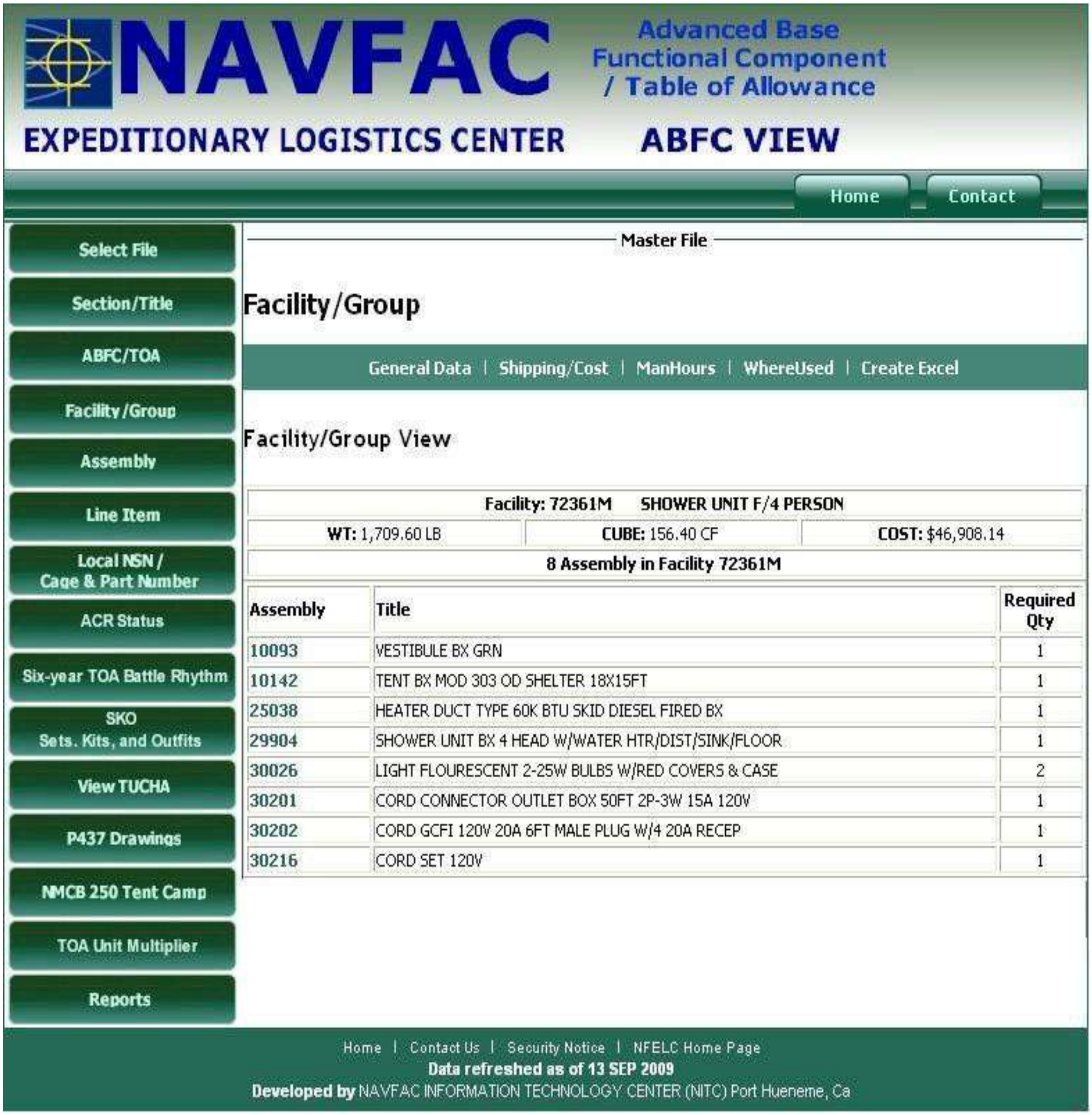
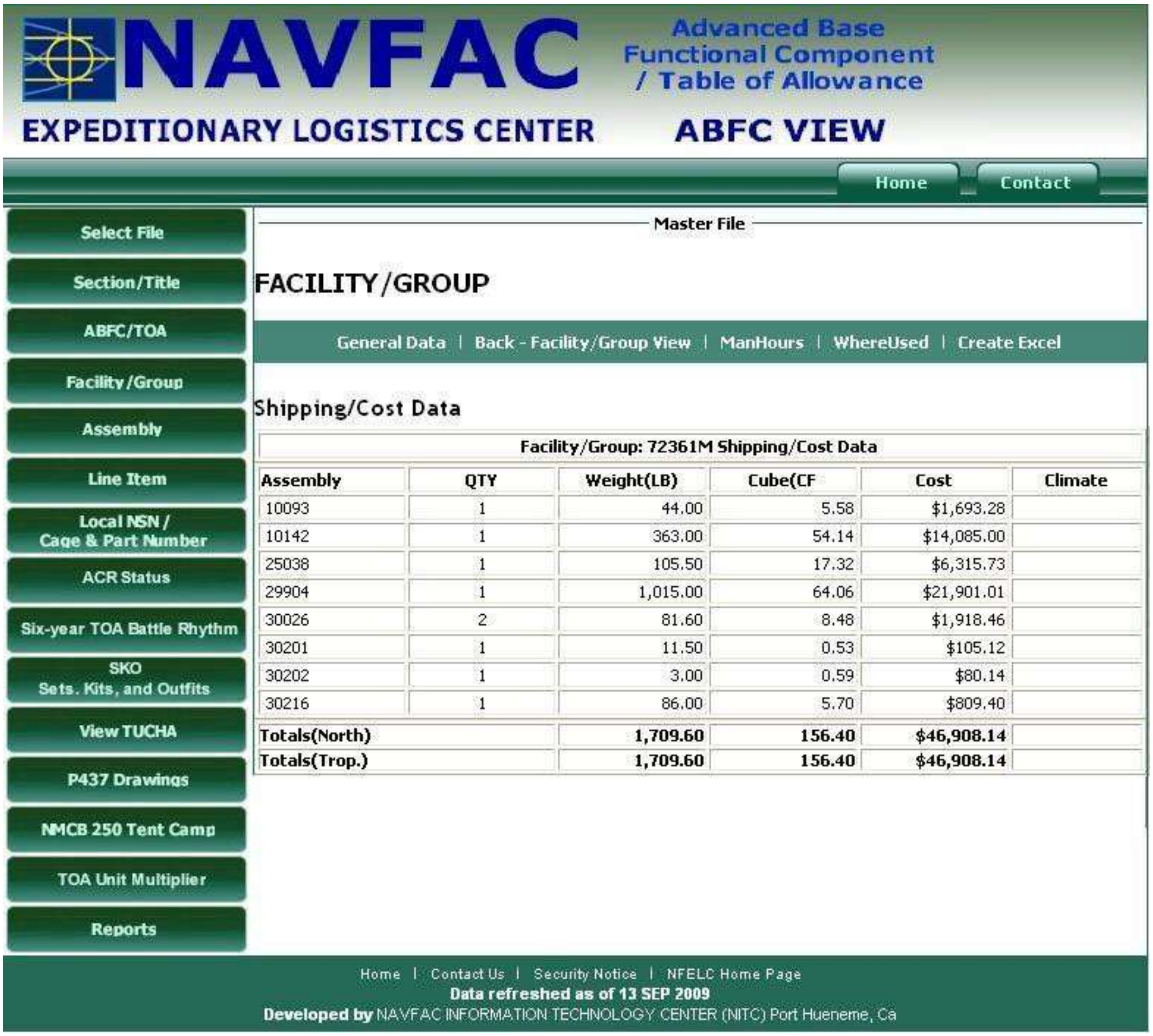


Figure 1-9 — ABFC/TOA facility/group view screen.

The Weight, Cube, and Cost for the facility display below the header. The assemblies required to make the facility functionally operational are listed in assembly number sequence. These numbers were derived from the prime trade involved in the construction. The 20,000 series indicates the Utilitiesman.

A brief description appears in the next column. This is followed by the required quantity for each assembly in the facility. The required quantity is used as a multiplier, indicating the number of assemblies to be ordered.

Access the shipping/cost data screen by selecting Shipping/Cost from the banner. *Figure 1-10* shows the Shipping/Cost Data screen for Facility/Group 72361M.



Assembly	QTY	Weight(LB)	Cube(CF	Cost	Climate
10093	1	44.00	5.58	$1,693.28	
10142	1	363.00	54.14	$14,085.00	
25038	1	105.50	17.32	$6,315.73	
29904	1	1,015.00	64.06	$21,901.01	
30026	2	81.60	8.48	$1,918.46	
30201	1	11.50	0.53	$105.12	
30202	1	3.00	0.59	$80.14	
30216	1	86.00	5.70	$809.40	
Totals(North)		**1,709.60**	**156.40**	**$46,908.14**	
Totals(Trop.)		**1,709.60**	**156.40**	**$46,908.14**	

Figure 1-10 — ABFC/TOA facility/group shipping cost screen.

Weight and cubic feet are measured in normal terms for export packing. Weight, cubic feet, and dollar value reflect totals for each line. Climate shows which zone the assembly is rated for, indicated by N for the North Temperate Zone or T for the Tropical Zone. Only assemblies required for arctic operation are designated code N. Other facilities or assemblies are designed for use in both North and South Temperate Zones and Tropical Zones.

Construction estimates are computed in the same manner as components except for the addition of the primary facility capacity and the secondary capacity, as described in the NAVFAC P-72. This is used, for example, in the 700 series of facilities where the primary capacity is expressed in personnel and the secondary is expressed in square feet.

The recoverability code is a broad indication of the relocatability or recoverability of the facility. The code A indicates total recoverability, and D indicates a disposable facility. More details are found in *Table 1-2*, Recoverability Code.

Table 1-2 — Recoverability Code.	
A. Relocatable:	Designed for the specific purpose of being readily erected, disassembled, stored, and reused. Includes tentage.
B. Pseudo-relocatable:	Not specifically designed to be dismantled and relocated, but could be, with considerable effort and loss of parts. Rigid-frame building included.
C. Nonrecoverable:	A structure not designed to provide relocatability features or one where the cost of recovery of the shelter exceeds 50% of the initial procurement cost.
D. Disposable:	Those temporary structures having low acquisition and erection costs, which are not designed for relocation and reuse and may be left on site or destroyed, such as SEAHUTS.

1.1.2.3 Assembly

Search for assemblies by first clicking on 

. This brings up the Assembly search screen shown in *Figure 1-11*.

Figure 1-11 — ABFC/TOA assembly search screen.

Enter the assembly you are searching for and press SEARCH.

Figure 1-12 shows a typical entry for an assembly which provides the necessary material required to build this assembly.

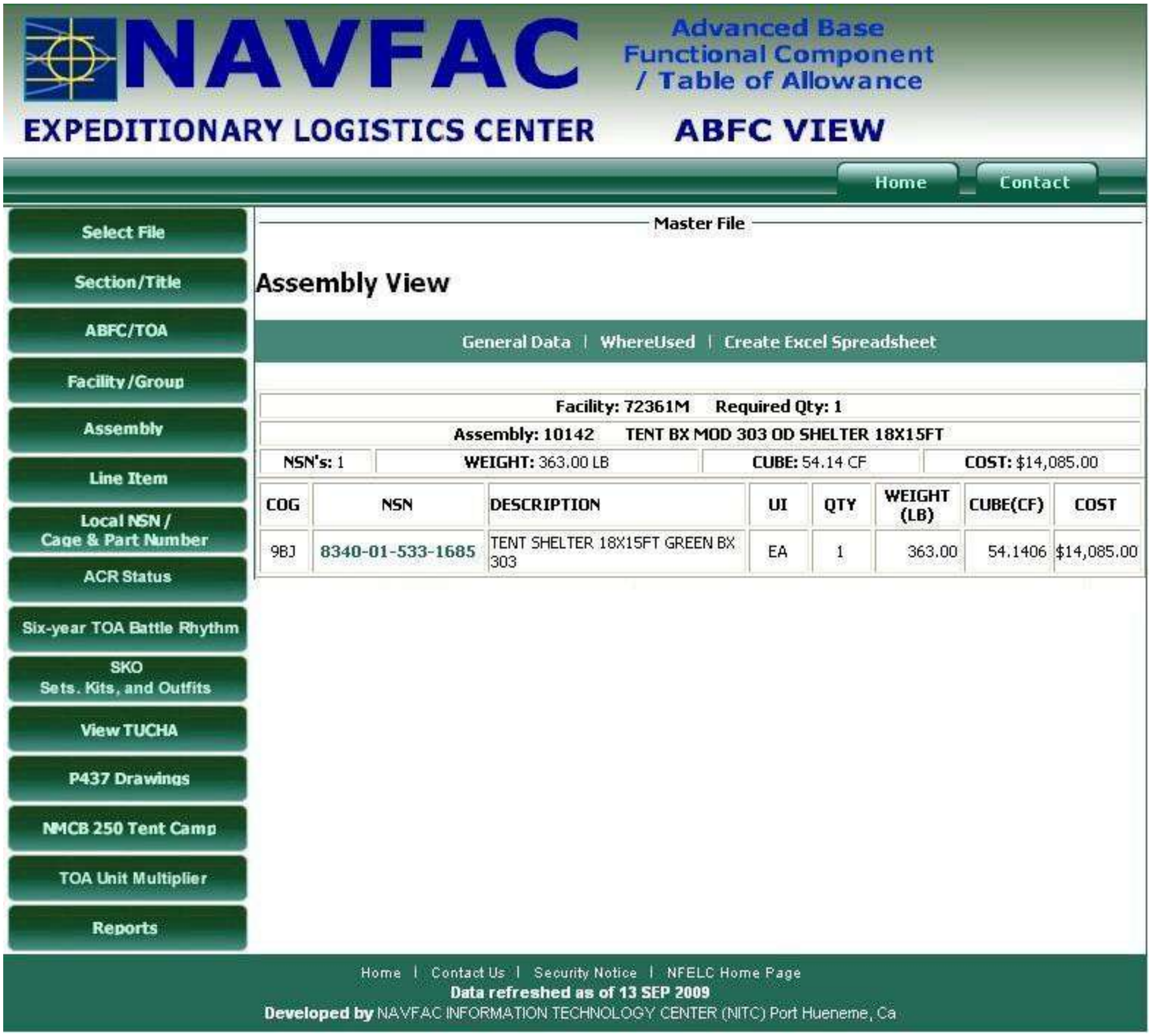


Figure 1-12 — ABFC/TOA assembly view screen.

Header information is the same as that for a facility. Assembly line-item requirements are listed by cognizance symbol and NSN. The unit of issue, weight, cubic feet, and dollar value are extracted from supply files once the requirement data is entered. This data changes often, and is updated in the system as the need arises. Access the manpower information for this assembly by selecting General Data from the banner.

Figure 1-13 shows a typical entry for an assembly which provides the estimated manpower required to build this assembly.

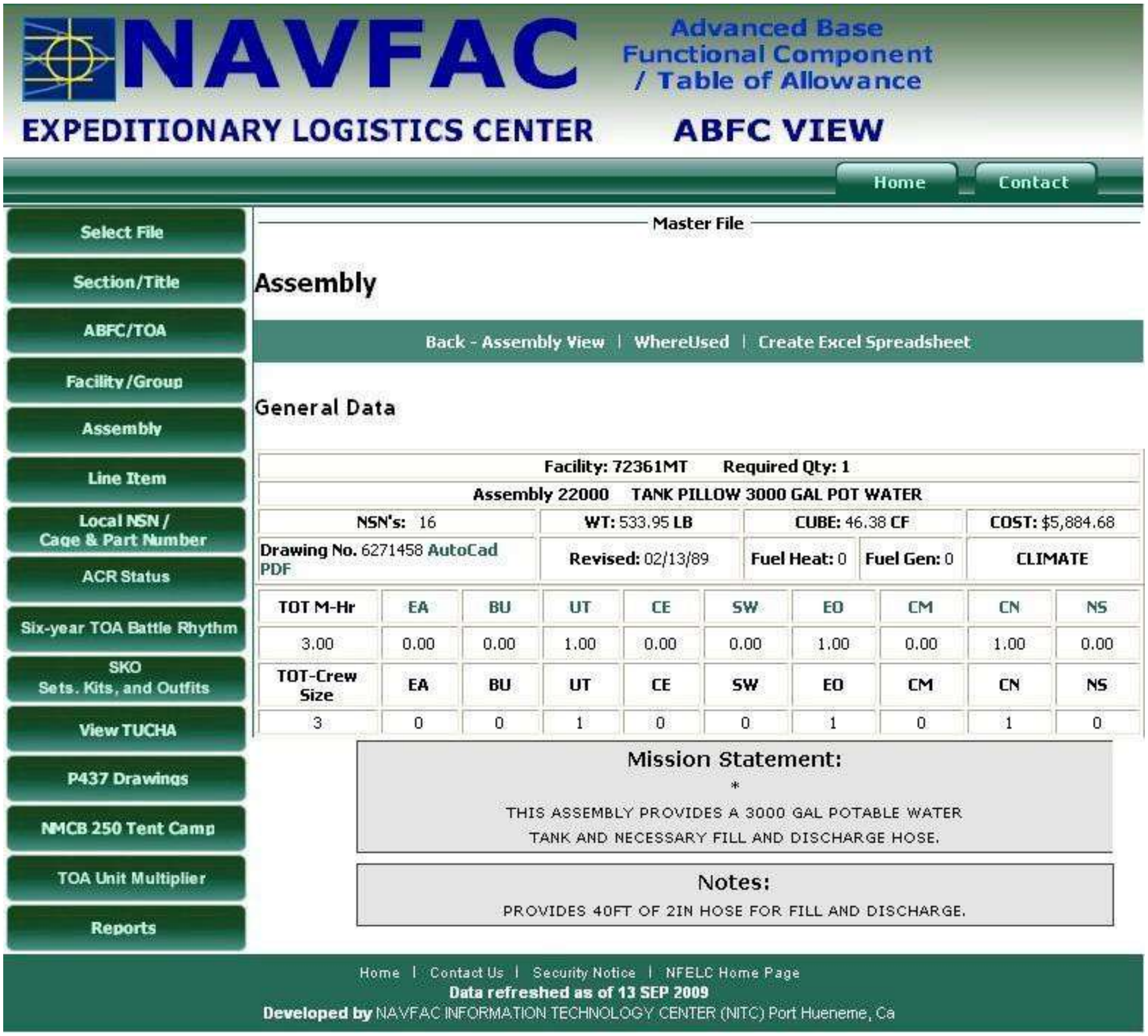


Figure 1-13 — ABFC/TOA assembly general data screen.

Figure 1-14 shows a typical entry for an assembly, but this assembly is not associated with any facility. Assembly 11900 is an augment assembly tailored specifically for contingency operations. The 16 by 32-foot tent frame (strongback) is the most versatile tent assembly used throughout the NCF.

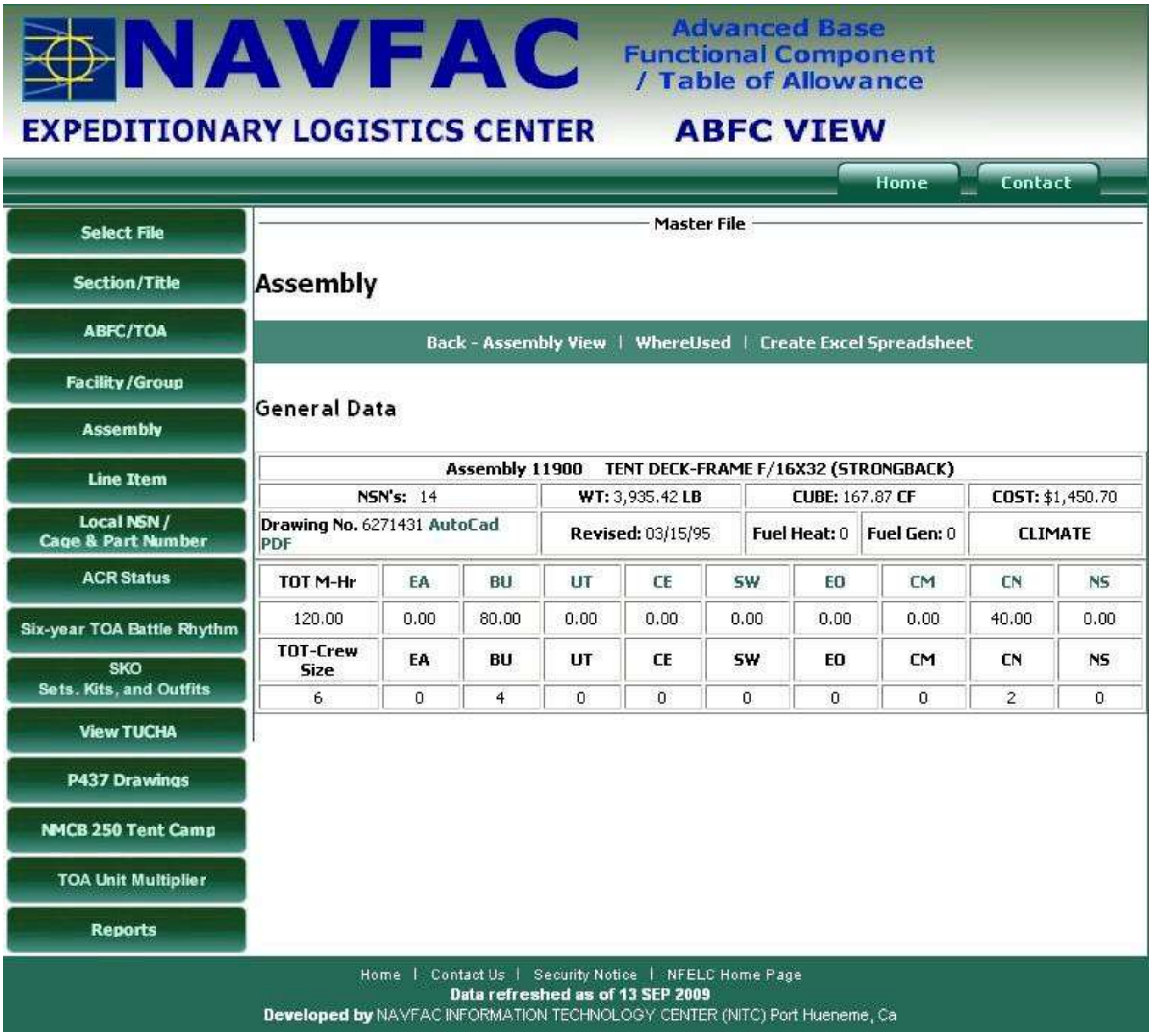


Figure 1-14 —Strongback tent assembly.

1.1.3 Index of Facilities

Suppose you have a requirement for an electrical distribution system underground. To determine what is available in the ABFC system to satisfy the requirement, click on 

.

Figure 1-15 shows the ABFC/TOA Facility/Group search screen.

Facility/Group	Title;
00000A	ABRIDGED FORMAT
00101AR	RSA RNMCB (MINUS AIR DET) PERSONNEL (RANKS/RATES)
00301AR	RSA TENT CAMP AND GALLEY MESSING SUPPORT
00301EOASD	TENT BERTHING COLLATERAL EQUIPMENT F/ASD
00301EOD	TENT CAMP COLLATERAL EQUIPMENT F/DETS/PLATOONS
00301MCM	TENT CAMP COLLATERAL EQUIPMENT F/MCM PLATOON
00301MU	TENT CAMP COLLATERAL EQUIPMENT F/38 PERSONNEL
00301P	COLLATERAL F/NCTC BRAVO CO. CE SCHOOL
00301SOF	COLLATERIAL MATERIAL F/GENERATOR FUEL SUPPORT
00301T21WP	SSB T21WP COLLATERAL
00301T22TP	FTC T22TP COLLATERAL
00301T3MP	NCHB T03MP COLLATERAL FOR T03MP-LS
00301T40MR	COLLATERAL FOR NCHB MP-LS
00301TC2	BMU SEA ECH COLLATERAL SUPPORT FOR FACILITIES
00331ACU	COLLATERAL SUPPORT FOR FACILITIES
00331B15A	COLLATERAL SUPPORT TENT CAMP
00331B15B	COLLATERAL SUPPORT TENT CAMP
00331B15C	COLLATERAL SUPPORT TENT CAMP
00331B15D	COLLATERAL SUPPORT TENT CAMP
00331B15E	COLLATERAL SUPPORT TENT CAMP
00331B15F	COLLATERAL SUPPORT TENT CAMP
00331B16B	COLLATERAL SUPPORT TENT CAMP
00331B17	RIVERINE SQUADRON TENT CAMP SUPPORT
00331B171A	RIVERINE BOAT DETACHMENT TENT CAMP SUPPORT
00331CMOC	TENT CAMP SUPPORT F/CMOC

Figure 1-15 — ABFC/TOA Facility/Group search screen.

Scroll down to the 800 series (Utilities and Ground Improvements) or enter 8 in the search box and click on SEARCH.

Scroll through the entries until you find an approximate 11,000-foot system. In this case, facility 81230B can be used. Click on the entry for facility 81230B.

Figure 1-16 shows the facility/group view screen that gives the basic information you need to fulfill the requirement for an underground electrical distribution system.

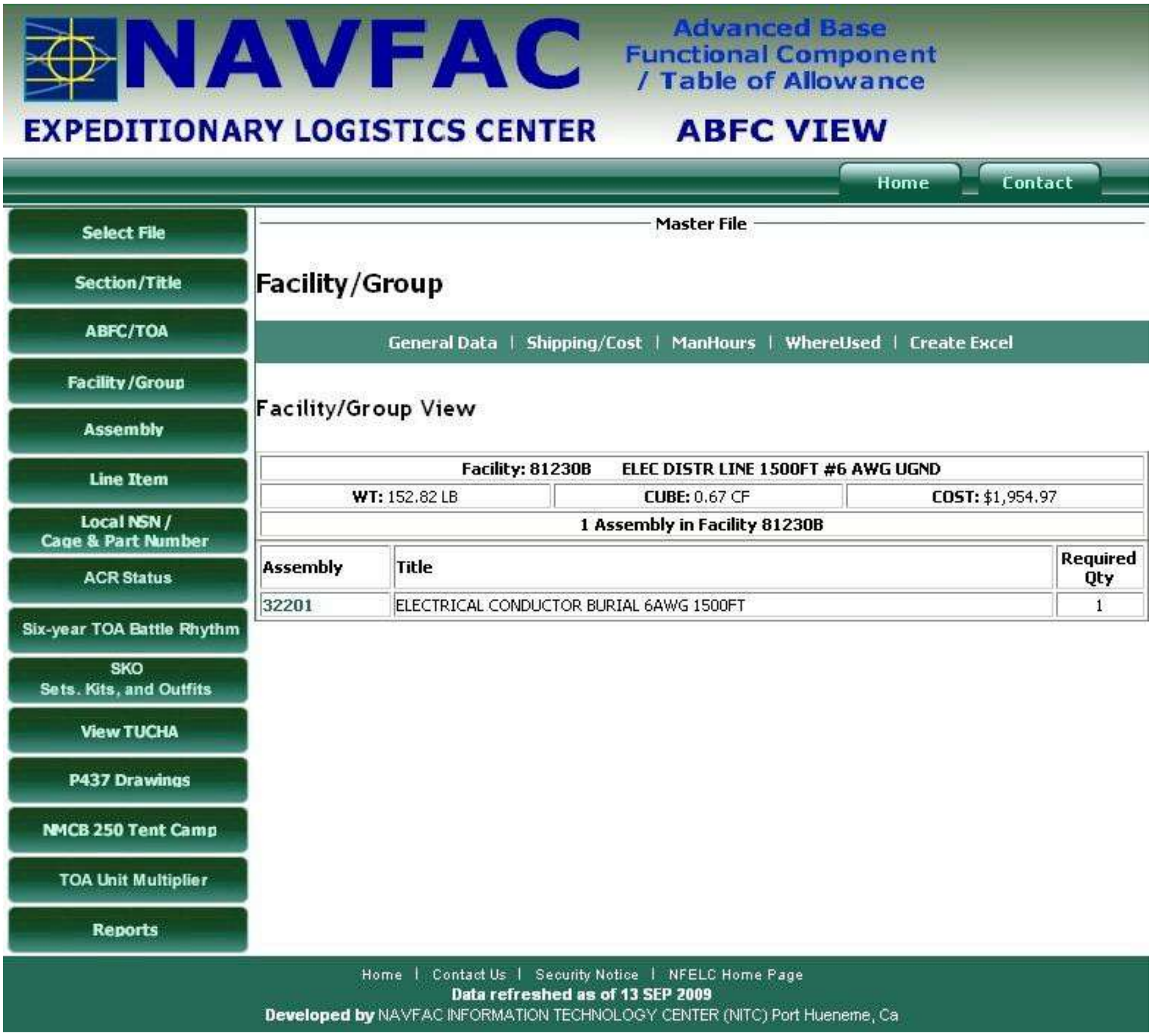


Figure 1-16 — ABFC/TOA Facility/Group view screen.

Access more detailed information on the facility by selecting General Data from the banner. *Figure 1-17* shows the general data screen for facility 81230B.

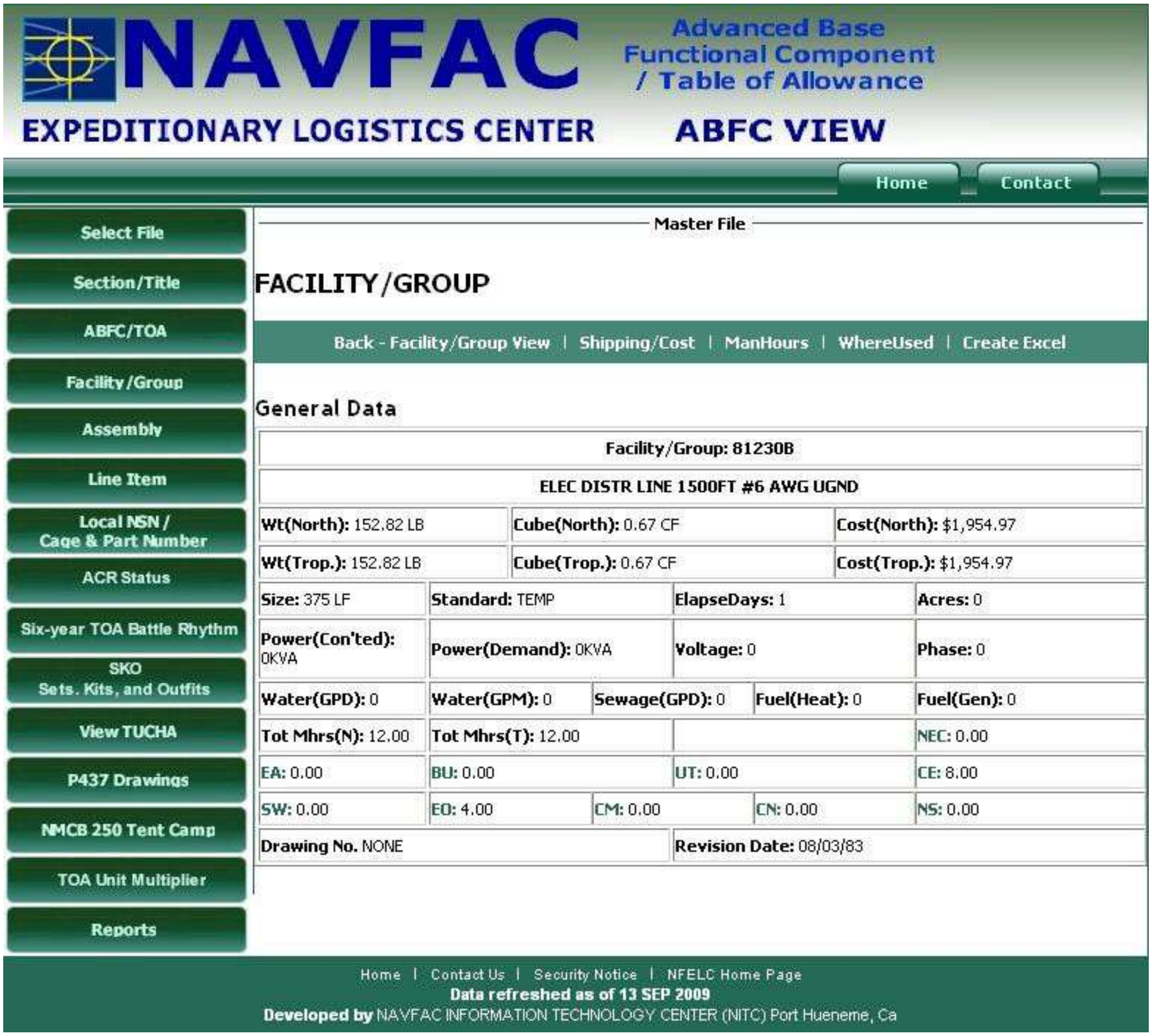


Figure 1-17 — ABFC/TOA Facility/Group general data screen.

Certain installed equipment or collateral equipment, such as furniture and fixtures contributed by others, is not furnished with the facilities or the assemblies listed in the ABFC/TOA system. You must request these items separately. The assembly listings indicate what is installed or what NAVFAC collateral equipment is provided.

Test your Knowledge (Select the Correct Response)

1. Fuel usage is computed on a how many day requirement for installed fuel-fired or engine equipment devices?

   A. 120
   B. 90
   C. 60
   D. 30

2.0.0 FIELD STRUCTURES

This section covers the procedures for the set up and operation of the portable shower facility, the portable laundry facility, the portable latrine facility, the 3000D, the 3000LMT, and the ROWPU (Reverse Osmosis Water Purification Unit) water units.

2.1.0 Portable Bath Unit

The nine-shower head Portable bath unit is a liquid fuel-fired water-heating device that supplies warm water to each of the shower nozzles. The bath unit is equipped with the necessary water heater, water pump assembly, mixing unit, hoses, and shower stands to supply all of the warm water needed for operation. The water pump draws water through the suction strainer and the hose from the water source and forces it through the discharge hose to the water heater. The water heater raises the temperature of the incoming water and maintains it at the desired temperature. The heated water is then forced through one discharge hose to the mixing unit, where it is mixed with cold water to provide water at the desired temperature to the shower heads.

The electrical power required to operate the bath unit should be supplied by a self-contained portable 3 kW, 60 Hz, 208 V, three-phase power generator source. All of the components of the bath unit that are operated electrically should be grounded through a fifth wire incorporated in the power cables.

A description of major components to the portable bath unit is listed below. The location of each component is shown in *Figure 1-18*.

A. Shower Stand Assembly. Each of the three shower-stand assemblies comes equipped with three shower heads. Each shower head has a valve to control the water flow. A curtain is supplied to enclose each shower.

B. Water Hose Assembly. There are five 1- inch inside diameter (ID) hoses, each measuring 7 1/2 feet in length. The hoses interconnect with the water pump assembly, the water heater assembly, the mixing valve assembly, and three shower-stand assemblies.

C. Mixing Valve Assembly. The mixing valve assembly mixes hot water from the water heater and cold water from the water pump and water source to provide heated water to the shower stands at temperatures of approximately 105°F.

D. Water Heater. The water heater is a self-contained, liquefied fuel-fired boiler that heats water supplied by the water pump. The major subassemblies or components that make up the water heater are the water vessel, the burner assembly, the blower assembly, the control box assembly, the sight glass assembly, and the transformer and ignition cables.

E. Drum Fill Adapter Assembly. The drum fill adapter assembly can be used with either a 55-gallon fuel drum or a 5-gallon gasoline can. The fuel level can be checked visually and refueled without disconnecting the fuel lines.

F. Fuel Container. The fuel container may be either a 55-gallon fuel drum or a 5-gallon gasoline can.

G. Fuel Feed And Return Hose Assemblies. Flexible hoses provide supply and return fuel between the fuel storage container and the fuel pump assembly on the water heater.

H. Power Cable Assembly. The power cable assembly consists of two cables that extend from the Power source to the bath unit. The short cable connects to a 208

V, three-phase Power source. The long cable connects to the short cable, the water heater, and the water pump.

I. Water Pump Heater-Hose Assembly. The assembly consists of one 1 1/24nch ID hose, measuring 6 feet in length, that connects the water pump to the water heater.

J. Water Pump. The water pump draws water from the source through the intake hose and the in-line strainer then supplies it through a discharge line to the water heater.

K. Suction Hose Assembly. The suction hose assembly has one l-inch ID hose, measuring 25 feet in length that connects the water supply to the water pump.

L. Suction Strainer Assembly. The suction strainer assembly is connected to the suction hose assembly. It prevents leaves and debris from entering the water system.

Figure 1-18 — Major components of a portable bath unit.

2.1.1 Setting up the Bath Unit

Locate the bath unit so drainage from the shower area is carried downstream or downhill from the suction hose strainer to prevent wastewater from being drawn back into the water source. If this arrangement is not possible, dig a ditch or build a dike around the shower stands to allow wastewater to drain away from the water source. When a pressurized water source is used, discharge the water into an open reservoir before it is drawn into the bath system. This prevents excessive strain on the water pump. Use the following procedures to set up the bath unit:

WARNING

Do not connect the heater to an untested water supply. Contaminated water can cause illness or death.

CAUTION

To prevent equipment damage, be sure the hose couplings are free of dirt or foreign matter and the coupling gaskets are in place before you couple the hoses.

1. Connect the section hose strainer to the male end of a 25-foot long, l-inch ID hose.
2. Connect the female end of the water hose to the water pump suction port.
3. Place the water pump on a level surface approximately 20 feet from the water source. Be sure the suction line does not exceed 5 feet in length.
4. Place the suction hose assembly and strainer into the water source using one of two methods:
    a. Place the strainer on a mound of stones or gravel and make a large pile of stones upstream from the strainer to divert debris from it.
    b. Build a tripod using tree branches and suspend the strainer from the tripod. Build a barrier using tree branches upstream from the strainer to prevent leaves, weeds, or other debris from entering the strainer.
5. Place the water heater on level ground approximately 5 feet from the water pump. When it is possible, arrange a suitable shelter or windbreak for the water heater to conserve fuel.
6. Connect the male coupling of a 1 1/2-inch water hose to the water pump and connect the female end of the hose to the water heater intake.
7. Connect the female end of a 7 1/2-foot, 1-inch ID hose to the water heater and the male end of the hose to the HOT fitting on the mixing valve.
8. Connect the male end of a 7 1/2-foot, 1-inch ID hose to the water pump outlet and the female end of the hose to the COLD fitting of the mixing valve.
9. Erect the shower stand approximately 20 feet from the mixing valve. Connect sections of the shower stand assembly using a 7 1/2-foot, 1-inch ID hose. Install the cap on the shower stand end connector.
10. Connect the female end of a 25-foot, 1-inch ID hose to the MIXED fitting of the mixing valve. Connect the male end of the hose to the female fitting of the shower stand.
11. Install an elbow on the water heater with a slight turn to the right to seat the pin in the slot.
12. Insert a smokestack and guard assembly through the bracket onto the elbow.
13. Tighten the screw on the bracket to secure the smokestack and guard assembly.
14. Place the fuel container approximately 5 feet from the water heater.

WARNING

The fuel used with the bath unit is highly flammable and may be dangerous to human life if handled improperly. Tighten all fuel fittings firmly. Recheck all fittings when the water heater is operating to ensure there are no leaks with the system under pressure.

15. Screw the drum fill adapter into the fuel container.
16. Connect the fuel line from the pump filter to suction the fitting on the drum fill adapter assembly.
17. Connect the fuel line from the pump to the return fitting.
18. Connect the cable assembly to the water heater, the water pump, and the power source.

WARNING

Use only the fuel specified. Failure to do so may result in injury to personnel or equipment.

CAUTION

The lack of lubrication may cause pump damage when pure gasoline is used as fuel. To avoid failure, when firing the fuel burner with gasoline, mix 1 quart of oil with each 5 gallons of gasoline. This mixture provides internal lubrication for the fuel pump. To ensure proper mixture, pour the gasoline into the oil.

19. Fill the fuel container with the approved fuel mixture.

2.1.2 Preventive Maintenance Checks and Services (PMCS)

To ensure that the equipment is ready for operation at all times, you must inspect it systematically before operation, during operation, and after operation, so defects may be discovered and corrected. The necessary preventive maintenance checks and services (PMCS) will be performed before operation. The defects discovered during operation of the unit will be noted, and corrections made as soon as operation has ceased. Stop the operation immediately if a deficiency is noted that could damage the equipment. After operation, the necessary PMCS must be performed. Report defects or unsatisfactory operating characteristics beyond your scope to your supervisor.

The PMCS procedures are contained in the operating manual provided with the field unit.

2.1.3 Preparation for Use

Before you start the bath unit, go to the “Operator’s Preventive Maintenance Checks and Services (PMCS)” and do the “Before Operation” checks and then proceed as follows:

- Make certain the water heater load limit switch is turned to OFF.
- Make sure the manual fuel valve is closed.
- Press the reset button to ensure the flame safeguard control is not locked out.
- Open the blower shutter approximately halfway.
- Open the fuel pump primer plug and fill the fuel container with the fuel mixture.
- Replace the plug.

Make sure that one end of the hose is connected to the supply fitting of the fuel filter and to the fittings on the vent. Connect the return fuel line to the drum fill adapter.

NOTE

The operator must periodically monitor the level of the fuel supply. The fuel container should be kept as full as possible to reduce water condensation. The frequency of refueling depends on the size of the fuel container. Excessive water in the fuel supply decreases heater efficiency and corrodes both the chamber and the burner.

WARNING

Exposed fuel and fuel vapor can ignite or explode, resulting in possible serious injury and even death. Observe proper safety precautions when servicing the fuel system. Ensure the water heater is cold before servicing the burner.

- Check to see that all water lines are connected.
- Be certain the water heater drain cock is closed.
- Check to be sure the smoke-pipe elbow, the two lengths of the smoke-pipe guard assembly, and the smoke pipe are securely installed.

2.1.4 Start-up Procedures

After having performed the recommended PMCS and the water heater is ready for use, proceed as follows:

- Turn off the limit switch and connect the power cable to the power source. Close the fuel valve by turning it to the right.
- Remove the plug and fill the coupling with water.
- Replace the plug.
- Open the fuel valve and turn the load limit switch and power source ON. The fuel pressure gauge should indicate 100 psi.
- View the ignition spark through the sight tube after the power is turned ON.
- Wait 7 seconds; then view the combustion through the sight tube.
- If combustion does not occur after an additional 12-second wait, the buzzer sounds and the ignition spark shuts down. Wait 2 minutes after the buzzer sounds and press the safety reset button. If combustion still does not occur, troubleshoot the unit according to *Table 2-1*.
- After start-up, the exhaust gases from the exhaust stack should be transparent and smokeless. When smoke is present, open the air band on the blower assembly slowly until the exhaust gases are transparent and smokeless. The water heater is now in automatic operation.

2.1.5 Shutdown Procedures

Perform the following shutdown procedures after normal use or when the equipment will not be used for an extended period:

- Turn off the fuel valve.
- Turn off the load limit switch.
- Turn off the water pump.

If there is danger of the bath unit freezing, perform the following procedures:

- Open the drain cock on the water pump by turning it to the left and tilt the water pump on end to let the water drain out.
- Reach under the water heater and open the drain cock by turning it to the left.

When the bath unit is not scheduled for use for 5 days or more, perform the following procedures:

- Remove the fuel feed hose from the fuel container.
- Place the end of the hose into a quart container.
- Fill the container with diesel fuel.
- Turn on the load limit switch and allow the unit to operate until the quart container is almost empty. Turn off the water heater fuel shutoff valve and let the system operate until the flame is extinguished.
- Turn off the load limit switch.

2.1.6 Troubleshooting Procedures

This section contains troubleshooting information for locating and correcting most of the operating troubles that may develop in your bath unit. The troubleshooting procedures are listed in *Table 1-3*. The table lists the common malfunctions that you may find during operation or maintenance of the bath unit or its components. You should perform the tests/inspections and corrective actions in the order listed. Each malfunction for an individual component, unit, or system is followed by a list of tests or inspections to help you determine what corrective action(s) to take. This manual does not attempt to list all possible malfunctions and corrective actions or all the necessary tests and inspections. Remember, you should always notify your supervisor when something unusual occurs.

Table 1-3 — Troubleshooting Procedures.

Component	Malfunction	Corrective Check
Water Heater	Fails to start	Electrical power source Load limit switch Flame safeguard Blower motor reset Water supply in tank Low-water probe Low- water relay
Burner	Flame failure during fire cycle	Fuel supply Fuel hoses Fuel nozzle UV scanner Flame safeguard control Fuel pump strainer Fuel pump drive coupling Fuel pump Fuel solenoid valve

Component	Malfunction	Corrective Check
Burner	Fails to ignite or is delayed	Fuel supply Fuel hoses Burner nozzle Water in fuel Electrodes Ignition transformer Burner to transformer connection
Fuel Pressure Gauge	Pressure too high	Fuel Gauge Fuel Pump Fuel nozzle Fuel hose (return)
Fuel Pressure Gauge	Pulsating pressure	Suction hose Fuel pump strainer Fuel filter Burner nozzle Pressure Gauge
Fuel Pump	Noisy	Suction hose Fuel pump strainer Fuel filter Fuel pump
Fuel Pump	Leaks	Strainer cover Plugs Shaft seals Fuel pump for cracks
Fuel Pump	Fails to deliver fuel to burner	Fuel supply Reversed pump rotation Suction/discharge fuel hoses Fuel pump strainer Burner nozzle Pump drive coupling Fuel solenoid valve
Blower Motor	Continues to trip off	Fuel pump and motor
Smokestack	Gases are smoky	Electrode spark Contaminated fuel Burner nozzle Blower operation Power source - low-voltage output
Smokebox Cover	Escaping smoke	Boiler box gasket Smokebox cover bolts
Water Temperature Gauge	Indicates overheating	Temperature control Low-water probe
Water Pump	Fails to deliver water	Pump motor Shaft seals
Shower Stand Nozzles	Not discharging enough water	Water flow control valves Fittings

2.2.1 ETS Shower Facility

The ETS shower (*Figure 1-19*) provides shower facilities at field locations. The shower is housed in a 6'6" x 8'8" TRICON container which is modified to include an expandable wing section at each end. The wings are expanded for operation, providing approximately three times the floor space of a basic, non-expanding TRICON. Each shower unit contains to following equipment:

- two showers in separate privacy stalls
- hand sink
- mirror
- soap dispenser
- paper towel dispenser
- air conditioner
- space heater
- 115 V GFCI duplex service receptacle
- ventilation fan and makeup air vent
- ceiling light

Figure 1-19 — ETS shower facility.

A control panel in the front end of the unit contains switches, indicating lights, and an audible alarm for controlling and monitoring various components.

External panels on the left side of the unit provide electrical supply, ground, source water, and wastewater connections. The necessary electrical cables, ground rod assembly, and hose assemblies are included with the unit, as well as two 3000-gallon fabric tanks, one for source water and the other for wastewater. Letter-coded hose assemblies provide supply and drain connections for the sinks. A power distribution panel also mounted on the exterior left side, houses circuit breakers for the electrical components.

A small mechanical compartment, located next to the shower stalls, houses the water supply pumps, accumulator tank, water heater, waste tank, waste pump, and other mechanical components.

2.3.0 WS-D Field Shower

Each WS-D (*Figure 1-20*) can be used as a Two-Stall Shower System or a dressing room/single stall shower combo. The shower systems feature an articulated aluminum mainframe; snap-lock eave and base bars; and the hook-and-loop attachment cover system. The fabric cover is 14 oz. vinyl coated polyester. Shower catch basins are plumbed for the recovery of gray water. The units can either be individual to stall showers or combined up to a twelve stall combination unit.

Standard shower configuration is two individual shower stalls with zippered entry doors packaged in one durable fabric field bag. The shower can be set up and ready for use in less than fifteen minutes. The shower can also be configured as a single stall with dressing room. No tools are required for assembly.

Figure 1-20 — WS-D Two-Stall portable shower facility.

2.4.0 4 Head Portable Shower Shelter

The 4 Head Portable Shower Facility (*Figure 1-21*) is an 8’ x 12’ base with a 7’2” maximum height and has built-in floors and skylights. It contains 4 removable stalls with plumbing and shower heads. The unit can is operated with water conserving shower heads that utilize ½ gallon of water per minute.

Figure 1-21 — 4 head portable shower facility.

The unit weighs 150 lbs. including drain lines and all components for the shelter. It is packed in 2 separate bags for easy transportation and can be erected in as little as 7 minutes.

2.5.1 ETS Laundry Facility

The ETS-Laundry provides laundry facilities at field locations. The Laundry is housed in a 6' 6" x 8' 8” TRICON container which is modified to include an expandable wing section at each end. The wings are expanded for operation, providing approximately three times the floor space of a basic, non-expandable TRICON, and very similar to the shower facility.

As a reference for describing the location of various components, the end of the container where the equipment nameplate is attached is considered the front end of the unit. Each end of the Laundry contains the following equipment:

- two washers
- two dryers (mounted above the washers)
- air conditioner
- space heater
- 115 V GFCI duplex service receptacle
- Ventilation fan and makeup air vent
- Ceiling light

A control panel in the front end of the unit contains switches, indicating lights, and an audible alarm for controlling and monitoring various components.

Exterior panels on the left side of the unit provide electrical supply, ground, source water, and wastewater connections. The necessary electrical cables, ground rod assembly, and hose assemblies are included with the unit, as well as two 3000-gallon fabric tanks, one for source water and the other for wastewater. An exterior power distribution panel, also mounted on the left side, houses two circuit breaker panels, each supplying half of the Laundry's electrical components.

A small mechanical compartment, located on the right side of the container next to the washers, houses the water supply pump, accumulator tanks, water heaters, waste tank, wastewater discharge pump, and other mechanical components.

2.6.1 ETS Latrine Facility

The ETS-Latrine (*Figure 1-22*) provides sanitation facilities at field locations. The Latrine is housed in a 6'6" x 8' x 8' TRICON container which is modified to include an expandable wing section at each end. The wings are expanded for operation, providing approximately three times the floor space of a basic, non-expandable TRICON.

Figure 1-22 — Portable latrine facility.

As a reference for describing the location of various components, the end of the container where the equipment nameplate is attached is considered the front end of the unit. Each end of the Latrine contains the following equipment:

- two toilets, each in a separate privacy stall
- wall-mounted urinal
- hand sink
- mirror
- soap dispenser
- paper towel dispenser

- air conditioner
- space heater
- 115 V GFCI duplex convenience receptacle
- Ventilation fan and makeup air vent
- Ceiling light

A control panel in the front end of the unit contains switches, indicating lights, and an audible alarm for controlling and monitoring various latrine components.

External panels on the left side of the unit provide electrical supply, ground, source water, and wastewater connections. The necessary electrical cables, ground rod assembly, and hose assemblies are included with the unit, as well as two 3000-gallon fabric tanks, one for source water and the other for wastewater. Letter-coded hose assemblies provide supply and drain connections for the sinks and latrines. A power distribution panel, also mounted on the exterior left side, houses circuit breakers for latrine electrical components.

A small mechanical compartment, located next to the toilet stalls, houses the water supply pumps, accumulator tank, water heater, waste tank, sewage ejector pump, backflow preventer, and other mechanical components.

2.7.0 Water Purification Units

The remainder of this topic concerns the NCF water purification equipment. One of the most important jobs as a UT is the purification of water.

Insufficient quantity or quality of water is not only debilitating to the individual but also has a significant impact on unit readiness. Water that is not properly treated and disinfected can spread bacterial diseases, such as cholera, shigellosis, typhoid, and paratyphoid fever. Untreated water can also transmit viral hepatitis, gastroenteritis, and parasitic diseases, such as amoebic dysentery, giardiasis, and schistosomiasis.

The treatment process includes one or more of the following processes: coagulation, sedimentation, filtration, and disinfection.

The medical department representative advises the commanding officer on water quality issues. This entails assisting the UT in selecting water sources, surveying the potable water system, conducting routine bacteriological examination of the potable water supplies, and testing the water for halogen levels. The medical representative also informs the UT of water quality and type of treatment required, if any.

2.7.1 Diatomite Water Purification Unit (3000-D)

The 3000-D Water Purification System is portable and completely self-contained, as shown in *Figure 1-19*. The unit purifies ***turbid*** and bacteria-polluted water. Particular attention was paid to design and packaging to increase efficiency, mobility, and cost effectiveness. It also provides a trouble-free method of producing potable water at the rate of 3,000 gallons per hour.

The system is constructed in separate modules, interconnected, and mounted in a common chassis. The chassis is not required for operation, but it greatly eases the transportability of the system. The system contains all of the functional apparatus and supplies necessary to process approximately 20,000 gallons of potable water. The user must have a water source and a water processing requires only diatomaceous earth (DE), chlorine, and fuel.

The major components of the system are also shown in *Figure 1-23*. This mobile water purification unit contains a diesel-powered pumping module, a control and chlorination module, a filter module, supplies, and components mounted within a protective frame. It is supported on a pair of skids. Each module may be operated independently in or out of the frame because the interconnections and external connections use the same cam-locking devices. The unit may or may not be mounted on a trailer. The 3000-D can be set up and operated by one person, and it requires no support equipment.

Figure 1-23 — 3000-D water purification unit.

The power for the system is supplied by an air-cooled diesel engine to take advantage of a greater fuel supply in the field.

A highly durable bronze pump, directly linked to the engine, provides both the suction to draw in the untreated water and to provide the water pressure to the unit. The 3000-D Water Purification System is designed to be transported to remote sites on its own optional trailer, on the back of a compact pickup truck, or air-lifted by helicopter with its own standard sling.

2.7.1.1 Set-up Procedures

Once at the site, the system should be located on a level area located as close to the water source as possible to reduce suction lift to a minimum. For best results, the system should be located not more than 15 feet above the liquid supply. The suction line should be as short as possible and have few bends to keep friction losses low. The system is usually placed within 30 feet of the water source. The semi-rigid suction hose segments are removed from the main frame mounting cam locks and fitted together with a suction strainer placed in the water source. The green freshwater hose is fitted to the freshwater discharge port on one end. The other end feeds the processed water to the potable water holding tank or dispersement center. One end of the blue wastewater hose is fitted to the wastewater discharge port. The other end is placed so runoff can take place without hampering or contaminating further operations.

2.7.1.2 Start-up Procedures

Follow the steps listed below before starting the engine.

1. Fill the pump strainer with water to prime; close the cover tightly.
2. Set all control valves to START.
3. Remove the DE storage container and set it aside.
4. Fill a 3-gallon bucket three-quarters full of water and add three 2000 ml measures of DE slowly, stirring the mixture as you add the DE. Do NOT add the DE to the DE tank at this time.
5. Fill a 3-gallon bucket three-quarters full of water and add 8 ounces of chlorine. After mixing the calcium hypochlorite solution, allow the solution to settle. When the mixture is settled, pour the solution into the hypochlorite tank.

The engine of the 3000-D is equipped with an automatic decompression device and an excess fuel starting device that allows the engine to start easily and safely. The automatic decompression device has three positions:

1. Operation—the decompression is OFF, the engine has compression.
2. Neutral—for cold starting, compression is OFF.
3. Start position—cranking the engine causes the automatic decompression to operate. When the pin moves into the operating position, decompression ends and the engine fires.

WARNING

Never use the decompression device to stop the engine. This causes internal engine damage.

CAUTION

Wear hearing protection.

2.7.1.3 Cold Start-up Procedures

The procedures for a cold start are as follows:

1. Place the automatic decompression device in START and pull the excess fuel-starting device.
2. Insert the crank handle into the crank-handle guide. If you are not sure of the proper way to place your hand on the crank handle while cranking, then ask your supervisor for instructions.
3. Crank the engine slowly for four cranks and then turn the crank as quickly as you can. Once the engine starts, run the engine at half speed for about 1 minute.
4. Raise the engine to full speed.

Once you have precoated the filter, the unit is ready to perform the function of purifying water. Every 30 minutes, check the chlorine residual, the turbidity of the potable water, and the DE tank for slurry mixture.

Backwashing of the filter must be done when the pressure difference between the filter inlet and the outlet exceeds 20 psi.

2.7.1.4 Securing the 3000-D

When the device is no longer required, set the control valves as follows:

- Outlet selector valves—WASTE
- Waste outlet valve—OFF
- Backwash valve—BACKWASH
- Precoat valve—FILTER
- Filter drain valve—DRAIN

Let the engine idle for 5 minutes, and then place the speed- regulating lever to STOP until the engine stops. Pull the excess fuel-starting device, and place the speed-regulating lever to FULL LOAD.

2.7.2 3000LMT

The 3,000 Gallons per Hour (GPH), Light, Medium, Tactical (LMT), Water Purification System (3000 LMT) is capable of purifying a fresh water source (less than 1,500 TDS) at a rate of 3000 gallons per hour. The unit was designed to be transported by tactical vehicle or air lifted by helicopter to remote sites. The unit can also perform numerous additional functions such as decontamination, fire fighting, and irrigation.

The 3000 LMT weighs 680 lbs, is a frame mounted, skid based, diesel operated, diatomite type unit, that requires 2 personnel to operate. The 3000 LMT uses three different chemicals for the filtration and storage process.

- Chlorine. The Chlorine is used to kill bacteria in the water and to prevent its growth during storage. The chlorine comes in a granular form and is mixed with water into a solution.
- Polymer. Polymer is a coagulant used to aid in the filtration process**.** Polymer creates a chemical reaction in which two or more small molecules bond together to form larger molecules. This makes the filtration more efficient.
- Diatomaceous Earth. Diatomaceous Earth (D.E.) is any class of minute planktonic unicellular or colonial algae with solidified skeletons that form a diatomite, which is a light friable siliceous material derived chiefly from diatom remains and used especially as a filter. D.E. is a white powdery substance similar in appearance to flour and baking soda. The D.E. is going to be forming a cake on your filter elements to perform the filtration process. The purpose of the filter is to decrease the filters micron size to remove more particles during the filtration process.

2.7.3 Reverse Osmosis Water Purification Unit (ROWPU)

Potable water is a critical element in the operational functioning of the Seabees. The 600 Gallon per Hour (GPH) Reverse Osmosis Water Purification Unit (ROWPU), as shown in *Figure 1-24*, purifies water by reducing the dissolved and suspended solids in water. The unit processes raw water, brackish water, and seawater into potable water. Additionally, the ROWPU can treat water contaminated with CBR agents.

Figure 1-24 — Reverse osmosis water purification unit.

The purification is done by filtering the water to remove the majority of suspended solids. Once the majority of the suspended solids are removed, high pressure forces the water through a semi-permeable membrane. A maximum of 600 pounds psi is used for fresh and brackish water, and a maximum of 900 pounds psi is used for salt water. Chemicals are added to the product water to kill bacteria.

2.7.3.1 Support Equipment

The self-contained skid-mounted ROWPU unit requires a portable generator capable of providing 30 kilowatts of power (*Figure 1-25*).

Figure 1-25 — 30 kilowatt generator.

Other equipment includes the portable onion skin bladders (3,000 gallons), as shown in *Figure 1-26*; four frame-mounted, portable, electrical motor-driven water pumps with hoses and fittings; water test equipment (TDS meter, color comparator, etc.); and an operating supply of chemicals (chlorine, sodium hex, polymer, and citric acid).

Figure 1-26 — 3,000 gallon portable onion skin bladder.

2.7.3.2 Reverse Osmosis Process

The process of making clean water through reverse osmosis is a relatively simple matter. The list below takes you through the process. Refer to the flowchart (*Figure 1-27)* as you read through the 19 items listed.

1. This is the water source that you are going to purify through the ROWPU.

2. The strainer is attached to the end of the intake hose to keep rocks, leaves, and any other foreign objects from entering the pumps and filters.
3. The first of the two pumps draws water from the water source and pumps the water to the ROWPU.
4. The second of the two pumps draws water from the water source and pumps the water to the ROWPU.
5. The polymer pump adds a polyelectrolyte solution to the raw water. The polymer causes coagulation of small floating particles. This enables the filters to remove the particles.
6. The sodium hex pump adds a solution of sodium hexametaphosphate to prevent scaling of the filters.
7. The multimedia filter is the first actual filter that the raw water goes through.
8. After the water has been filtered, the booster pump draws the water and forces it through the cartridge filter.
9. As the water goes through the cartridge filter, tiny particles that were not filtered out by the multimedia filter are filtered out.
10. The reverse osmosis (RO) pump increases the filtered water pressure and forces the water through the RO elements (semi-permeable membranes).
11. The pulse dampener is simply a ball-shaped device that reduces the shock caused by the piston action of the pump.
12. All of the dissolved solids are removed from the water in the membranes. The membranes consist of rolls of thin film that separate dissolved solids from the water.
13. Once the water comes out of the RO elements, the chlorine pump injects chlorine into the product water to kill bacteria that is present. If the chlorine pump is not in use, you must batch chlorinate the water in the bladder or storage container.
14. The product water tank is a storage device for holding product water (potable water). The tank may be a bladder, a container, or a collapsible tank.
15. The distribution pump is used to move the product water from the product-water tank into vehicles, tank trailers, and so forth.
16. A distribution nozzle is used to fill the end-users container.
17. Diluted citric acid cleans the RO elements. The citric acid lowers the pH of the water and improves the salt rejection of the elements.
18. A separate storage tank is used for the brine water. The brine is used to flush the multimedia filter. The backwash pump (19) forces the brine backwards (from bottom to top) through the filter media to flush out any unwanted accumulation in the filter.
19. The backwash pump provides pressure that pumps the brine through the multimedia filter for backwashing.

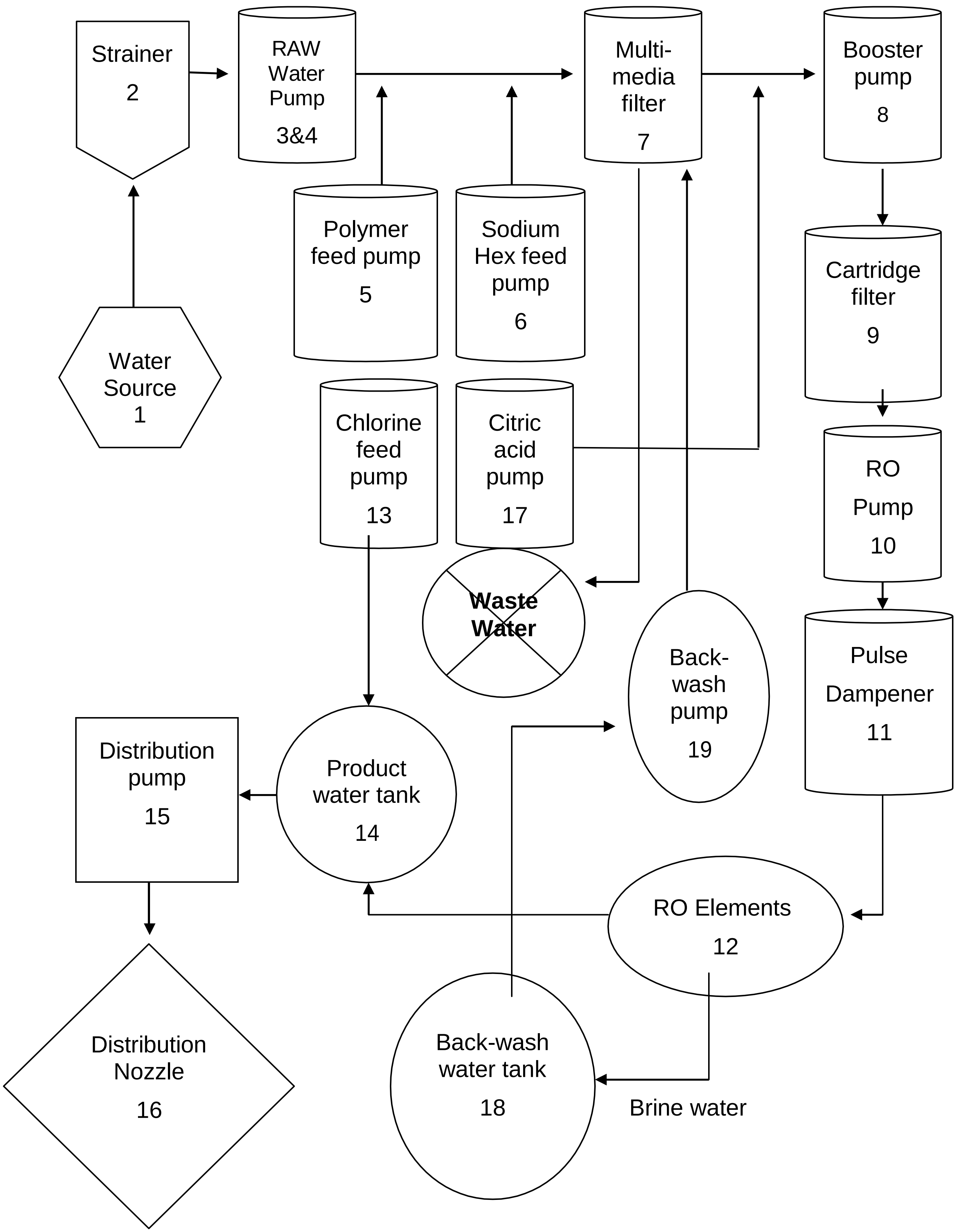


Figure 1-27 — Reverse osmosis water purification flow chart.

The ROWPU can purify 13.5 gallons per minute of product water from a fresh or brackish water source and 12 gallons per minute of potable water from a seawater source.

Temperature has a substantial effect on the quantity of product water the ROWPU can produce. The higher the temperature of the raw water, the more product water the ROWPU can produce. At 77°F the ROWPU can produce 600 gph from fresh or brackish water and 400 gph from seawater. Again, as the temperature of the water increases, so does the flow of product water.

Summary

You have learned the principles involved in the use of the Advanced Base Functional Component system as well as the procedures used in the field. Furthermore, you have learned about the portable bath unit and two types of water purification units. This knowledge will help you provide the leadership necessary for effective Seabees' construction support in contingency operations.

Review Questions (Select the Correct Response)

1. An ABFC system does NOT include which group?

   A. Component
   B. Facility
   C. Assembly
   D. Supply

2. Component Site Plans are contained in what part of the ABFC/TOA system?

   A. ABFC/TOA Component View
   B. ABFC/TOA General Data
   C. Facility/Group Component View
   D. Facility/Group General Data

3. You have the NSN for an assembly that you want to design and need the line item requirements. In this situation, you should refer to what part of the ABFC/TOA system?

   A. Assembly View
   B. ABFC/TOA Component View
   C. Facility/Group Component View
   D. All of the above

4. In NAVFAC P-72, what is the category code for Hospital and Medical?

   A. 700
   B. 500
   C. 300
   D. 100

5. **(True or False)** An ABFC building can be tailored to meet your specific needs.

   A. True
   B. False

6. ABFC assemblies required only in the North Temperate Zone are coded with what letter?

   A. A
   B. C
   C. N
   D. T

7. When setting up the bath unit, the water pump should be at least how many feet from the water source?

   A. 40
   B. 30
   C. 20
   D. 10

8. Who informs the UT of water quality and type of treatment required?

   A. Commanding Officer
   B. Division Officer
   C. Medical representative
   D. World Health Organization representative

9. What device is installed on the 3000-D to allow for easy and safe starting?

   A. Automatic decompression
   B. Automatic recompression
   C. Advanced decompression
   D. Advanced recompression

10. The ROWPU can process water contaminated with ______?

   A. CBR agent
   B. Fuel
   C. Fungus
   D. All of the above

11. The ROWPU can purify 13.5 gallons per minute of water from a fresh water source and how many gallons per minute from a seawater source?

   A. 13
   B. 12
   C. 11
   D. 10

Trade Terms Introduced in this Chapter

ABFC	Advanced Base Functional Component system. Provides support facilities for construction utilizing the building block concept
Component	A basic grouping of the ABFC, a component is a complete unit.
Facility	A portion of a complete component
Assembly	A portion of a facility, the smallest part of the ABFC
Turbid	Water that is cloudy or hazy caused by particles suspended in the fluid

Additional Resources and References

This chapter is intended to present thorough resources for task training. The following reference works are suggested for further study. This is optional material for continued education rather than for task training.

Department of the Navy Facility Category Codes, NAVFAC P-72, Naval Facilities Engineering Command, Alexandria, VA, 1981.

Engineering Aid Intermediate/Advanced, NAVEDTRA 12540, Naval Education and Training Professional Development and Technology Center, Pensacola, FL, 1994.

Facilities Planning Guide, NAVFAC P-437, Naval Facilities Engineering Command, Alexandria, VA, 1991.

NCF/Seabee 1 & C, NAVEDTRA 12543, Naval Education and Training Professional Development and Technology Center, Pensacola, FL, 1995.

Naval Construction Force Manual, NAVFAC P-315, Naval Facilities Engineering Command, Alexandria, VA, 1988.

Projected Operational Environment and Required Operational Capabilities for the Naval Construction Force, POE/ROC, OPNAVINST 3501.115, Department of the Navy, Washington, DC, 1974.

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Chapter 2

Plumbing Planning and Estimating

Topics

1.0.0 Planning plumbing projects

To hear audio, click on the box.

Overview

In your day-to-day work as a Utilitiesman, you will be planning and installing many types of plumbing systems. To do these jobs properly, you must have the knowledge and ability to plan and install plumbing systems within the structure while following the proper building codes. After studying this chapter, you should be familiar enough with building codes to be able to plan and install plumbing systems.

Objectives

When you have completed this chapter, you will be able to do the following:

1. Describe the process for planning plumbing projects.

Prerequisites

None.

This course map shows all of the chapters in Utilitiesman Advanced. The suggested training order begins at the bottom and proceeds up. Skill levels increase as you advance on the course map.

Air Conditioning and Refrigeration	↑	U T A D V A N C E D
Duct and Ventilation Systems		
Boilers		
Compressed Air Systems		
Sewage Treatment and Disposal		
Water Treatment and Purification		
Fire Protection Systems		
Interior Water Distribution and Interior Waste Systems		
Plumbing Planning and Estimating		
Contingency Support		

Features of this Manual

This manual has several features which make it easier to use online.

- Figure and table numbers in the text are italicized. The figure or table is either next to or below the text that refers to it.
- The first time a glossary term appears in the text, it is bold and italicized. When your cursor crosses over that word or phrase, a popup box displays with the appropriate definition.
- Audio and video clips are included in the text, with an italicized instruction telling you where to click to activate it.
- Review questions that apply to a section are listed under the Test Your Knowledge banner at the end of the section. Select the answer you choose. If the answer is correct, you will be taken to the next section heading. If the answer is incorrect, you will be taken to the area in the chapter where the information is for review. When you have completed your review, select anywhere in that area to return to the review question. Try to answer the question again.
- Review questions are included at the end of this chapter. Select the answer you choose. If the answer is correct, you will be taken to the next question. If the answer is incorrect, you will be taken to the area in the chapter where the information is for review. When you have completed your review, select anywhere in that area to return to the review question. Try to answer the question again.

1.0.0 PLANNING PLUMBING PROJECTS

1.1.0 Responsibilities

As you become a more senior, you are the technical advisor during both the planning and execution phases of plumbing projects. You will be supervising crews in the field and following an approved project schedule. Planning is not worth the paper it is written on unless it is executed properly on the job.

1.1.1 Technical Advisor

As technical advisor, the Operations Officer, your company, and crew expect you to have answers to their questions about plumbing jobs. You must have access to plans, specifications, plumbing codes, technical references, and manufacturers' manuals. You are not expected to know every detail of your rating. You can be an effective technical advisor by knowing and using the resources available to you.

Many problems will require you to make decisions based on personal experiences. Do not rely on rate training manuals or formal schools to provide you with everything you need to know to be a UT. The extra effort of self-study, combined with on-the job training and field experience, will enable you to make recommendations with confidence.

1.1.2 Planner

Now that you are advising people on the technical aspects of installing and maintaining plumbing systems, you may become involved in the planning of these tasks.

Planning takes on many applications and phases. Home-port project planning results in a schedule that you should use to decide how and when your work is going to be done. The resulting precedence diagram, along with other available information about a project, can help you in managing and supervising your project.

1.1.3 Supervisor

In operational units, your company should follow the construction schedule that was prepared during the home-port period. After arriving at the deployment site, you may need to make changes to the schedule to show actual conditions on the job, such as changes in personnel, equipment availability, or material delays. The schedule is designed to be a management tool to assist the supervisor. Used properly, the schedule will alert you to problems and job requirements in enough time to avoid project delays.

Coordinate your requirements with other companies and departments. For example, decide on material, equipment, and personnel requirements about 30 days in advance at the company level, 2 weeks in advance at the job supervisor level, and no less than 1 week in advance at the crew leader level. This should provide the time necessary for supporting elements of the organization to break out, deliver, and provide support to your job. The project you are working on should decide the amount of lead time planning you should allow. The location is also a key aspect to lead times and material availability. During home-port planning, you may not know the conditions on a particular jobsite. After being on the site, you may have to reevaluate the original schedule. Generally, you can make changes to the schedule within 45 days of crew arrival on the job. Good supervisors ensure equipment, material, tools, and other facilities are on the job when needed. Missing items require an extra trip back to camp; this affects both production and crew morale.

1.2.0 Planning, Estimating, and Sizing Plumbing Systems

You will provide input on the planning, estimating, and sizing of plumbing systems. This input may concern installation techniques, types of material required, quantity and size of piping or fittings, and so forth. This section provides information you must consider for planning and estimating a plumbing project. The National Standard Plumbing Code, military specifications, and job specifications provide more concise information.

1.2.1 Sanitary Systems

Various types of pipe and fittings are used for sanitary waste and drainage. However, the location of the installation determines the type of material you must use. Threaded pipe that is underground requires coal tar protection. Install underground sanitary waste and drainage lines in a separate trench from the water-service line. The underground water service and the building drain or sewer should not be less than 6 feet apart horizontally and placed on undisturbed or compacted earth. When separate systems of sanitary drainage and storm building drains are placed in one trench, they should be placed side by side. A building sewer or building drain installed in fill dirt or unstable ground should be made of cast-iron soil pipe, except that nonmetallic drains may be used when laid on an approved continuous supporting system. *Table 2-1* depicts code requirements for pipe usage. Remember to always refer to the current edition of the IPC.

Table 2-1 — Sanitary waste and drain piping.

Piping Material	Sewers Outside Buildings	Under Ground Within Buildings	Above Ground Within Buildings
ABS Pipe and Fittings, Schedule 40 DWV (ASTM D2661)	X	X	X
ABS Pipe Cellular core (ASTM F628) and DWV Fittings	X	X	X
ABS Sewer Pipe and Fittings (ASTM D2751)	X		
Brass Pipe (ASTM B43)			X
Cast-Iron Soil Pipe and Fittings – Bell and Spigot (ASTM A74)	X	X	X
Concrete Drain Pipe, Nonreinforced (ASTM C14)	X		
Concrete Drain Pipe, reinforced (ASTM C76)	X		
Copper Pipe (ASTM B42)			X
Copper Tube – DWV (ASTM B306) and Copper Drainage Fittings (ANSI B16.23)	X	X	X
Galvanized Steel Pipe (A53) and Cast-Iron Drainage Fittings (ASME B16,12)			X
PVC Pipe and Fittings, DWV (ASTM D2665)	X	X	X
PVC Sewer Pipe – Cellular Core (ASTM F891)	X	X	X
PVC Sewer Pipe (PS-46) and Fittings (ASTM F1866)	X		
PVC Sewer Pipe (PSM) and Fittings (ASTM D3034)	X		
Vitrified Clay Pipe – Standard Strength (ASTM C700)			X
Vitrified Clay Pipe – Extra Strength (ASTM C700)	X	X	
(1) Plastic drain, waste, and vent piping classified by standard dimension ratio shall be SDR 26 or heavier (lower SDR number). (2) Plastic Sewer pipe classified by pipe stiffness shall be PS-46 or stiffer (higher PS number). (3) Piping shall be applied within the limits of its listed standard and the manufacturer's recommendations.			

Pay special attention to the joints so roots do not grow into the piping. The depth of the piping should be below the frost line. Also, you should encase the piping with concrete or sleeve it with a metallic material when laying piping under roadways. It may be necessary to install the building sewer and the water-service pipe in the same trench (*Figure 2-1*). If so, use the following precautions:

- Ensure the bottom of the water pipe is at least 12 inches above the top of the building sewer.
- Place the water pipe on a solid shelf at the side of the trench.
- After installation, test the building sewer with a 10-foot head of water, or equivalent test.

Figure 2-1 — Building sewer and the water service pipe in the same trench.

1.2.1.1 Grading

Install sanitary drainage piping on a uniform slope. This slope, pitch, grade, or drop per foot decides the flow velocity of liquid within the pipe. Piping with a diameter of 3 inches or less requires a slope of not less than 1/4 inch per foot. Pipe 4 inches or larger slopes no less than 1/8 inch per foot. This allows a velocity of not less than 2 feet per second and provides the scouring action necessary to keep a pipe free from fouling. Sewer mains may have slopes of less than 1/8 inch per foot, as long as there is a cleaning velocity of 2 feet per second or greater. See *Table 2-2* for code requirements. Use the following precautions when designing a system, but always refer to codes, this example can be used as a basic rule of thumb.

Table 2-2 — Slope of horizontal drainage pipe.

Size (inches)	**Minimum slope (inch per foot)**
2 ½ or less	¼
3 to 6	⅛
8 or larger	1/16

Higher velocities, or greater drop per foot, will increase the carrying capacity of a drain. When designing fixture branches, remember that a slope/drop of more than 1/4 inch per foot may cause ***siphonage*** of the trap seal.

1.2.1.2 Sizing Building Drains

The building drain in a sanitary system must be of sufficient size to carry off all the water and waste materials that may be discharged into it at any one time. The minimum allowable size is 3 inches, but sound practice prescribes a 4-inch pipe, and most plumbing codes or ordinances require 4-inch pipe as a minimum. Increasing the size beyond that computed as required (the minimum of 3 inches still applies) does not increase the efficiency of the drain. The passage of liquid and solid waste through a horizontal pipe creates a natural scouring action, which is partially lost when the size of the drain is increased above the necessary size. The flow in too large of a pipe is shallow and slow, and solids tend to settle to the bottom. The solids may accumulate to such an extent that they cause stoppages in the line. The optimum size of pipe should flow half full under normal use. This will create an efficient, natural scouring action and still allow capacity for peak loads.

The standard method used in determining the size of a building drain is the Unit System. Drainage fixture unit system values for standard plumbing fixtures have been established and some of the most common are shown in *Table 2-3*. Use the trap size listing at the bottom of *Table 2-3* for estimating drainage fixture unit (d. f. u.) values for fixtures that are not listed.

Table 2-3 — Drainage fixture unit values for various plumbing fixtures.

Type of fixture of group of fixtures	Drainage fixture unit value
Automatic clothes washer, commercial	3
Automatic clothes washer, residential	2
Bathroom group (1.6 gpf water closet)	5
Bathroom group (water closet greater than 1.6 gpf)	6
Bathtub	2
Bidet	1
Combination sink and tray	2
Dental lavatory	1
Dental unit or cuspidor	1
Dishwashing machine, domestic	2
Drinking fountain	½
Emergency floor drain	0
Floor drains	2
Kitchen sink, domestic	2
Laundry tray	2
Lavatory	1
Shower (based on the total flow rate through showerheads and body sprays) Flow rate: Less than 5.7 gpm 5.7 gpm to 12.3 gpm 12.3 gpm to 25.8 gpm 25.8 gpm to 55.6 gpm	 2 3 5 6

Type of fixture of group of fixtures	Drainage fixture unit value
Service sink	2
Sink	2
Urinal	4
Urinal, 1 gallon per flush or less	2
Urinal, nonwater supplied	½
Wash sink (circular or multiple) each set of faucets	2
Water closet, flushometer tank, public or private	4
Water closet, private (1.6 gpf)	3
Water closet, private (flushing greater than1.6 gpf)	4
Water closet, public (1.6 gpf)	4
Water closet, public (flushing greater than1.6 gpf)	6
Fixtures not listed above: Trap size 1 ¼ " or less Trap size 1 ½ " Trap size 2" Trap size 2 ½" Trap size 3" Trap size 4"	 1 2 3 4 5 6

To select the correct size of pipe for a horizontal sanitary drainage system, you must first calculate the total volume of liquid waste, by multiplying the number and type of fixtures by the unit value that will be expressed in drainage fixture units that the system will be subjected.

Number and Type of Fixtures x Unit Values = Total Discharge in DFU.

Assume, for example, that a plumbing installation is to consist of 20 water closets, valve-operated; 22 lavatories with 1 1/4-inch traps; 15 shower heads in group showers; 20 wall urinals; 2 service sinks with standard traps; and 4 floor drains (2-inch). The total discharge, expressed in drainage fixture units, would be calculated as follows from *Table 2-4*.

Table 2-4 — Calculating drainage fixture load.

Number and Type of Fixtures	Unit Values	Total Discharge
20 Water closets	6	120
22 Lavatories	1	22
15 Shower heads	2	30
20 Urinals	4	80
2 Sinks (service)	3	6
4 Floor drains (2-inch)	3	12
		270 D.F.U.

After calculating the total discharge and determining the slope of the piping and the velocity of flow, select the correct size of pipe by using *Table 2-5*. Assume that the cast-iron house drain to be installed will have a slope of 1/4 inch per foot. From *Table 2-5*, the minimum size pipe for the horizontal sanitary drainage system under discussion is 5 inches.

Table 2-5 is for cast-iron soil pipe or galvanized steel pipe house drains, house sewers, and waste and soil branches. When copper tubing is used, it may be one size smaller than shown in the table. Note that the size of building drainage lines must never decrease in the direction of flow. When provision is made for the future installation of fixtures, those provided for must be considered in determining the required sizes of drainpipes. Construction to provide for such future installation should have a plugged fitting or fittings at the stack to eliminate any dead ends.

Table 2-5 — Maximum loads for horizontal drains.

Diameter of pipe (inches)	Horizontal fixture branch	Building drain or building sewer			
		Slope (inches per foot)			
		1/16	1/8	1/4	1/2
1¼	1	—	—	1	1
1½	3	—	—	3	3
2	6	—	—	21	26
2½	12	—	—	24	31
3	32[1]	—	36[2]	42[1]	50[1]
4	160	—	180	216	250
5	360	—	390	480	575
6	620	—	700	840	1,000
8	1,400	1,400	1,600	1,920	2,300
10	2,500	2,500	2,900	3,500	4,200
12	3,900	3,900	4,600	5,600	6,700
15	7,000	7,000	8,300	10,000	12,000

1. Not more than two water closets or two bathroom groups
2. Less than 2 feet per second

1.2.1.3 Sizing Stacks and Branches

The term ***stack*** is used for the vertical line of soil or waste piping into which the soil or waste branches carry the discharge from fixtures to the house drain. A ***waste stack*** carries liquid wastes that do not contain human excrement; a ***soil stack*** carries liquid wastes that do.

Most buildings do not have separate soil and waste stacks. A single stack, known as the soil and waste stack, or simply the soil stack, serves to carry both soil and waste material. Soil stacks are usually made of cast-iron pipe with caulked joints. They may, however, be made of other materials, such as galvanized steel or copper tubing.

Branches are usually either threaded, galvanized steel pipe with drainage (recessed) fittings or copper tubing.

1.2.1.4 Sizing the Stack

The stack is sized in the same way as the building sewer. The maximum discharge of the plumbing installation is calculated in drainage fixture units. This figure is applied to *Table 2-6* to obtain the proper stack size.

Continuing our example, the 270 drainage fixture units would require a 5-inch stack, if the stack had less than three branch intervals. (No soil or waste stack should be smaller than the largest horizontal branch connected, except that a 4 x 3 water closet connection should not be considered as a reduction in pipe size.)

Table 2-6 — Maximum loads for soil and waste stacks.

Diameter of stack	Maximum number of drainage fixture units			
	Total for horizontal branch	Stacks[1]		
		Total discharge into one branch interval	Total for stack of three branch intervals or less	Total for stack greater than three branch intervals
1 ½	3	2	4	8
2	6	6	10	24
2 ½	12	9	20	42
3	20	20	48	72
4	160	90	240	500
5	360	200	540	1100
6	620	350	960	1900
8	1,400	600	2200	3600
10	2,500	1,000	3800	5600
12	3,900	1,500	6000	8400
15	7,000	Note 2	Note 2	Note 2

- Table does not include branches of the building drain

1. Stacks shall be sized based on the total accumulated connected load at each story or branch interval. As the total accumulated connected load decreases, stacks are permitted to be reduced in size. Stack diameters shall not be reduced to less than one-half of the diameter of the largest stack required.
2. Sizing load based on design criteria.

1.2.1.5 Offsets on Drainage Piping

An offset above the highest horizontal branch is an offset in the stack vent and should be considered only as it affects the developed length of the vent.

An offset in a vertical stack with a change in direction of 45 degrees or less from the vertical piping may be sized as a straight vertical stack. In piping where a horizontal branch connects to the stack within 2 feet above or below the offset, a relief vent should be installed.

A stack with an offset of more than 45 degrees from the vertical should be sized as follows:

1. The portion of the stack above the offset should be sized for a regular stack, based on the total number of drainage fixture units above the offset.
2. The offset should be sized as for the building drain. See *Table 2-5*.
3. The portion of the stack below the offset should be sized as for the offset, or based on the total number of drainage fixture units of the entire stack, whichever is larger. A relief vent should be installed for the offset. Never connect a horizontal branch or fixture to the stack within 2 feet above or below the offset.

1.2.1.6 Sizing Individual Waste Lines

The water closet, strictly speaking, have no waste. It is usually connected, by the use of a closet bend, directly into the stack on a separate branch of its own that is as short as possible. The closet bend is 3 or 4 inches in diameter if made of cast iron, steel or PVC and 3 inches if made of copper.

Because lavatories are used for washing hair, loose hair is often carried down into the waste pipe, causing a stoppage. Lavatory drainage is improved by using a minimum number of fittings and by eliminating long horizontal runs. The minimum pipe size for lavatory wastes is 1 ¼ inches, but 1 ½ inches is more satisfactory.

Urinals present a particular problem because cigarette butts, cigar stubs, chewing gum, matches, and so forth are often discarded in them. These materials can easily cause a stoppage. For this reason, urinals should be equipped with an effective strainer. Size of waste pipe should be at least 1 ½ inches for wall-mounted urinals and 3 inches for the pedestal siphon jet urinal.

Shower wastes seldom cause trouble because they have a relatively clear water waste flowing through them. The usual diameter of the waste pipe for a single shower is 2 inches if made of cast iron or steel, and 1 ½ inches if made of copper.

A domestic kitchen sink requires a 1½ inch cast-iron, steel or PVC waste pipe. When a sink is equipped with a garbage disposal unit, a minimum of 2 inches is required.

There are two styles of service sinks (slop sinks): the trap-to-wall and the trap-to-floor. They are used for disposal of wash water, filling swab buckets, and washing out swabs. The trap-to-wall type requires a 2-inch or 3-inch waste pipe; the trap-to-floor, a 3-inch waste pipe. For both types, if copper tubing is used, a one size reduction is allowed.

Scullery sinks are large sheet metal sinks used for washing large pots and pans and for general scouring purposes. The large amount of grease that usually passes through a scullery sink makes a 2-inch waste pipe necessary.

Drinking fountains carry only clear water wastes and a 1 ¼ inch waste pipe is suitable. An indirect drain (covered later in this chapter) should be used.

1.2.1.7 Sizing Sanitary Collecting Sewers

The design and sizing of collecting sewers, the sub trunks, and the main trunk lines are provided by engineers. However, the UT should understand the factors that contribute to the design and the requirements that must be met.

While the unit system is used to size the building sanitary piping and the building drain, the sewage quantities used in sewer design normally are computed on a contributing population basis. The population to be used in design depends upon the type of area that the sewer is to serve. If the area is strictly residential, the design population is based on full occupancy of all quarters served. If the area is industrial, the design population is the greatest number employed in the area at any time. There are exceptions to the general rule that sewers must be designed on a population basis. Among these exceptions are laundry sewers and industrial-waste sewers. The per capita contribution for sewer design varies. Typical values are 100 gallons per person per day for permanent residents and 30 gallons per person in the industrial area per 8-hour period.

The sizing of the sewer includes the average rate and the extreme (peak) rate of flow (which occurs occasionally). The ratio of the peak rate of flow to the average rate of flow may vary with the area served because the larger the area or the greater the number of persons served, the greater the tendency for flow to average out. Typical peak flows might range from 6 for small areas down to 1.5 for larger areas.

An allowance for infiltration of subsurface water is added to the peak flow to obtain the design flow. A typical infiltration allowance is 500 gallons per inch of pipe diameter, per mile of sewer per day.

Additional capacity to provide for population increase is usually included for areas that are likely to continue to develop. Provision of approximately 25 percent additional capacity over the initial requirements is advisable.

Each length of pipe from one manhole to the next is sized to carry the design flow. However, to help prevent clogging and to facilitate maintenance, a minimum size is usually specified that may be larger than is necessary to carry the design flow at the upper ends of the system. Typical minimum sizes are 6-inch pipe for house and industrial-waste sewers, and 8 inch pipe for all other sewers.

It is sometimes the practice to select a pipe size that will carry the design flow when the pipe is half full, thus allowing for expansion. More often, however, sufficient safety factors in the future population estimate and the peak flow factor are included so the pipe may be designed to carry the design flow when flowing full.

The formulas or tables used in sizing the pipe are based on experiments and experience. One of the factors taken into account is the roughness of the pipe. Asbestos-cement pipe, for example, is smoother than concrete pipe. Because there is less friction on the inside of the asbestos-cement pipe, it will carry a greater flow than concrete pipe of the same size.

Another factor is the slope at which the pipe will be laid. The slope will generally be determined by the fall available on the natural ground area through which the sewer runs. The plans for collecting sewer systems generally show slope (or grade) in terms of fall per hundred feet. Slope is sometimes expressed as a percent rather than in inches per foot. A 1 percent slope means 1 foot of fall in a 100-foot length of pipe, or about 1/8 inch per foot. A 0.5 percent slope (6 inches in 100 feet) is about 1/16 inch per foot.

Table 2-7 gives the minimum slope for some of the most commonly used pipe sizes. The slope should remain constant in the section between each manhole. Each section between successive manholes should be analyzed and the slope for that particular section determined. If the fall is relatively steep, the velocity of the flow is faster and a smaller pipe size may be used. If the slope is relatively flat, the velocity is slower and a larger pipe size may be used. In the larger pipe, the depth of flow may decrease to such extent that the velocity might be no greater than a smaller pipe on the same grade. Therefore, an increase in pipe size to obtain the desired flow velocity is limited by the rate of flow. Typical minimum flow velocities are 2 feet per second when the design flow

Table 2-7 — Minimum slope for sewer pipe.

Inside pipe diameter (inches)	Minimum fall (ft per 100 ft)
6	0.6
8	0.4
10	0.3
12	0.24
18	0.14

fills the pipe, and 1.6 feet per second at the average rate of flow. Maximum velocities must also be considered; too high of a velocity will erode the pipe. A typical maximum velocity is 15 feet per second for concrete pipe. Because of the differences in available slopes, smaller pipe may be used in some sections than is required in an upper section of the same sewer. The pipe size should be reduced whenever better flow conditions would result.

Manholes provide access to sewers for inspection and cleaning. They are placed where there is a change in grade, a change in pipe size, a junction of two or more sewer lines, or a change in direction. Otherwise, they are placed at intervals of 300 or 500 feet of sewer line. The manholes should be built so there is no decrease in velocity and a minimum of water disturbance. The channel should be deep enough to prevent sewage from spreading over the manhole bottom. The covers should be of a weight strong enough to support the expected traffic. Perforated covers should not be used for sanitary sewer manholes because openings in the sewer manhole would permit the entrance of sand, grit, and surface water. The sewers are ventilated by the stacks of the building plumbing systems.

1.2.2 Storm Drain Systems

Storm drainage systems are designed to drain all surface and sometimes subsurface water that may cause damage to facilities, property, or adjoining land. They consist of pipe, inlets, catch basins, and other drainage structures to carry the surface runoff and subsurface water to a point of disposal.

Storm drainage systems should be separate from sanitary sewage systems wherever possible. Some locations may have combination systems still in use. However, storm water should never be drained into sewers intended for sanitary sewage only.

EOs and BUs generally are responsible for building ditches, culverts, and other structures that are a part of storm sewers. Therefore, construction of these facilities is not covered in this chapter.

The UT is generally concerned with only the pipe work itself. This involves laying storm drain lines both inside and outside buildings and other structures. This pipe material may be the same as that used for the sanitary system. Storm sewer systems, however, may include pipe of much larger sizes than are needed for sanitary sewers. Plain or reinforced concrete pipe (rather than clay, cast iron, or asbestos cement) is generally used for the larger lines. Also, it is not so important that the joints be watertight in storm sewer systems. In fact, the mortar is sometimes omitted from a portion of the joint and washed gravel is placed next to the opening; the storm drain thus serves also as an under drain to pick up subsurface water.

1.2.2.1 Installation Considerations

Storm and sanitary systems may differ in the installation of the piping. Building storm drains should generally be graded at least 1/4 inch per foot whenever feasible. This amount of drop per foot provides an unobstructed and self-scouring flow. However, a greater drop per foot may be given as no fixture traps, which might lose their seals, are associated with it.

When a change of direction is necessary, long radius fittings are used and a cleanout need not be installed. This is especially true in and under buildings, but a manhole is used outside buildings when a change of direction is necessary, or when two or more lines are connected together.

1.2.2.2 Sizing Building Storm Drains

To determine the size of building storm drains, a number of factors must be considered, such as rainfall intensity, roof size, and pitch of roof. Tables have been made for use in estimating the size of pipe to select. One example is *Table 2-8*, which shows storm drain sizes. Remember that this table is to be used only as a guide when estimating for storm drainage, as different areas have different intensities of rainstorms.

Another method for sizing building storm drains is to provide 1 square inch of pipe cross-sectional area for each 100 square feet of roof area. This method is easy to remember: 1 square inch for 100 square feet. (However, it is not as accurate as using *Table 2-8*.)

Table 2-8 — Size of horizontal building storm drains and building storm sewers.

Diameter of drain (inches)	**Maximum projected area for drains of various slopes**					
	⅛ inch slope		**¼ inch slope**		**½ inch slope**	
	square feet	gpm	square feet	gpm	square feet	gpm
3	822	34	1160	48	1644	68
4	1880	78	2650	110	3760	156
5	3340	139	4720	196	6680	278
6	5350	222	7550	314	10700	445
8	11500	478	16300	677	23000	956
10	20700	860	29200	1214	41400	1721
12	33300	1384	47000	1953	66600	2768
15	59500	2473	84000	3491	119000	4946
Sizes are based upon a maximum rate of rainfall of 4 inches per hour for a 5-minute duration and a 10-year period. Where maximum rates are more or less than 4 inches per hour, the figures for drainage area shall be adjusted by multiplying by four and dividing by the local rate in inches per hour.						

1.2.2.3 Sizing Site Storm Sewers

While rules of thumb, such as those just described, are used to size building storm drains, different procedures are used to size the storm sewers that carry the runoff from the building site and surrounding land areas. The design and sizing of storm drains are provided by engineers. It is not necessary that the UT understand the factors that contribute to the design. Therefore, the information is not included here.

1.2.3 Water Supply Systems

After the pipe runs and fittings are located on a print or drawing, the size, quantity, and joining requirements of the pipe must be determined. When a plumbing print is available for the job, it will contain this information. If there is no blueprint, you must determine these requirements yourself. The quantity of pipe required and the number and types of fittings you intend to use are easily determined by tracing the layout of the water supply system, as drawn in a print or sketch. Determining the size of pipe you will require to meet the fixture demand of a facility is more complicated and will be discussed in this section.

1.2.3.1 Sizing Cold Water Supply Systems

Some factors that affect the size of the water service in a plumbing system are the types of flush device used on the fixtures, the pressure of the water supply in pounds per square inch (psi), the length of the pipe in the building, the number and kind of fixtures installed, and the number of fixtures used at any given time. The stream of water in a pipe is made up of a series of layers moving at different speeds with the center layer moving the fastest. The resistance to flow is called ***pipe friction*** also known as friction loss and causes a drop in pressure of the water flowing through the pipe. Friction loss may be overcome by supplying water at greater pressure than would normally be required or by increasing the size of the pipe.

The two most important things to consider are the maximum fixture demand and the factor of simultaneous fixture use. The ***maximum fixture demand*** in gallons is the total amount of water that would be needed to supply all fixtures if they were being used at the same time for 1 minute. Because it is very unlikely that all fixtures would be turned on at the same time, a probable percentage of the fixtures in use at any given time must be found. This is the factor of simultaneous use. The more fixtures in a building, the smaller the possibility that all will be used at the same time. Therefore, simultaneous use factors decrease as the number of fixtures increases.

To estimate the maximum fixture demand in gallons, the number and type of all fixtures in the completed plumbing system must be known. *Table 2-9* is used to obtain the maximum fixture demand. For example, assume a plumbing system consists of three urinals, two water closets, one slop sink, two shower stalls, one kitchen sink, one laundry tray, and four lavatories. From *Table 2-9,* a maximum fixture demand of 321 gallons per minute (gpm) can be figured. Normally, only a small percentage of fixtures would be used at the same time, so the maximum fixture demand is reduced by applying the factor of simultaneous use.

Table 2-9 — Fixture demand.

Fixtures	Units	Gallons per minute
Water closet	6	45
Urinal	5	39 ½
Slop sink	3	22 ½
Shower	2	15
Laundry tray	2	15
Bathtub	2	15
Kitchen sink	2	15
Lavatory	1	7 ½
1 unit =7 ½ gallons per minute		

The factor of simultaneous use, also called the probable demand, is only an estimate. *Table 2-10* gives data for making an estimate of probable demand. When using this table, take the actual number of fixtures installed, not the fixture unit value. For example, five fixtures would have a probable demand of about 50 percent, while 45 fixtures would have a probable demand of about 25 percent. When a table showing the factors of simultaneous use is not available, a practical way of figuring the probable demand is 30 percent of the maximum fixture demand in gallons.

Table 2-10 — Factors of simultaneous use.

Number of fixtures	Percent of simultaneous use
1-4	50-100
5-50	25-50
51 or more	10-25

Many factors affect the flow of water through pipes, resulting in a loss of water pressure. Difficult calculations are required to consider all the factors involved that may cause a loss of water pressure. These calculations are beyond the range of this manual. For simple systems, approximate figures are acceptable for most plumbing installations.

The minimum practical size for a water-service line is 3/4 inch. This size should be used even when calculations show that a smaller size could be used.

1.3 Corrosion Prevention and Protection

As a UT, you must consider the effects of corrosion on the equipment that you are installing. When planning a project, the necessary materials and equipment required for galvanic cathodic protection of underground pipes and fittings must be considered. First, you must understand what corrosion is and how it occurs.

1.3.1 Types of Corrosion

There have been corrosion problems to contend with ever since we started making articles out of metal. For thousands of years, the only fact known about corrosion was that it affects some metals more than others. For example, iron, one of the most abundant and useful metals, corrodes very much, whereas metals such as gold, platinum, and silver corrode very little. Later, corrosion was studied to find out what caused it. As might be expected, many theories were proposed to explain corrosion and its causes. Among the many theories, the electrochemical theory is most generally accepted as an explanation of corrosion.

The electrochemical theory of corrosion is best explained by the action that takes place in a galvanic cell. A galvanic cell (*Figure 2-2*) can be produced by placing two dissimilar metals in a suitable electrolyte. The resulting electrochemical reaction develops a potential difference between these metals. This causes one metal to be negative or anodic and the other metal to be positive or cathodic. In a dry cell battery, the zinc case is the anode and the carbon rod the cathode. When an external electrical circuit is completed, current flows from the zinc case into the electrolyte, taking with it particles of zinc. This is an example of galvanic corrosion of the zinc case. It is this electrochemical action that illustrates the electrochemical theory.

Figure 2-2 — Galvanic cell showing internal galvanic action.

Corrosion may be divided into several types, such as uniform corrosion, localized corrosion, and compositional corrosion. Each type will be explained in the following paragraphs.

1.3.1.1 1.1 Uniform Corrosion

Uniform corrosion is caused by direct chemical attack. An example of this type of corrosion is zinc exposed to hydrochloric acid. If you examine the surface of zinc in a solution of hydrochloric acid, you will find that the entire surface is corroding. Furthermore, if the zinc is left in the acid long enough, it will be dissolved by the acid.

1.3.1.2 Localized Corrosion

Localized corrosion is caused by the electrolytic action of a galvanic cell. A local galvanic action is set up when there is a difference of potential between the areas on a metallic surface that is an electrolyte. Localized corrosion may be in the form of pits, pockets, or cavities due to the deterioration or destruction of metal.

Localized corrosion may develop under a number of various conditions when different types of equipment are buried in the ground. Some examples of localized corrosion are discussed in the following paragraphs:

- Corrosion due to mill scale. The mill scale embedded in the walls of iron pipe during its manufacture is one cause of pipe corrosion. It actually becomes the cathodic area, the iron pipe the anodic area, and the moist soil the electrolyte, as shown in *Figure 2-3*. Current leaves the iron pipe wall and passes through the electrolytic soil to the mill scale. This electrochemical action causes severe pitting of the pipe metal at the anodic areas. Continued action of this type will eventually weaken the pipe to the extent of failure.

Figure 2-3 — Pipe with corroding anode and noncorroding cathode areas.

- Corrosion due to cinders. Another type of corrosion occurs when iron pipe is laid in a cinder fill in direct contact with the cinders. The cinders and the iron pipe make up the dissimilar metals. The pipe forms the anodic area, the cinders form the cathodic area, and the highly ionized soil serves as the electrolyte. The current leaves the pipe through the soil to the cinders and returns to the pipe. Severe corrosion occurs at the points where the current leaves the pipe.
- Corrosion due to dissimilarity of pipe surface. This type of galvanic corrosion occurs when there are bright or polished surfaces on some areas of the pipe walls in contact with suitable electrolytic soil. These bright surfaces become anodic to the remaining pipe surfaces. In highly ionized soil, the polished surfaces corrode at an accelerated rate, thus weakening the pipe at that point.
- Corrosion due to different soil conditions. This is a general corrosion problem, especially prevalent in highly alkaline areas. Corrosion currents leave the pipe wall and pass into compact soils and enter the pipe wall from light, sandy soils. The intensity of the corrosion currents and the resulting rate of corrosion at the anodic areas of the pipe are directly proportional to the conductivity of the soil.
- Corrosion due to stray currents. Direct current circuits that pass in and out of an electrolyte usually cause stray currents, many of which are a direct cause of corrosion. Corrosion does not occur at the point where the current enters the structure because it is catholically protected. However, at the section where the current leaves the structure, severe stray current corrosion occurs. Over a period of a year, this type of corrosion has been known to displace as much as 20 pounds of pipe wall for every ampere of current.
- Corrosion due to bacteria. Biological corrosion is another distinct type of corrosion caused by electrolytic or galvanic cell action. It is the deterioration of metals by corrosion processes that occurs as either a direct or an indirect result of the metabolic activity of certain minute bacteria, particularly in water or soil

environments. These organisms that cause bacterial corrosion are bacteria, slime, and fungi.

- Microbiological corrosive action in the soil is due to physical and chemical changes in the soil caused by the presence of these organisms. Some bacteria are responsible for the production of active galvanic cells. These bacteria are mostly found in highly waterlogged, sulfate-bearing, blue clay soils. The bacteria concentration, as well as the corrosion rate, varies considerably with the different seasons of the year. Cast-iron and steel pipes are corroded mostly by sulfide production.

1.3.1.3 Compositional Corrosion

Compositional corrosion alters the composition of metals. Some of the specific types of compositional corrosion are discussed in the following paragraphs:

- Dezincification. This is a selective type of corrosion that occurs in copper and zinc alloys. When alloys of this kind (brasses) are exposed to this type of corrosion, the zinc dissolves out of the alloy and leaves only the copper.
- Graphitization. Another type of compositional corrosion is graphitization or graphitic softening. It is a peculiar form of disintegration that attacks grey cast iron. Cast iron is an alloy made of iron and carbon, the carbon being in the form of graphite. When cast iron with such a composition is subjected to graphitization, the iron dissolves out and leaves only the graphite. This action leaves cast-iron pipes and other similar equipment weakened mechanically. However, after graphitization corrosion occurs, the graphite pipe may last for many years if it is not subjected to any mechanical forces or sudden pressures. The action of this type of corrosion is similar to dezincification.
- Hydrogen embrittlement. This is a term applied to metal that becomes brittle because of the action of some form of corrosion that causes the formation of hydrogen on its surface. When hydrogen forms on the surface of steel, the action of the hydrogen may form blisters or actually embrittle the metal. Hydrogen liberated near the surface of steel in an electrolyte will diffuse into the metal quite rapidly. The hydrogen picked up by the steel is in an atomic state and causes the steel to become brittle.

When the production of atomic hydrogen on the surface of the metal stops, the hydrogen leaves the metal in a few days and the metal again regains its original ductility.

1.3.1.4 Stress Fatigue of Metals

Corrosion affects metals that are under stress. The action caused by stresses on a pipeline or structure is due to the shifting of the various rocks and soils of the earth. Usually a complete pipeline is not under stress; certain sections are under stress while adjacent sections are not. Because of these pressures and strains, localized electrochemical action takes place. The section of the pipe or structure under stress becomes anodic, whereas the unstressed sections become cathodic. In this way, the pipe under stress begins to corrode and weaken because of the action of corrosion.

1.3.1.5 Corrosion caused by Nonelectrolytes

Nonelectrolytes are materials that will not conduct electricity. These materials include nonelectrolytic vapors, liquids, and bacterial organisms. Because they do not conduct electricity, they do not, in themselves, cause corrosion.

1.3.1.5.1 Nonelectrolyte Gases and Vapors

Nonelectrolytic gases and vapors usually must be subjected to high temperatures before corrosive action can take place. Hydrogen sulfide causes scaling of iron at temperatures from 1400°F to 2000°F. High-chromium alloy steels resist this type of corrosion best. The only remedy for this type of corrosion is to keep the gases away from the metal or use a metal that can resist corrosion.

High-carbon steels are attacked by hydrogen at temperatures above 750°F. This hydrogen combines with the carbon grains in the steel and causes the metal to weaken at the grain boundaries between the iron and carbon.

Oxygen will combine directly with most metals at high temperatures. The temperature at which oxygen will combine with the metals depends mostly upon the type of metal. In the process of cutting iron with an oxyacetylene torch, the oxygen combines with the iron.

1.3.1.5.2 Nonelectrolytic Fluids

Nonelectrolytic fluids include such liquids as pure water, lubricating oils, fuel oils, and alcohols. These fluids do not cause corrosion, but corrosion does occur in storage tanks that contain these liquids and in pipelines that carry them. The corrosion is not caused by the nonelectrolyte liquids, but by the foreign products in them. For example, if impure water is introduced into an oil pipeline, the water will cause the inside of the pipe to corrode. The water collects on the inside of the pipe because the pipe is usually cooler than the oil. In a storage tank, the water will settle to the bottom of the tank because water is heavier than oil, and will cause the bottom to corrode. Hydrogen sulfide and sulfur dioxide may also be introduced into the pipeline to add to the corrosiveness of the water that collects on the metal. The only way to prevent corrosion from this source is either to coat the inside of the pipeline and tanks with a protective film or to remove the water from them.

1.3.1.6 Bacterial Organisms

Bacterial organisms may also cause microbiological corrosion. Colonies of bacteria that live close to the metal surface in stationary slimy deposits produce corrosive substances, such as carbon dioxide, hydrogen sulfide, ammonia, and organic and inorganic acids. These corroding substances are found only in the locality of the colony and may be undetected in the surrounding water or soil. Bacteria that cause corrosion in this way need to produce only small amounts of corrosive products for localized attack. However, colonies of bacteria that do not produce corrosive products may act as a protective film around the metal, causing unequal distribution of electrical potential, which gives rise to local anodes and cathodes. In this way, the production of local cells will cause increased corrosive action.

Biological corrosion is extremely difficult to control because the organisms are very resistant to normal methods of sterilization. Probably the most logical method to reduce microbiological corrosion is by the use of some barrier coating between the environment and the metal.

1.3.1.7 Corrosion Caused by Electrolytes

An electrolyte is any substance that conducts electricity. It conducts electricity because it contains ions that carry electrical charges, either negative or positive, that move in electrical fields. Some of the more important electrolytes are discussed in the following paragraphs.

1.3.1.7.1 Atmospheric Conditions

Corrosion due to atmospheric conditions is caused mainly by the water in the atmosphere. Pure water is a nonelectrolyte, but because water is a universal solvent, it is not found to be pure very often. Rain water is often considered to be pure, but this is not true. As rain falls to the ground, it dissolves gases out of the atmosphere and becomes impure. For this reason, any water vapor in the atmosphere is also impure. If a piece of metal is exposed to atmospheric air, and the metal is cooler than the air, water vapor from the air will collect on the surface of the metal. The layer of water on the metal may be so thin that it cannot be seen, but there is enough of it, if impure, to start corrosion. In this case, when the gases dissolve into the water, the water becomes an electrolyte. When metal is exposed to an electrolyte, galvanic cells are produced on the surface of the metal because there are impurities in it. Each one of these cells starts to act on the metal, causing corrosion by electrochemical action.

1.3.1.7.2 Water and Water Solutions

If metal is exposed to water or water solutions, corrosion is likely to occur if the water or metal is impure. If the water or metal is pure, corrosion probably will not occur; however, these conditions seldom exist in nature. Impurities in the water and metal produce galvanic cells that cause corrosion.

1.3.1.7.3 Chemical Agents

Chemical agents, such as acids and salts, also cause corrosion. When these agents are present in the environment, direct chemical attack on metal is the result. For example, if a piece of zinc is exposed to hydrochloric acid, a definite chemical reaction takes place. The zinc and hydrochloric acid combine, producing zinc chloride and hydrogen. This action continues until the zinc is completely dissolved or the acid is too weak to act on the zinc. Corrosion causes the zinc to dissolve. Another example that may be used to illustrate corrosion through the use of a chemical agent is to place aluminum in a lye solution. The lye will pit (corrode) the aluminum as long as chemical action continues between the aluminum and lye.

1.3.2 Materials Least Likely to be Affected by Scale and Corrosion

Whenever installing various types of plumbing equipment in areas where corrosion is active, you should select equipment made of materials least affected by corrosion. To prevent electrochemical action in plumbing equipment, the equipment should be made of materials that are not affected by electrolysis. Plastic materials, such as polyethylene polyester and polyvinyl chloride, are not acted upon by corrosion. Glass is another material that is not acted on by corrosion. (This is why hot-water tanks are lined with glass.) Other materials used for the manufacture of pipe that resists corrosion are vitrified clay, cement, fiber, asbestos, and rubber. Glass fibers reinforced with epoxy or polyester resins are also resistant to corrosion.

Dielectric bushings may be installed to stop electrolytic action in plumbing systems or wherever dissimilar metals are used. These bushings are made of nylon and are usually colored. They withstand pressures to 100 psi and temperatures up to 300°F. The bushings are usually placed in pipe systems as recommended by the manufacturer. Some metals least likely to be affected by corrosion are copper, brass, Monel, and stainless steel.

1.3.3 oatings and Wrappings for Corrosion Protection

Coatings and wrappings are commonly used to combat corrosion on exterior piping systems. There are many different types of coatings, such as asphalts, coal tars, plastics, mastics, greases, and cements. These coatings are considered to be insulating materials, but each is not effective in all environments. Each one was developed for a certain type of corrosive environment.

1.3.3.1 Asphalt Coatings

Asphalt coatings are the most common type of protective coating. Asphalt coatings can take considerable abrasion, impact, and temperature changes without losing effectiveness.

1.3.3.2 Coal Tar Coatings

Another type of protective coating is coal tar. Although it is less expensive than asphalt and adheres well to the pipe, wide temperature changes could cause the coating to crack.

1.3.3.3 Paint Coatings

Some of the most important paint coatings are coal tar, asphalt, rubber, and vinyl.

Coal tar paints have the outstanding characteristics of low permeability and resistance to electrolytic reaction. They are not affected by the action of water. These paints are recommended for piers, marine installations, flood control structures, sewage disposal plants, and industrial concrete pipelines.

Asphalt paints are weather resistant and durable against industrial fumes, condensation, and sunlight action. Because of their resistance against water solvency, they are used on steel tanks and concrete reservoirs.

Rubber base paints are very resistant to acids, alkalies, salts, alcohols, petroleum products, and inorganic oils. The resistance of these products makes them ideal for use on the inside of metallic and concrete storage tanks. If these structures are submerged in water or are under ground, a special form of this paint should be used because of condensation.

Vinyl paint is one of the many synthetic resin base paints. These paints dry to a film that is tough, abrasion proof, and highly resistant to electrolysis. They are odorless, tasteless, nontoxic, and nonflammable. The film is especially resistant to oils, fats, waxes, alcohols, petroleums, solvents, formic acid, organic acids, ammonium hydroxides, and phenols. Because of these characteristics, vinyl paint is very applicable for tanks, pipelines, wellheads, offshore drilling rigs, pipe used in oil industries, railroad hopper cars, dairy and brewery equipment, storage tanks, and concrete exposed to corrosive environments.

1.3.3.4 Grease Coatings

Grease is another material used to form a protective coating on structures. It is usually made from a petroleum base and resembles paraffin or wax, Grease can be applied either hot or cold. However, it must be protected by some type of wrapping to keep the grease from being displaced or absorbed by the backfill soil when it is applied to underground surfaces.

1.3.3.5 Concrete Coatings

Concrete coatings have been used with success when properly applied to pipelines to be laid in highly corrosive soils, such as areas containing acid mine drainage or in brackish marshes. Well-mixed concrete, usually a mix of one part portland cement to two parts sand, may be applied to pipelines. The thickness of the coating applied may be up to 2 inches. If the concrete is properly mixed and tamped around the pipe, it may last 40 years. However, concrete has a tendency to absorb moisture and crack, which in many ways limits its use. In fact, in places where the coating cracks, electrolysis immediately starts to corrode the metal. This corrosion can be partially prevented by painting the pipe with a bituminous primer before coating it.

1.3.3.6 Metallic Coatings

Metallic coatings such as galvanizing (zinc coating) are very effective in protecting metallic structures or pipes against atmospheric corrosion. This type of coating is ideal for cold-water lines and metals exposed to normal atmospheric temperatures. However, metals such as iron corrode rapidly when used in high-temperature equipment because at a critical temperature of approximately 140°F, iron becomes anodic to zinc. This results in the iron's becoming the ***sacrificial*** anode that corrodes readily.

1.3.3.7 Plastic Wrapping

Plastic tapes for wrapping come in rolls. They may be procured in various widths. The tape is wrapped around the pipes before they are laid in the trench. The wrappings are applied by a simple device that is clamped on the pipe and turned by the UT. Pipe joints are wrapped after the pipes are laid in the trench.

1.4.0 Galvanic Cathodic Protection

Galvanic cathodic protection is a method used to protect metal structures from the action of corrosion. As explained before, galvanic cell corrosion is the major contributing factor to the deterioration of metal by electrochemical reaction. The area of a structure that corrodes is the anode or positive side of the cell. Corrosion occurs when the positive electric current leaves the metal and enters the electrolyte. Galvanic cathodic protection is designed to stop this positive current flow. When the current is stopped, the corrosive action stops and the anodes disappear. This type of protection depends upon the neutralization of the corroding current and the polarization of the cathode metal areas.

1.4.1 Methods of Galvanic Cathodic Protection

Galvanic cathodic protection is a means of reducing or preventing the corrosion of a metal surface by the use of sacrificial anodes or ***impressed*** currents. When sacrificial anodes are used, it is known as the galvanic anode method. If impressed currents are used, it is known as the impressed current method. These two methods can be used separately or with each other, depending upon the corrosive characteristics of the electrolyte surrounding the structure.

1.4.1.1 Galvanic Anode Method

Use of sacrificial anodes (*Figure 2-4*) is one method of cathodic protection. The most common type of sacrificial anode is made of magnesium. The anode is packaged in a mixture of gypsum bentonite/sodium sulphate to optimize contact with the electrolyte (soil). The anode is then connected to the pipeline with an insulated wire that is welded to the pipe surface. Electrical current will flow from the anode through the conductor (insulated copper wire) to the pipe. The current then travels along the pipeline and thereby protects it from the effects of corrosion. The anode is corroding by giving off ions that migrate into the soil. Ultimately, the anode will completely dissipate and require replacement.

Figure 2-4 — Sacrificial anode.

Sacrificial anode systems are simple and relatively inexpensive when used to protect small systems. Because they rely on the very small, naturally occurring voltages between dissimilar metals, their range of protection is limited. Using this type of system on a long pipeline requires the placement of anodes every 40 or 50 feet.

1.4.1.2 Impressed Current Method

Impressed current (*Figure 2-5*) is designed to protect large metallic distribution systems, such as water supply pipelines. With this method of protection, an AC power source must be available. A rectifier then changes the AC power to DC. The rectifier pulls current from the anodes, and that power flows onto the cathode (the structure to be protected, in this case the pipeline). Simultaneously, the anode is corroding by giving off ions that migrate into the soil. Ultimately, the anodes will completely dissipate and require replacement.

Figure 2-5 — Impressed current method of cathodic protection.

The main advantage between a sacrificial anode system and an impressed current system is the range of protection afforded to the pipeline from a single location. Because a galvanic system depends upon the naturally occurring difference in potential (voltage) between the anode and the cathode, its range of protection is limited to a small area. An impressed current system, on the other hand, taps into an external source of electrical power that allows for much higher voltages, multiple anodes, and therefore a much greater range of protection (miles in some cases). In addition, a rectifier allows for greater control and monitoring of the cathodic protection process.

1.4.2 Field Test Equipment for Cathodic Protection

The items of field test equipment that the UT uses to make tests when installing, operating, and maintaining cathodic protection systems are the volt-millivoltmeter, multicombination meter, resistivity instrument, buried pipe locator, and the protective coating leak detector. This equipment is discussed in the following paragraphs.

1.4.2.1 Volt-Millivoltmeter

In corrosion and cathodic protection testing in the field, it is necessary to measure the potential of the structure being investigated as compared to the earth along the structure and to other metallic structures. It is also necessary to measure the potential of rectifiers, batteries, galvanic anodes, and sometimes potentials along the earth's surface to determine the distance being protected. The potentials may vary from millivolts to 20 volts or more. Various types of voltmeters are used for this purpose. One of these instruments is the volt-millivoltmeter. It is a recording instrument designed with a chart that makes one revolution in 24 hours. The instrument will record the variations in potential and reveal the electrolytic conditions around a structure.

1.4.2.2 Multicombination Meter

The multicombination meter is used quite often in cathodic protection work. It is designed as a combination unit and actually consists of more than one instrument. The meter can be used as a high-resistance voltmeter, an ammeter, a milliammeter, a low-resistance voltmeter and millivoltmeter, and a potentiometer voltmeter.

The multicombination meter may be used to measure galvanic anode current between an anode and structure, galvanic current between structures, and potentials as with other types of voltmeters and millivoltmeters.

1.4.2.3 Resistivity Instruments

Resistivity measuring instruments are units used to test the corrosive action of a soil. Tests regarding soil corrosivity are necessary when designing cathodic protection systems. Information from these tests is used to locate the most corrosive areas where a pipeline is to be laid and the most corrosive areas of an existing pipeline. It is also used to decide the location for anode beds.

One of the simplest methods for making a resistivity test is to use a single probe resistivity meter. It consists of a probe with two electrodes, an indicating instrument, switches, and the required wiring. To use this instrument, the probe is inserted into the ground and current is applied to it. The indicating instrument gives a reading that indicates the corrosiveness of the soil.

1.4.2.4 Buried Pipe Locator

In the field of cathodic protection work, it is necessary to locate pipes in order to locate interferences in the cathodic protection system. An electronic pipe locator is used for this purpose. The main components of the locator are the directional transmitter and the directional receiver. Each one of these units is carried by an operator. The operators are usually about 30 feet apart. During actual operation, the transmitter sends out signals that travel along the pipeline. The receiver, in turn, picks up these signals in varying intensities, depending on the distance the operators are from the pipe. When both operators are directly over the pipe, a maximum response is obtained in the phones and on the visual meter of the receiver. Most pipe can be located easily and accurately in this manner.

1.4.2.5 Protective Coating Leak Detector

A protective coating leak detector (referred to as a ***holiday*** detector) is used to detect the imperfections (holidays) in pipe coatings. The holiday leak detector is an instrument that operates on an electric current. When it is being moved along a pipe that is covered by a coating or wrapping, a completed circuit between it and the pipe reveals a holiday and causes a bell to ring, a bulb to light, or a buzzer to sound.

1.4.3 Maintenance of Anode Systems

The anode system of cathodic protection requires little maintenance because there is no power source. Magnesium and zinc anodes used in the anode system sometimes suffer local or self-corrosion that reduces their efficiency. Replace the anode when the efficiency drops to a minimum. Anode life varies from 5 to 30 years, depending upon the type of anode used. It is conservative to figure that about 17 pounds of magnesium or 25 pounds of zinc are wasted away by electrolysis from an anode per ampere year. To detect the effectiveness of cathodic protection, you should install test stations in anode systems.

1.4.4 Maintenance of Impressed Current Systems

The impressed system of cathodic protection requires considerably more maintenance than the anode system. This is because an electrical current is used for the operation of the system. The current may come from any alternating current source. When alternating current is not available, you can use other generating sources to furnish the alternating current. The transformer rectifier used in the system requires much less maintenance and servicing than other sources of current. However, systematic maintenance procedures must be used to keep these units in operating condition.

The transformer-rectifier set consists of two units: a transformer and a rectifier. The transformer steps the voltage down to a value from 12 to 40 volts. The rectifier changes the alternating current to direct current. Remember to keep all of the connections on this unit airtight.

The materials most often used for anodes with impressed current are aluminum, high-silicon cast iron, and graphite. Scrap iron and steel may be used for anodes because they waste away at a rate of 20 pounds per ampere year. Replace anodes when they are wasted away. Insulated wire that resists electrolytic action must be used to make the connections between the anodes and the structures to be protected. The insulation on existing current-carrying lines should be checked. Replace the wires if they are deteriorating. Ensure that overhead wiring is fastened securely to the poles and that all connections are tight.

Summary

In this chapter we have covered how to plan and size water lines, some of the national codes involved with pipe planning, storm drain systems, water supply systems, and corrosion of pipes and how to protect them. Learning how to properly install and protect these systems enables the building to last longer and improve morale in the long run.

Review Questions (Select the Correct Response)

1. You can make changes to the schedule within how many days after arrival on the job site?

   A. 60
   B. 45
   C. 30
   D. 14

2. When placing a water pipe in the same trench as a sewer pipe, how many inches must the vertical separation be?

   A. 24
   B. 16
   C. 12
   D. 6

3. The building drain in a sanitary system must be at least how many inches?

   A. 8
   B. 6
   C. 4
   D. 3

4. Which type of vent or stack receives waste water that contains fecal matter?

   A. Main vent
   B. Waste stack
   C. Wet vent
   D. Soil stack

5. An offset in a vertical stack with a change in direction of how many degrees from the vertical pipe may be sized as a straight vertical stack?

   A. 45
   B. 30
   C. 22.5
   D. 15

6. The minimum pipe size for a lavatory is how many inches?

   A. 2 1/2
   B. 2 1/4
   C. 1 1/2
   D. 1 1/4

7. A one percent slope means that there is a one foot of drop in 100 feet of pipe, or how many inches per foot?

   A. 1/8
   B. 1/4
   C. 1/2
   D. 1/16

8. One method for sizing a building storm drain is one inch of pipe per how many square feet of roof area?

   A. 200
   B. 150
   C. 100
   D. 50

9. Which of the following metals corrodes the fastest?

   A. Gold
   B. Iron
   C. Platinum
   D. Silver

10. A biological corrosion is another type of corrosion caused due to what?

   A. Dissimilar pipe surfaces
   B. Bacteria
   C. Cinders
   D. Mill scale

11. This type of corrosion occurs in copper and zinc alloys.

   A. Dezincification
   B. Graphitization
   C. Embrittlement
   D. Hydrogen embrittlement

12. What is the most common type of protective coating used in corrosion control?

   A. Coal tar
   B. Vinyl
   C. Cathodic
   D. Asphalt

13. When utilizing the sacrificial anode system on a long pipeline, what is the minimum distance between anodes?

   A. 10 feet
   B. 20 feet
   C. 30 feet
   D. 40 feet

14. The impressed current system is designed to protect what type of system pipelines?

A. Waste discharge
B. Water return
C. Waste collection
D. Water supply

Trade Terms Introduced in this Chapter

Siphonage	Draining the trap of the water used to create its seal
Stack	A vertical line of soil or waste piping into which the soil or waste branches carry the discharge from fixtures to the house drain
Waste stack	A pipe that carries liquid wastes that do not contain human excrement
Soil stack	A pipe that carries liquid waste that does contain human excrement
Pipe friction	A resistance in the flow through a pipe
Maximum fixture demand	The total amount of water that would be needed to supply all fixtures if they were being used at the same time for one minute
Sacrificial	Pertaining to or concerned with sacrifice
Impressed	To produce (a voltage) or cause (a voltage) to appear or be produced on a conductor or circuit
Holiday	An unintentional gap left on a plated, coated, or painted surface

Additional Resources and References

This chapter is intended to present thorough resources for task training. The following reference works are suggested for further study. This is optional material for continued education rather than for task training.

OSHA Regulations (Standards – 29 CFR)

Naval Construction Force Manual, *NAVFAC P-315*, Naval Facilities Engineering Command, Washington, D.C., 1985.

Engineering Aid Basic, NAVEDTRA 10696-A, Naval Education and Training Professional Development and Technology Center, Pensacola, FL, 1995.

Facilities Planning Guide, NAVFAC P-437, Volumes 1 and 2, Naval Facilities Engineering Command, Alexandria, VA, 1982.

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Chapter 3

Interior Water Distribution and Interior Waste Systems

Topics

To hear audio, click on the box.

Overview

A Utilitiesman also installs, inspects, and troubleshoots many types of plumbing systems. To do these jobs properly, you must have the knowledge and ability to install, inspect, and repair plumbing systems within the structure. After studying this chapter, you should be able to inspect, detect leaks, and make temporary or permanent repairs to the systems.

Objectives

When you have completed this chapter, you will be able to do the following:

1. Describe the inspection and maintenance procedures associated with interior water distribution systems and fixtures.
2. Describe the inspection and maintenance procedures associated with interior waste systems.

Prerequisites

None.

This course map shows all of the chapters in Utilitiesman Advanced. The suggested training order begins at the bottom and proceeds up. Skill levels increase as you advance on the course map.

Air Conditioning and Refrigeration	↑	U T
Duct and Ventilation Systems		
Boilers		
Compressed Air Systems		A
Sewage Treatment and Disposal		D
Water Treatment and Purification		V
Fire Protection Systems		A
Interior Water Distribution and Interior Waste Systems		N C
Plumbing Planning and Estimating		E
Contingency Support		D

Features of this Manual

This manual has several features which make it easier to use online.

- Figure and table numbers in the text are italicized. The figure or table is either next to or below the text that refers to it.
- The first time a glossary term appears in the text, it is bold and italicized. When your cursor crosses over that word or phrase, a popup box displays with the appropriate definition.
- Audio and video clips are included in the text, with an italicized instruction telling you where to click to activate it.
- Review questions that apply to a section are listed under the Test Your Knowledge banner at the end of the section. Select the answer you choose. If the answer is correct, you will be taken to the next section heading. If the answer is incorrect, you will be taken to the area in the chapter where the information is for review. When you have completed your review, select anywhere in that area to return to the review question. Try to answer the question again.
- Review questions are included at the end of this chapter. Select the answer you choose. If the answer is correct, you will be taken to the next question. If the answer is incorrect, you will be taken to the area in the chapter where the information is for review. When you have completed your review, select anywhere in that area to return to the review question. Try to answer the question again.

1.0.0 INSPECTION and MAINTENANCE of INTERIOR WATER DISTRIBUTION SYSTEMS and FIXTURES

1.1.0 Pressure Loss

A water supply system is designed to operate under a specified pressure. When the recommended pressure is above or below what the system was designed for, problems may arise.

1.1.1 Customer Notification

Customer notification is really a two-way process. First, the customers are notified by the utilities personnel of a water outage or lack of water pressure to their home or business during a repair to a ***water main*** or related components. The second way is for the customers to notify utility personnel of the lack of water pressure to their buildings. When the customer service desk is notified, then the customer service personnel will notify utilities personnel of the lack of pressure, or a possible water main break. Another indication of a possible water main break is when the water plant operator notices that the pressure gauges suddenly drop, for example, from 55 psi to 35 psi.

1.1.2 Identification of Affected Area

Identifying the affected area is not always a complicated process. The most common method of identification is when a customer calls to report the decrease in water pressure.

1.1.3 Possible Causes of Pressure Loss

There are many reasons for pressure loss in a plumbing system. One reason could be that a valve was closed to the building, or maybe someone has opened a ***fire hydrant***. As the utilities systems specialist, it will be your job to determine why there is not enough pressure in the system.

1.1.4 Determining the Cause

Once you have arrived at the job site, you should ask yourself the following questions: Did someone open up a main water system before your site? Did a worker close a valve shutting off the water supply to the building? Remember, if a water main break occurred previously, there may be rocks or pebbles in the system. This can cause a lot of problems, and as a last resort, you may have to dig down to the water main or service line and clear out any obstructions.

1.2.0 Leakage

1.2.1 thods of Locating Leaks

Locating leaks in an interior plumbing system is one of the many jobs that you will have as a Utilitiesman. The first thing you want to do is isolate the leak. Some leaks are obvious when you arrive at the job site. You may have water is flowing from the ceiling or a wall. So, the first thing you want to do is isolate the leak. This is the easy part because you will know where to start your repairs. The difficult part is to locate a leak that is flowing between two concrete walls or from under a concrete floor, and the water is not visible at the break but is only visible somewhere else. This is because water takes the path of least resistance.

1.2.2 Leak Detection Procedures

When locating leaks in a system, the first thing to do is to locate the area from where the most water is coming. After finding the main flow of water, you have to determine if the water is coming from a broken pipe at that location, or from somewhere else. Another way to detect a leak is to listen for the sound of water spraying in the wall or for a constant dripping sound inside the wall. If there is a possibility of a leak but you are not sure and the area is dark or unlit, you can place a piece of paper under the suspected leak and listen for a dripping sound or inspect the paper for the presence of water.

1.2.3 Methods of Leak Repair

There are two types of repairs: temporary and permanent.

1.2.3.1 Temporary Repairs

1.2.3.2 Purpose

There are several reasons for making temporary repairs:

- Temporary repairs minimize the time consumers are without water; if the water has to be off for a long period of time, for example, fire protection is jeopardized.
- Temporary repairs minimize unnecessary loss of water, which is a valuable resource that should not be wasted.
- If there is a leak within the walls of a building, the leak could cause structural damage to the building; a temporary repair stops the leak, thus minimizing damage to the building.

Repairing leaks and broken pipes is a task that utilities specialists will face daily. Because of the wide variety of materials used on piping systems, you must take care when attempting to repair them. We have already discussed factors that may require you to make temporary repairs until a more permanent repair can be made. We will now discuss the removal and replacement of piping and fittings and the methods of making temporary and permanent repairs on various types of piping.

1.2.3.3 Steel

Steel pipe can be temporarily repaired by using an emergency pipe clamp (*Figure 3-1*). Fasten the clamp around the pipe until a permanent repair is made. To make the repair, position the clamp so that the gasket covers the hole. Close the clamp around the pipe. Insert bolts and tighten the nuts finger tight. Use a wrench to completely tighten the bolts. This clamp can be used either aboveground or underground. Remember that emergency repair clamps are for temporary use only.

Figure 3-1 — Emergency pipe clamp.

1.2.3.4 Copper

Make temporary repairs on copper tubing with a pipe clamp sometimes referred to as a "band-aid." Place the clamp around the copper pipe and over the leaking area. Tighten the bolts until the leak stops.

1.2.3.5 Cast Iron

Full circle clamps and split repair clamps are two means of temporarily repairing cast iron pipe. These clamps usually come in lengths of 6 to 30 inches. They have a rubber gasket that goes around the inside of the band. The ends of the gasket are tapered where it overlaps in order to form an overlapping seal of consistent thickness. The band is usually made of stainless steel. The ends of the band have lugs attached. The split repair clamp consists of two bands and two sets of lugs. These lugs have holes in them for the bolts. Some clamps have slots instead of holes on one of the lugs. The slots make installing the bolts easier. Before installing the clamp, clean the pipe of all dirt or rust. *Figure 3-2* shows a full circle clamp. *Figure 3-3* shows another fitting used as a temporary repair on cast iron pipe, a bell joint clamp. Use the bell joint clamp to repair leaks at caulked joints or fittings.

Figure 3-2 — Full circle clamp.

1.2.3.6 Plastic

Use pipe clamps and full circle clamps to make temporary repairs on plastic pipe. Remember to use the proper size clamp. You may need to measure the OD of the pipe to ensure you get the correct size.

1.2.4 Permanent Repairs

Permanent repairs are better than temporary repairs. Make a permanent repair in a manner that will function just as well as the original installation.

Figure 3-3 — Bell joint clamp.

1.2.4.1 Steel

Use ***unions*** when making a permanent repair. Cut out the damaged section (at least 4 inches from the fittings) and remove it. See *Figure 3-4, View A***.** Cutting the pipe at least four inches from a fitting gives you working room to thread this length and use it when you reassemble the pipe. The new section is made up of two lengths of pipe, one of which may be part of the old pipe and a union, which, when assembled, equals the length of the old pipe (*Figure 3-4, View B*). Install a single length of pipe only when the old length of pipe is disconnected at a union. Follow a similar procedure when cutting a branch into an existing line, except that a T-fitting is required between two new lengths, (*Figure 3-4, View C*). This assembly must also be equal to the original length of pipe that was removed.

Figure 3-4 — Replacing a section of pipe.

1.2.4.2 Copper

You must drain all the water from copper tubing before trying to repair it. Cut out the damaged portion of tubing with a tubing cutter or hacksaw. Pattern a new section of tubing using measurements from the damaged section. Then use copper ***couplings*** to position the new section into the system. Each end of the tubing should have a coupling on it. Use proper soldering procedures to ensure that the repair will be leak-proof. After you finish, test the repairs for leaks. However, if the system uses compression type joints, just tighten the affected ones with a wrench. When making repairs to a copper hot water line, ensure the heat source to the water heater is off before draining.

1.2.4.3 Cast Iron

Cut out the damaged section of pipe. Try to make the ends of the pipe as straight as possible. Clean the ends of the pipe thoroughly. This will help strengthen the seal between the pipe and the compression couplings. Measure and cut a new section of piping. Use compression couplings to insert the repair pipe into the system. The procedures for installing a compression coupling are as follows:

Slide the follower onto the pipes.

Slide the gaskets onto the pipes.

Slide the middle ring onto the pipe and place the repair section into position.

Slide the middle ring back until it is centered between the pipe and the repair piping.

Figure 3-5 — Compression coupling.

Slide the gaskets and followers up the middle ring.

Install the bolts and hand-tighten them.

Use a wrench to tighten the bolts using the criss-cross method.

Use a compression coupling on each end of the repair piping.

Figure 3-5 shows the components of a compression coupling.

1.2.4.4 Plastic

Permanent repairs to plastic pipe are quick and easy:

Cut out the damaged section of pipe. Make the cuts as straight and square as possible.

Measure, cut, and ream a repair section.

Make sure the ends of all the pipes to be joined are clean and dry. Use solvent to clean the ends of repair piping and couplings.

Apply glue to the piping and couplings.

Slide the couplings onto the pipe.

Repeat the solvent cement procedure to install the repair pipe onto the system.

Allow the joints to dry according to manufacturer's specifications before turning the water on.

Leaks in piping and at fittings are common. Since many joints are made in the middle of a system, you cannot just unscrew a defective fitting or piece of piping and replace it with new materials. Each type of piping has certain fittings and procedures for making a repair.

1.2.5 Identification of Affected Area

A water main break can cause a pressure loss and is considered a leak. This is apparent when customers call in large numbers to report a pressure loss. When you arrive at the area where the pressure loss was identified, you will most likely find water gushing from the ground. But when only one customer calls, the problem may be isolated to a single residence.

1.2.6 Possible Causes of Pressure Loss

A broken water main or just a broken water supply line can cause leaks. Another cause can be poorly fitted joints or bad seals in valves. As the Utilitiesman, it will be your job to determine why there is a leak in the system.

1.2.7 Determining the Cause

On the job site, finding a leak may be fairly easy, but determining the cause can be difficult. Seeing the leaking water is only half the battle. You need to determine the answers to certain questions. Why did the pipe break? Did the pipe freeze? Why is the faucet dripping? Is the washer worn out? Once you have determined the cause, making the repair will enable you to be sure that the problem is solved.

Test your Knowledge (Select the Correct Response)

1. **(True or False)** There are two types of leak repair.

   A. True
   B. False

2.0.0 INSPECTION and MAINTENANCE of INTERIOR WASTE SYSTEMS

2.1.0 Repair of Interior Waste Systems

Locating and repairing leaks on interior waste systems are two common jobs that you will have as a UT. You first need to locate the leak, then gather your materials, and lastly, make the repair.

2.1.1 Locating Defective Piping

There are three common ways to locate leaking pipes: the visual inspection, the smoke test, and the peppermint test. These tests can be used on all types of pipes.

2.1.1.1 The Visual Inspection

If the drain line runs along the wall, water or water stains will indicate where the leak is. The smell of sewer gases will indicate a leaking drain line. At times, you may need to crawl under the building to inspect the piping.

2.1.1.2 The Smoke Test

First, plug off the entire system using drain plugs or caps. Next, introduce smoke into the system with a smoke machine or use a smoke pellet. When smoke appears at the vent(s) on the roof, plug them. Then, add ½ psi to the system. Wait 15 minutes before you start the inspection. Ensure that a pressure gauge has been installed on the system for monitoring purposes. The smoke leaking from the broken pipe will reveal where the break is located.

2.1.1.3 The Peppermint Test

After the system has been completely plugged off (as described above) add peppermint to the system. Pour 2 ounces of peppermint oil down each vent. If the building is over 5 floors, then add another ounce per vent for the next 5 floors.

Remember: 1-5 floors = 2 ounces per vent.

6-10 floors = 3 ounces per vent.

Once the peppermint oil has been added to the system, pour 5 gallons of hot water into each vent. Close off the vents. If there is a leak in a drain system, the peppermint odor will reveal where it is. Always use two people to conduct this test because the peppermint oil smell is so strong that the individual adding the peppermint will become less sensitive to the smell. After locating the leak, make the necessary repairs.

2.1.2 Repair Materials

When making repairs to a drainage system, always replace the old or broken pipe with the same type of material. Of course, when replacing the entire piping system, you will use the material that has been specified for the job.

2.1.3 Repair Procedures

Repairs on an interior drainage system will be different depending on the type of piping and the type of joints used. There are two types of pipe primarily used on interior drainage systems: cast iron soil pipe (CISP) and plastic pipe.

2.1.3.1 Cast Iron Soil Pipe

Cast iron soil pipe is usually repaired by using compression joints or no hub joints.

2.1.3.1.1 Assembling Compression Joints

This type of joint uses a bell and spigot. It is sealed with a neoprene rubber gasket. When the spigot end of the pipe and the neoprene gasket are lubricated and pushed or drawn into the gasket hub, the joint is sealed by displacement and compression of the rubber gasket.

2.1.3.1.2 Assembling No Hub Joints

This type of joint uses a one piece neoprene gasket and a stainless steel shield and retaining clamps. The advantages of this type of joint are that joints can be made in confined spaces, joints can be made quickly, and few tools are required. The disadvantage is that extra hangers are required. These types of junctions should not be buried or put into inaccessible areas.

2.1.3.2 Plastic Pipe

Making repairs on PVC drainage systems is not difficult. First, cut out the bad section of pipe with a hacksaw or pipe cutter. Next, apply PVC cleaner to both ends of the existing pipe (both PVC couplings and the new piece of PVC pipe). After applying the cleaner, apply the PVC solvent cement to the areas that have been cleaned.

Finally, push all the pipes and couplings together and twist the couplings and the new piece of pipe 1/8 to 1/4 of a turn. This spreads the glue throughout the joint. Once joined, allow the joints ample time to dry as prescribed by the manufacturer's directions. No hub couplings may also be used to repair PVC drainage systems since CISP and PVC have the same outside diameter.

2.1.4 Safety

2.1.4.1 Cast Iron Pipe

Cast iron soil pipe is heavy. You will need assistance on repairs. When cutting out the damaged section of cast iron with a snap cutter, it is necessary for you to wear safety goggles and gloves, and have your sleeves rolled down because of the danger of flying pieces of cast iron.

2.1.4.2 Plastic Pipe

Plastic pipe is light, inexpensive, durable, and easily assembled. The dangers involved with solvent gluing are the fumes from the cleaner and the solvent cement. Also, the chemicals in the cleaner and solvent cement are highly flammable. The area in which you are working will need adequate ventilation. Keep open flames away from the cleaner and solvent cement.

Test your Knowledge (Select the Correct Response)

2. What is a disadvantage of the no hub joint?

   A. It is very heavy
   B. It requires extra hangers
   C. It requires extra sealant
   D. It is too unreliable

Summary

This chapter presented information on the detection and repair of water lines, the purpose of temporary repairs, types of clamps, and installation procedures for clamps. Learning how to properly make repairs on interior water distribution and waste systems and knowing about the associated safety hazards are of major importance in your job as a UT. Repair these systems correctly the first time, and it will pay off in the long run.

Review Questions (Select the Correct Response)

1. Why is it difficult to pinpoint a leak where water is flowing between two concrete walls?

   A. Because water flows up.
   B. Because water only flows down.
   C. Because water only flows horizontally.
   D. Because water flows in the path of least resistance.

2. What is another name for a temporary repair device used on copper pipe?

   A. Patch
   B. Band-aid
   C. Wrap
   D. Stop leak

3. How many means of temporarily repairing cast iron pipe are there?

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

4. What two clamps are used to temporarily repair a CISP?

   A. Compression coupling and full circle
   B. Split repair and band-it
   C. Band-it and compression coupling
   D. Full circle and split repair

5. When repairing a steel pipe, how many inches from the damaged section do you make the cuts?

   A. 6
   B. 5
   C. 4
   D. 3

6. Other than a broken pipe, what is another reason for a water leak?

   A. Poorly fitted joints
   B. Tightly fitted joints
   C. Loose dirt around the pipe
   D. Use of too many threads

7. How many different ways of locating leaking pipes are there?

A. 5
B. 4
C. 3
D. 2

8. At least how many people are necessary to complete the peppermint test?

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

Trade Terms Introduced in This Chapter

Water main	A main pipe or conduit in a system for conveying water.
Fire hydrant	An upright pipe with a nozzle or spout for drawing water from a water main.
Unions	A device utilized to combine two or more things into one.
Couplings	A short length of plumbing pipe used to join two straight pieces.

Additional Resources and References

This chapter is intended to present thorough resources for task training. The following reference works are suggested for further study. This is optional material for continued education rather than for task training.

Basic Machines, NAVEDTRA 12199, Naval Education and Training Professional Development and Technology Center, Pensacola, FL, 1994.

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Chapter 4

Fire Protection Systems

Topics

1.0.0 Introduction

2.0.0 Automatic Sprinkler System Characteristics

3.0.0 Water Supply Requirements

4.0.0 Inspection, Testing, and Maintenance Requirements

5.0.0 Gaseous Extir guishing Systems

6.0.0 Dry Chemical Extinguishing Systems

To hear audio, click on the box.

Overview

This chapter describes the operation, testing, and maintenance of fire protection systems commonly used in buildings and other structures. Fire protection systems include automatic sprinkler systems, standpipe and hose systems, foam extinguishing systems, gaseous extinguishing systems, and chemical extinguishing systems. Fire alarm and detection equipment will be discussed, showing the relationship between the mechanical and electrical components of these systems.

With the large number of manufacturers and models of fire protection systems, the UT cannot be expected to acquire a detailed knowledge of all installations and maintenance considerations involved with this equipment. The principles presented in this chapter apply on a general basis for any given device or system you may encounter in the field. Refer to the manufacturers' manuals, job specifications, the National Fire Protection Association Codes, and local codes for in-depth information regarding specific types of equipment.

Objectives

When you have completed this chapter, you will be able to do the following:

1. Describe the characteristics of automatic sprinkler systems.
2. Identify water supply requirements.
3. Describe the inspection, testing, and maintenance requirements for fire protection systems.
4. Describe the purpose, types and components of gaseous extinguishing systems.
5. Describe the purpose, types, and components of dry chemical extinguishing systems.

Prerequisites

None.

This course map shows all of the chapters in Utilitiesman Advanced. The suggested training order begins at the bottom and proceeds up. Skill levels increase as you advance on the course map.

Air Conditioning and Refrigeration	↑	U T A D V A N C E D
Duct and Ventilation Systems		
Boilers		
Compressed Air Systems		
Sewage Treatment and Disposal		
Water Treatment and Purification		
Fire Protection Systems		
Interior Water Distribution and Interior Waste Systems		
Plumbing Planning and Estimating		
Contingency Support		

Features of this Manual

This manual has several features which make it easier to use online.

- Figure and table numbers in the text are italicized. The figure or table is either next to or below the text that refers to it.
- The first time a glossary term appears in the text, it is bold and italicized. When your cursor crosses over that word or phrase, a popup box displays with the appropriate definition.
- Audio and video clips are included in the text, with an italicized instruction telling you where to click to activate it.
- Review questions that apply to a section are listed under the Test Your Knowledge banner at the end of the section. Select the answer you choose. If the answer is correct, you will be taken to the next section heading. If the answer is incorrect, you will be taken to the area in the chapter where the information is for review. When you have completed your review, select anywhere in that area to return to the review question. Try to answer the question again.
- Review questions are included at the end of this chapter. Select the answer you choose. If the answer is correct, you will be taken to the next question. If the answer is incorrect, you will be taken to the area in the chapter where the information is for review. When you have completed your review, select anywhere in that area to return to the review question. Try to answer the question again.

1.0.0 INTRODUCTION

Suppose there was fire in a building that was unoccupied and no one was in the area to report it. The building could be severely damaged or completely destroyed before the fire department could respond. However, if this same building had a fire suppression system installed in it, the system would control or put out the fire and signal the fire department. Today, more and more buildings are being equipped with fire sprinkler systems. Part of your job is to install and then keep these systems operating. To do this, you need to know the types of systems and how they work.

2.0.0 AUTOMATIC SPRINKLER SYSTEM CHARACTERISTICS

Automatic sprinkler systems automatically distribute water upon a fire in sufficient quantity to either extinguish the fire or prevent its spread. All sprinkler systems have three basic components. They are a water supply, a piping network to carry the water, and sprinklers that distribute the water.

2.1.0 Types of Sprinkler Systems

There are several types of sprinkler systems. The most common ones are the wet pipe, the dry pipe (that uses the differential dry pipe valve, the low-differential dry pipe valve, or the mechanical or latched-clapper dry pipe valve), the water deluge, the pre-action, and the combined systems.

2.1.1 Wet pipe System

The wet pipe sprinkler system (*Figure 4-1*) is the most common type. This system has automatic sprinklers attached to a piping network that is under pressure at all times. The sprinklers are actuated by the heat of a fire. A wet pipe system is generally used when there is no danger of the water in the pipes freezing or when there are no special conditions that require a special purpose sprinkler system.

Figure 4-1 — Wet pipe sprinkler system.

The wet pipe sprinkler system may have an alarm check valve (*Figure 4-2*). This device is used to maintain a constant pressure on the system piping network above the valve. When there is a fire, the flowing water causes the ***clapper*** assembly inside the alarm check valve to open. This permits a portion of the water to flow through a port in the valve that is connected to an alarm device. To prevent false alarms, you can place a retard chamber in the piping between the alarm check valve and the alarm device.

Figure 4-2 — Wet pipe system alarm check valve.

2.1.2 Dry Pipe System

In a dry pipe system (*Figure 4-3*), the pipes normally contain either air or nitrogen under pressure. Dry pipe systems are used in areas where the water in the pipes is subject to freezing.

A dry pipe valve acts as a control between the water supply and the air under pressure in the piping network. The dry pipe valve must be in a heated enclosure because pressurized water is at the underside of the valve. A small amount of water, called ***priming water***, is also inside the dry pipe valve itself to ensure a tight seal of the clapper and to keep the rubber gaskets pliable. The valve is usually made so that a moderate air pressure holds back a much greater water pressure. There are several types of dry pipe valves.

Figure 4-3 — Dry pipe sprinkler system.

2.1.2.1 Differential Dry Pipe Valve

The differential dry pipe valve (*Figure 4-4*) has a large clapper on the air side that bears directly on a smaller water side clapper. The differential between the areas of the two clappers is approximately 6 to 1. Therefore, relatively low air pressure can hold back a much larger water pressure. For example, 30 pounds per square inch (psi) air pressure can hold back 180 psi water pressure.

Figure 4-4 — Differential dry pipe valve.

To eliminate an accidental trip of the valve and false alarms, air pressure should be maintained at least 20 psi greater than the calculated trip pressure of the dry pipe valve. This is based on the highest normal water pressure of the supply system.

In operation, when there is a fire the heat actuates the sprinklers and allows the air pressure to be relieved from the piping network. The differential is destroyed. The water pressure below the valve opens the clapper, allowing water to flow through the piping to the open sprinklers. This operation has an inherent time delay between the actuation of the sprinklers and the application of water to the fire. This delay can be shortened by adding an accelerator or an exhauster to the dry pipe system.

The ***accelerator*** (*Figure 4-5*) allows air from the system's piping to enter the intermediate chamber in the dry pipe valve, destroy the differential, and open the clapper.

The ***exhauster*** (*Figure 4-6*) opens and exhausts air from the piping system faster than through the sprinklers, destroying the differential sooner.

Figure 4-5 — Dry pipe system accelerator.

Figure 4-6 — Dry pipe system exhauster.

2.1.2.2 Low-Differential Dry Pipe Valve

Occasionally the water supply to dry pipe valves contains debris. With a Low-differential dry pipe valve, there is a high velocity of water entering the system when the valve trips. This velocity of water can carry debris into the system and cause the system to become blocked. If debris in the water is a problem, the low-differential dry pipe valve may be useful.

The clapper in the low-differential dry pipe valve is only slightly larger on the air side than on the water side. The air pressure in the system is maintained approximately 15 to 20 psi greater than the water pressure. Because the sprinkler system piping contains air pressure about equal to the water pressure, the sudden rush of water is slowed and only a slight amount of water is diverted into the branch lines, which do not have operating sprinklers after the valve opens.

With either a differential or low-differential dry pipe valve, an automatic air maintenance device must be used to maintain air pressure and prevent accidentally tripping the dry pipe valve. Also, an automatic drain or high-water level alarm is required for the priming water level so the water does not accumulate. (If there is too much priming water, the valve cannot operate.)

2.1.2.3 Mechanical or Latched-Clapper Dry Pipe Valve

The mechanical or latched-clapper dry pipe valve (*Figure 4-7*) operates under the same theory as other dry pipe valves. It has system air pressure against a small disk, diaphragm, or clapper. An arrangement of levers, links, and latches on the valve clapper provides the leverage for the closing force placed on the water clapper.

Figure 4-7 — Mechanical dry pipe valve.

2.1.3 Water Deluge System

A water deluge system (*Figure 4-8*) is used where there is an extra hazard, such as areas where flammable liquids or propellants are handled or stored, or where there is a possibility that a fire might grow faster than ordinary sprinkler systems can control. These systems are also often used in aircraft hangars where ceilings are unusually high and where drafts may deflect the direct rise of heat so that sprinklers directly over the fire would not open promptly but others, at some distance away, might open without having any effect on the fire.

Figure 4-8 — Water deluge system.

In the water deluge system, all sprinklers connected to the piping network are open and the water supply is controlled by a water deluge valve (*Figure 4-9*). The water deluge valve remains closed until a fire is detected by a heat-actuated device that in turn causes the valve to open. Heat actuated devices (HAD) can be either mechanical or electrical in operation. They are discussed in further detail later in this chapter.

Figure 4-9 — Deluge valve.

The deluge system has a time delay between detection of a fire and the discharge of water at the sprinkler heads. This delay is due to the time required to operate the valve and fill the piping network with water, similar to the dry pipe system. To reduce the delay, the deluge system may be preprimed by filling the piping network with water downstream from the deluge valve. To prevent water from escaping from the sprinklers, pre-prime plugs (*Figure 4-10*) are placed on the sprinklers. These plugs blow out of the sprinklers at approximately 20 psi water pressure.

Figure 4-10 — Sprinkler pre-prime plugs.

2.1.4 Pre Action System

A pre-action system differs from a deluge system only in that it has automatic sprinklers that are normally closed. When the fire detecting device is actuated, the water control valve opens and admits water into the piping system. The system then acts the same as a wet pipe system. Individual sprinklers are opened by the heat of the fire. The advantage of the pre-action system is that the probability of inadvertent water discharge is minimized because operation of both the detection system and automatic sprinklers is necessary for discharge of extinguishing water.

It is incorrect to refer to pre-action systems as dry pipe sprinkler systems. It is true that the pre-action system piping does not contain water. However, the term dry pipe system refers to the type of sprinkler system and the type of water control valve that operates the system.

There are two types of pre-action systems. The first system is the supervised system, which has air introduced into the system piping at a pressure of approximately 5 psi. This air pressure supervises the piping to detect leaks. The pressure switches used for detection of low air pressure on the supervised system should record in inches of water rather than pounds per square inch. The second system is the unsupervised pre-action system. It has no means of continuous monitoring.

2.1.5 Combined System

A combined system (*Figure 4-11*) is a special purpose arrangement using two modified dry pipe valves connected to tripping devices and piped in parallel to supply water to the same sprinkler system. The piping network is filled with air under pressure. When a fire is detected, an exhauster at the end of the system opens and releases the air within the system. The system then operates the same as a pre-action system. However, if the detection system fails, the combined system acts the same as a dry pipe system and allows water to be admitted to the system when the sprinklers open, discharging the air from the piping network.

Figure 4-11 — Combined system header arrangement.

2.2.0 Types of Sprinklers

Sprinklers are nozzles placed at intervals along the piping network to distribute a uniform pattern of water on the area being protected. To attain maximum efficiency, the stream of water must be broken into droplets. A deflector (part of the frame of the sprinkler) breaks up the water.

You, as a UT, will generally install sprinklers to meet the specifications and plans of a project. When you require more information on the proper locating of sprinklers, refer to the National Fire Protection Association Code Book Number 13 (NPFA #13), entitled Installation of Sprinkler Systems.

Automatic sprinklers are designed for specific applications based on orifice size, deflector design, frame finish, and temperature rating. Sprinklers have orifices ranging in size from 1/4-inch to 1/2-inch diameter graduated by 1/16-inch increments. There is also one 17/32-inch size orifice. Deflectors give different patterns of water distribution and allow the sprinkler to be placed in various locations, such as upright, pendent, or sidewall (*Figure 4-12*). Next, sprinkler frames may be plated for appearance or they may be coated for protection from an adverse environment. For example, sprinklers that will be used in corrosive atmospheres are either lead- or wax-coated. Finally, automatic sprinklers are normally held closed by heat-sensitive elements that press down on a cap over the sprinkler orifice and are anchored by the frame of the sprinkler. The heat-sensitive elements melt and release at different temperatures, depending on application. Sprinklers are color coded to identify the temperature range rating of the fusible element (*Table 4-1*). Color coding is not required for plated sprinklers, ceiling sprinklers, or similar decorative types.

Figure 4-12 — Different styles of sprinkler deflectors.

Table 4-1 — Sprinkler temperature ratings.

Maximum Ceiling Temperature (°F)	Temperature Rating (°F)	Temperature Classification	Sprinkler Color Code
100	135-170	Ordinary	Uncolored
150	175-225	Intermediate	White
225	250-300	High	Blue
300	325-375	Extra High	Red
375	400-475	Very Extra High	Green
475	500-575	Ultra High	Orange
625	650	Ultra High	Orange

There are basically four types of release mechanisms for automatic sprinklers. They are the fusible link, frangible bulb, frangible pellet, and bimetallic element.

The fusible link sprinkler (*Figure 4-13, Frame 1*) is kept closed by a two-piece link held together by a solder with a predetermined melting point. When the solder melts, the levers pull the two-piece link apart and fly away from the sprinkler. Pressure in the piping network pushes the cap from the orifice of the sprinkler to discharge water.

The frangible bulb sprinkler (*Figure 4-13, Frame 2*) has a small bulb made of glass between the orifice cap and the sprinkler frame. The bulb is partially filled with a liquid. Air fills the remaining space. Heat from a fire will cause the liquid to expand against the air, causing the glass bulb to shatter and opening the sprinkler for water discharge.

Figure 4-13 — Types of automatic sprinklers.

A frangible pellet sprinkler (*Figure 4-13, Frame 3*) has a rod between the orifice cap and sprinkler frame. The rod is held in place by a pellet of solder under compression. When the solder melts, the rod moves out of the way of the orifice cap. The cap is pushed off by the water pressure in the piping network.

The bimetallic element sprinkler (*Figure 4-13, Frame 4*) uses a disk made of two distinct metals as a heat-sensitive element. When the sprinkler is off, the disk maintains pressure on a piston assembly. When a fire occurs and the temperature reaches the sprinkler's rating, the disk flexes and opens, releasing pressure on the piston assembly and allowing a small amount of water to bleed out of the piston chamber faster than it can be replaced through a restrictor. The water pressure in the piping network pushes the piston down and allows water to discharge from the sprinkler. When the temperature of the heat-sensitive element is reduced, the element returns to its normal position and allows water to pass through the restrictor, filling up the piston chamber, forcing the piston into the closed position, and stopping water discharge. This sprinkler can be used to automatically cycle on and off as necessary, for example, to put out a rekindled fire.

Other sprinkler heads that do not have release mechanisms include the dry pendent sprinkler, the open sprinkler, and water spray nozzles.

A dry pendent sprinkler (*Figure 4-14*) is used when pendent sprinklers must be placed on dry pipe systems or in wet pipe systems when the area to be protected is subject to freezing, such as a walk-in reefer or outside shop area, and the piping network is installed in a heated area. This sprinkler is fitted with a tube within an attached pipe. The tube holds the water-sealing elements in place against a watertight seal at the top of the pipe. When the sprinkler is actuated, the tube drops down and releases the elements through the tube and out the open sprinkler with the water discharge.

Open sprinklers consist only of a sprinkler frame and deflector. They are used on special sprinkler systems, such as deluge or rapid reaction systems (*Figure 4-15*).

Figure 4-14 — Dry pendent automatic sprinkler.

Figure 4-15 — Open sprinkler.

Water spray nozzles (*Figure 4-16*) are used for special application of water in various patterns, for example, wide or narrow angle, long throw, or flat patterns. The different patterns may be achieved by either internal or external deflection of the water stream, depending on the type of nozzle.

Figure 4-16 — Water spray nozzles.

2.3.0 Sprinkler System Detection and Indicating Devices and Fittings

Sprinkler systems have many different controlling devices and fittings. These can be classified as detecting or initiating devices or fittings. Their function is to detect system operation and to initiate system operation or alarm systems connected to the sprinkler system. This section discusses these devices and fittings to aid you in installing and troubleshooting sprinkler systems and understanding the interface between the mechanical and electrical functions of these devices.

2.3.1 Water Flow Actuated Detectors

Sprinkler water flow detectors are generally pressure actuated or vane actuated. Pressure switches are used on both wet and dry pipe systems. Vane switches are widely used on wet pipe sprinkler systems. They cannot be used on dry pipe systems because the initial rush of water into the pipe could damage the vane and mechanism.

Dry pipe system alarms tend to be slow acting because it takes time to lose sufficient air through a fused sprinkler to trip the system. Various methods are used to speed up dry pipe systems, as discussed earlier.

Wet pipe system alarms have a different problem. Fluctuating water pressure frequently causes flow into a sprinkler system, equalizing the sprinkler system pressure with the supply pressure. Such surges of water or of pressure cause false water flow alarms if some method of slowing down the switch response to the surge is not used. Various retarding techniques are used, some associated with the sprinkler piping and some with the water flow detector.

The pressure increase type of water flow detector (*Figure 4-17*) comes in numerous styles. It is found in wet or dry pipe sprinkler systems. The usual arrangement for switch actuation includes a sealed, accordion-like bellows that is assembled to a spring and linkage. The spring-tension setting controls the pressure at which the flow detector is actuated. It can be field adjustable and/or factory set to the desired pressure that activates the electrical switch. If this pressure switch is to be used on a wet pipe system, it is usually mounted at the top of a retarding chamber. This reduces the speed of pressure buildup at the switch. Other styles of this switch incorporate a pneumatic retarding mechanism within the detector housing. The retard time is adjustable to a maximum of 90 seconds. Usual settings are in the range of 20 to 70 seconds. The retard switch is connected to the alarm port of a wet sprinkler system alarm check valve. It is usually set for a pressure range of 8 to 15 psi.

Pressure drop detectors can be used in wet pipe sprinkler systems equipped with a check valve (alarm check or swing check) that holds excess pressure on the system side of the check valve. These detectors are frequently used where a water surge or hammer causes false alarms with other types of water flow detectors. The construction of pressure drop detectors is similar to the pressure increase detectors. The switch for a pressure drop detector is arranged to actuate on a drop in pressure. There is no retarding mechanism or chamber. A typical switch of this type is adjusted for a normal operating pressure in the range of 50 to 130 psi. The alarm pressure is adjustable between 10 to 20 psi below normal pressure.

Figure 4-17 — Pressure increase type of water flow detector.

A vane type of water flow detector (*Figure 4-18*) is used only in wet pipe sprinkler systems. The detector is assembled at the pipe by drilling a hole in the wall of the sprinkler pipe, inserting the vane into the pipe, then clamping the detector on with U-bolts. When the sprinkler system is actuated by fire, the water flowing through the pipe causes the vane to move. A mechanical linkage connects the vane to an adjustable retarding device, usually a pneumatic dashpot. The retarding device actuates the alarm switch or switches and/or signal transmitter. The retarding device setting is usually in the range of 30 to 45 seconds. A maximum setting may be as high as 90 seconds, if necessary.

Figure 4-18 — Vane type of water flow detector.

The pressure pump/pressure drop type of water flow detector is used in large sprinkler systems and in those systems with inadequate water pressure to operate reliably one of the other types of water flow detectors. These detectors are also known as fixed-pressure, water flow detectors with pump (*Figure 4-19*). This detector has a pump, pump motor, and control unit. It is arranged for strap-mounting to the sprinkler system riser. The device provides a water flow alarm signal, a low system water pressure supervisory signal, and excess pressure in the system to prevent surges in the supply pressure from opening the alarm check valve and causing operation of the water motor gong or other alarm indicators.

Figure 4-19 — Fixed-pressure water flow detector with pump.

A typical detector of this type is adjusted to maintain the system pressure at 25 to 50 psi above supply pressure. A slow leak at the alarm check valve or anywhere in the system will cause the system pressure to drop slowly. When pressure decreases to 2 psi below the preset value, a pressure switch closes, causing the pump to start pumping water from the supply side to the system side of the alarm check valve at a rate of about 1 gallon per minute (gpm). If the total system leaks less than 1 gpm, the pressure switch opens and stops the pump when the preset pressure is reached. However, if the system leaks are greater than 1 gpm, system pressure will continue to drop even with the pump running. If system pressure decreases to 4 psi below the preset value, a trouble pressure switch opens to indicate that there is a leak greater than 1 gpm. If the water pressure continues to drop to 6 psi below the preset value, an alarm pressure switch closes, signaling a water flow alarm. Some water flow detectors of this type have an additional switch that disconnects pump power when the supply water pressure drops below 14 psi. This prevents pump burn up in case of total supply shutdown or a break in the supply line.

The electronic pressure drop detector is often used in sprinkler systems that must maintain a high excess system pressure over supply pressure that would delay actuation of a vane type of water flow detector. It is normally mounted to the riser pipe with a flexible hose connection to the system side of the check valve. This device requires a pressure drop of 5 to 20 ounces per square inch, continuing over a period of at least 3 seconds to signal an alarm. A pressure drop at a slower rate or of a shorter duration causes no alarm. A slow pressure drop to 15 psi or less causes a trouble signal indicating a system leak and low supply pressure. Pressure increases do not cause an alarm, but an over pressure condition (200psi) causes a trouble signal. Trouble signals will also be initiated when the detector’s cover is opened, supply voltage is outside normal ranges, and an internal circuit fails, interfering with detector function.

2.3.2 Supervisory Initiating Devices

Supervisory alarm initiating devices cause a signal at the supervisory control unit and/or remote receiver when an abnormal fire protection system condition occurs. In general, supervised valves are never closed unless a sprinkler system requires maintenance. Valves that control water flow to a water flow detector or valves in a sprinkler header room or fire pump room that are normally closed may be supervised. Supervisory devices for normally open valves signal when the valve is closed no more than two turns or 20 percent of its total travel. Supervisory devices for normally closed valves signal when the valve is opened no more than two turns or 20 percent of its total travel.

Outside screw and yoke (OS&Y) valve position indicators are firmly attached to the valve yoke (*Figure 4-20*). The spring-loaded switch operating lever (*Figure 4-21, View A*) or plunger (*Figure 4-21, View B*) rests in a smoothly tapered notch in the valve stem. When the valve is operated, the stem moves in or out; the lever or plunger moves up the incline at the edge of the notch. The switch is actuated before the lever or plunger is out of the notch. This causes a supervisory signal at the control unit and/or remote receiver.

Figure 4-20 — OS&Y valve position supervisory switch location.

Figure 4-21 — Lever and plunger type OS&Y valve position indicators.

A post indicator valve (PIV) will have a position indicator mounted to it (*Figure 4-22*). Usually a PIV is located outside the building and may be mounted on the ground or on the building wall. A spring-loaded lever rests against the side of the open/shut indicator, called a target. As the valve is operated, the target moves. The switch follows this movement. The position indicating switch is adjusted to cause a supervisory signal before the operating nut has rotated two turns or 20 percent of its full travel.

Nonrising stem valve position indicators are attached to nonrising stem valves, usually installed underground. The housing of the device is made of a non-corroding material, such as brass. The switch itself is a magnetically operated, sealed reed switch. As the valve is operated, the magnet moves away from the reed switch. After the valve has been opened two full turns, the magnet is far enough away from the reed switch to actuate it, causing a supervisory signal at the control unit and/or remote receiver.

Water level in sprinkler system reservoirs must be maintained within certain limits. There are usually automatic controls for maintaining the desired water level. Water level supervisory devices cause a supervisory signal when the water level is not maintained between the desired high and low limits.

Figure 4-22 — Post indicator valve.

A float-actuated level indicator is mounted outside on the wall of a tank with its float and lever extended into the tank. The lever arm pivots at the tank wall and rises or falls with the water level. A switch or switches (one for high level, one for low level) are actuated when the float moves outside normal limits. *Figure 4-23* shows a typical high-low water level supervisory device installed in a sprinkler system reservoir.

A pressure-actuated level indicator is physically very similar to the bellows-operated pressure switches used for water flow detection, as shown in *Figure 4-18*. As the water level changes in a reservoir, the water pressure at the supervisory switch also changes. The switch can be adjusted to actuate when pressure indicates a low water level or a high water level. This device is generally installed in the piping near the bottom of the reservoir.

Figure 4-23 — Water level and temperature supervisory device mounted in tank.

Electronic level indicators may also be found in some systems. These indicators read the conductivity of water to cause an electrical signal. These devices are most frequently used to sense high water levels. They are not commonly used in fire protection systems.

Temperature supervisory devices are used to prevent water freezing in fire protection systems.

UTs will most commonly work with low water temperature indicators. These are usually sealed, factory-set thermostats and may be installed in system pipe or reservoirs. The most frequent low temperature setting is 40°F. *Figure 4-23* also shows a low water temperature indicator installed in a system reservoir.

You may find other supervisory devices in use. They will usually be specifically designed for a particular system. The principles of operation are generally the same as those already discussed. Physical mounting provisions or other details may vary. Refer to NAVFAC MO-117, manufacturer's manuals, and NFPA #13 for more complete information when you must install or maintain these devices.

Test your Knowledge (Select the Correct Response)

1. What type of automatic sprinkler system is most commonly used?

   A. Wet pipe
   B. Semidry pipe
   C. Low-differential dry pipe
   D. Latched-clapper dry pipe

3.0.0 WATER SUPPLY REQUIREMENTS

Water supplies that serve sprinkler systems must be adequate and reliable. To determine the amount of water necessary for a sprinkler system, the rate of flow and pressure needed for effective performance must be known. If additional fire hoses are to be connected to the outside of the building, these should also be included. The combined water needed for all fire-fighting equipment is known as the ***fire flow demand***.

An adequate system can deliver the required fire flow for a specified time with normal water consumption at the maximum rate. To be reliable, the system must also be able to deliver the fire flow demand under certain emergency conditions, such as when a supply main or pump is out of service. The desired reliability of the system depends upon the nature of the protected structure (people, property, or mission). Water may be supplied by public or base sources, water tanks, or fire pumps.

For specific information regarding the fire flow demands of sprinkler systems, refer to NFPA #13, chapters 2, 7, and 8. These chapters will give you the information required for the sizing of each particular type of sprinkler system hazard based on residual pressure, acceptable flow rates, and duration times.

4.0.0 INSPECTION, TESTING, and MAINTENANCE REQUIREMENTS

Sprinkler systems, when properly installed, are an effective means of fire protection for life and property. To make sure these systems are reliable, periodic inspection and maintenance of system components are required. Inspection should include a visual check and, if possible, a test of the components to be sure a working condition exists. The frequency of the overall testing and inspection process is summarized in *Table 4-2*.

Table 4-2 — Summary of Inspection and Test Frequencies for Sprinkler Systems.

	Weekly	Monthly	Quarterly	Annually	Every 3 years
Check general condition of sprinklers and sprinkler system				X	
Conduct flow tests of open sprinklers				X	
Conduct main drain tests			X		
Test water flow alarms		X			
Check air and water pressure in dry pipe systems	X				
Trip test dry pipe valves				X	
Drain low points in dry pipe systems				X	
Trip test deluge and pre-action systems				X	X[1]
Trip test high-speed suppression systems					X
Check general condition of standpipe systems			X		
Perform water flow tests				X	
Check general condition of hydrants				X	
Check general condition of fire department connections				X	
Check water levels in tanks	X				
Check general condition of water storage tanks				X	
Check water level and air pressure in pressure tanks	X				
Check general condition of pressure tanks				X	
Check tank heating systems				X	
Inspect and test cathodic protection equipment				X	
Start fire pumps	X				
Check fuel supply to engine drivers	X				
Perform fire pump flow tests				X	
Inspect and test controllers				X	
Inspect valves for open position		X			
Conduct general preventive maintenance inspection of valves				X	
Inspect check valves, water flow meters, and backflow preventers					X[1]
Test pressure regulating and altitude valves				X	
1- Annual trip test may be dry: wet trip test including flow of water through heads/nozzles shall be conducted a minimum of once every 3 years.					

4.1.0 Inspection and Testing

During inspections of sprinklers, certain conditions indicate maintenance requirements. If these conditions are not corrected, they will reduce the reliability of the system. These conditions and some remedial actions are discussed in the following sections.

4.1.1 Automatic Sprinklers

Conditions that indicate the need for maintenance for automatic sprinklers include:

- Mechanical injury, such as bent or loose deflectors or bent frames. Where sprinklers are subjected to continual damage, provide approved sprinkler guards.
- Corrosion, such as marked discoloration or hard deposits. Use lead-coated or wax-coated sprinklers to prevent corrosion.
- Overheating, this causes soldered joints and cracked quartz bulbs to give way. Temperature ratings for soldered link sprinklers should be 50 ^{o}F above (for quartz bulb sprinklers, 25 ^{o}F above) normal room temperature.
- Freezing, which produces reduced tension in soldered links, bent struts, and distorted caps.
- Loading, or deposits of paint or other foreign materials.
- The need for replacement or relocation. Major construction and occupancy changes and changes to heating, lighting, and air-conditioning systems may require relocation or replacement of sprinklers or additions to the system. Changes in sprinkler location and pipe sizes should be based upon an engineering evaluation.
- A clearance of at least 18 inches under the sprinklers is necessary for proper water distribution where sprinklers are installed in areas where there is stockpiling of materials.

Keep a supply of extra sprinklers for the various types and temperature ratings required and a sprinkler wrench.

4.1.2 Outside Open Sprinklers

When you are servicing outside open sprinklers, you should do the following:

- Visually check the general condition of sprinklers.
- Close windows and doors and take proper precautions to avoid water damage to property before making flow tests.
- Conduct the flow test by opening the control valve.

After making flow tests, remove and clean any plugged or obstructed sprinklers.

4.1.3 Piping and Hangers

In servicing piping and hangers, check for mechanical injury and corrosion. Replace bent or damaged piping and fittings and replace or repair missing or loose hangers. Make sure that piping is not used to support stock, equipment, or other material.

Make sure wet pipe system piping is properly protected against freezing. Before and during freezing weather, check piping of dry pipe systems for proper drainage. During freezing weather, open drains for outside sprinkler systems. Drain water from low point drains and drum drips on dry pipe systems before freezing weather occurs.

4.1.4 Obstructed Piping

When evidence of obstruction of piping has been found, check for the following sources of obstructing material:

- Improperly screened inlets from open bodies of water
- Poorly maintained, elevated gravity tanks
- Dead end of extensive water distribution systems
- Poorly installed underground mains
- Highly acid, alkaline, or saline water
- Active chemicals in water supply
- Use of secondhand materials in the sprinkler system
- Frequent operation of systems (especially dry pipe systems) introducing additional foreign material and free oxygen

4.1.5 Alarm Check Valves

Perform a 2-inch drain test quarterly to test alarm check valves. Open the 2-inch drain valve fully and record pressure on the gauge located below the clapper at the lowest point. Close the 2-inch drain valve and record pressure at the stabilization point. Notice whether pressure returns quickly or slowly. Maintain a continuous record of drain tests. If recorded pressure when the valve is wide open is similar to previous recordings and pressure returns quickly, it is normal.

If recorded pressure when the valve is wide open is significantly lower or pressure is slow to return when the valve is closed, there may be an obstruction in the waterway. Check for the following problems:

- Partially closed valves to sprinkler system
- Obstruction in alarm valve preventing clapper from opening freely

Test local water flow alarm operation monthly by opening the test connection at the end of the system. Where there is no test connection, the alarm may be tested by opening the bypass valve to the circuit opener or closer or by opening the 2-inch drain valve about two and one-half turns. Do not test water motor alarms during freezing weather. To find principal causes of alarm failures, check for the following:

- Failure of automatic drain on retard chamber to close
- Closed or partially closed valve on piping to alarm devices
- Plugging of bell casings of water motor gongs by foreign material
- Corrosion of moving parts of water motor gongs
- Detachment of shaft couplings from water motor gongs
- Insufficient water flow to operate devices
- Alarm check valve corroded shut (This failure is not common and will not occur when systems are properly maintained.)

To find principal causes of false fire alarms, check for the following:

- Improper drainage of retard chamber (correct by opening the chamber and cleaning or repairing the automatic drain)
- Pressure surges through the alarm check valve

Fill wet pipe sprinkler systems slowly through throttled valves and open the control valve wide after the system has been filled. Be sure there is no drainage from retard chambers. Leakage means that the alarm valve clappers are not seating properly. They require cleaning and possibly overhauling.

Make internal inspections of alarm valves when normal testing procedures indicate the need:

- Examine valve body for tuberculation.
- Check clapper operation—the clapper should move freely without sticking or binding.
- Replace clapper facings as required.
- Resurface seat rings as required.

4.1.6 Dry pipe Valves and Air Check Valves

Air check valves are special, small, dry pipe valves that are usually connected to a wet pipe system. The alarms are actuated at the wet pipe system riser when the air check valve trips. To prevent premature operation, the valves should be fitted with an air chamber to maintain at least 50 gallons of air in the chamber and on the system.

Perform the 2-inch drain test quarterly by opening the 2-inch drain valve fully and recording the pressure at the lowest point. Close the 2-inch drain valve and record the pressure at the stabilization point. Notice whether pressure returns quickly or slowly. Maintain a continuous record of drain tests.

If the recorded pressure when the valve is wide open is similar to previous recordings and pressure returns quickly, it is normal.

If recorded pressure when the valve is wide open is significantly lower or pressure is slow to return when the valve is closed, there may be an obstruction in the waterway. Check for partially closed valves to the sprinkler system.

Because dry pipe sprinkler systems are installed in areas where temperatures are expected to drop below freezing, all parts of the system must be airtight and kept free of water. Complete drainage is essential.

Each fall, prior to the freezing season, check the pitch of all piping carefully using a spirit level to detect dips and small pockets in the lines. Check for:

- Broken, loose, or missing hangers; and
- Water in low point drains.

Check air and water pressures weekly. If air pressure losses exceed 10 psi, check the entire system for tightness and eliminate air leaks. Principal checking methods are as follows:

- Put a strong-smelling oil, such as oil of peppermint, into the air supply. This will produce a strong odor at the point of leakage.
- Paint fittings with a soapy water solution and watch for bubbles.

Check the temperature of valve enclosure and maintain a temperature above 42°F.

Make certain that the valve between the intermediate chamber and the alarm devices is open on dry pipe valves.

Check drip valves at intermediate chambers, making certain that clappers or balls are in a position to allow drainage. This is done by lifting push rods or by inserting a pencil in the opening. Water leakage through this valve is an indication that the water clapper is not holding tightly to the seat.

Check the air pressure. The air pressure versus water pressure for differential dry pipe valves should be as outlined in *Table 4-3*, unless otherwise specified by the manufacturer's operating instructions. Certain mechanical dry pipe valves are designed to trip at a fixed pressure of 10 to 15 psi. Maintain 30 psi air pressure on these valves.

Table 4-3 — Differential Dry Pipe Valve Air Pressure Specifications.

Maximum water pressure (PSI)	Air pressure range (PSI)
50	15-25
75	20-30
100	25-35
125	30-45
150	35-50

Basic inspections for accelerators and exhausters include the following:

- Check air pressure. The system and the quick-opening device air pressure should be the same.
- Relieve excess pressure in the quick-opening device by opening bleeder valves or loosening air gauges.

If the system pressure is high, relieve the excess pressure through the priming water test valve. Close the valve as soon as pressures balance. To avoid the possibility of tripping the dry pipe valve, do not open the priming test valve more than one turn and keep the valve to the quick-opening device closed while the priming test valve is open.

To make sure that dry pipe valves will operate effectively in fire situations, they should be trip-tested annually as follows:

1. Close the main control valve.
2. Open the 2-inch drain.
3. Open the main control valve until 5 psi pressure shows on the water gauge.
4. Close the 2-inch drain valve slowly.
5. Open the inspector's test connection of the system. Where there is no test connection, use the most remote low point drain.
6. As soon as the dry pipe valve trips, close the main control valve and open the 2-inch drain. This is particularly important in permanently cold areas.
7. Record initial air and water pressures, air pressure at the trip point, and time required for tripping.

8. Examine and clean the dry pipe valve interior. Replace facings and gaskets, if needed.
9. Reset the dry pipe valve and the open control valve.
10. When a dry pipe valve fails to trip or when a clapper fails to latch in the open position, notify the person responsible for fire protection so that a qualified sprinkler contractor may be contacted.

To test dry pipe valves, you should do the following:

1. Close the main control valve and open the 2-inch drain valve and low point drain valves. Close low point drain valves when water stops flowing.
2. Clean clapper facings and seats.
3. Clean the valve interior.
4. Place clappers on seats and make certain the anti-water column latch is in place. Bolt on the cover. Do not use grease or other material to help seat clappers. Fill the system with 10 psi air pressure to blow out any residual water through low point drains.
5. Open valves at the top and bottom of the priming chamber and priming test valves.
6. Admit water to the priming chamber until water flows out of the test valve. Close this valve.
7. Close the priming chamber valves.
8. Admit air pressure to the system.
9. Open the main control valve slowly.
10. Close the main 2-inch drain valve, except where water hammer conditions exist. In this case, leave the 2-inch drain valve open until pressures stabilize.

To check air supply piping, do the following:

- Note air pressure within 12 to 24 hours after resetting the dry pipe valve. If air leakage exists, test sprinkler piping for leaks.
- Make sure the valves to manually operated compressors are tightly closed. A slow air leak back through one of these valves can trip the dry pipe valve.
- Examine restriction orifices in air piping and air pressure regulators, if used, from automatic air compressors to dry pipe valves.

4.1.7 Deluge and Pre Action Valves

To test deluge and pre-action valves, perform the 2-inch drain test quarterly by opening the 2-inch drain valve fully and recording pressure at lowest point. Close the 2-inch drain valve and record pressure at the stabilization point. Notice whether pressure returns quickly or slowly. Maintain a continuous record of drain tests.

If the recorded pressure when the valve is wide open is similar to previous recordings and pressure returns quickly, it is normal.

If the recorded pressure when the valve is wide open is significantly lower or pressure is slow to return when the valve is closed, there may be an obstruction in the waterway. Check for partially closed valves to the sprinkler system. Check the water pressure and the local water flow alarm through the bypass connection.

Some deluge systems have both open and closed sprinklers. Make sure heat-responsive devices are provided in areas with both open and closed sprinklers and are in service. Fusing of a sprinkler will not operate a deluge valve. Where conditions permit, trip-test each deluge valve every 3 years by flowing water through the heads/ nozzles. To conduct a deluge valve dry-trip test, do the following:

1. Close the main control valve.
2. Apply an electric heat lamp to at least one heat-actuating device in each circuit, testing one circuit at a time. Note the time required to trip the valve. Where flammable vapors may be present, use a hot cloth or hot water in place of the electric test set.
3. Reset the deluge valve and trip using the manual release.
4. Where fixed temperature releases are involved, wait 15 minutes and trip by removing a fusible element from the tubing or a heat-responsive device.
5. When tests are complete, reset valves and open the main control valves.

Because there are so many designs of heat-responsive devices, test procedures for each device cannot be included here. See the individual manufacturer's information for detailed testing procedures. During routine inspections, check for painted or corroded contacts, plugged vents, or painted domes. Clean or replace affected devices.

4.1.8 Cathodic Protection Equipment

Inspect cathodic protection equipment as follows:

1. While equipment is operating, note and record current flow shown by meters. If there is no current, check for blown fuses, electrodes touching the tank, ground-wire connection to tank, or electrodes not immersed in the water. If equipment operates at voltages or amperages over those listed on the nameplate, the rectifier may be damaged. Check polarity and direction of current flow. (If connections to rectifier are reversed, rapid damage to the tank occurs.)
2. Check condition of electrodes that deteriorate because of action of current passing from electrodes to water. Replace worn electrodes. (Watch for diminishing current flow on the ammeter; this is a sign that the electrodes may be failing.)
3. Protect electrodes from ice. If ice formation is a serious problem, turn off current and remove and store the electrodes during the freezing season. Tank protection will continue for about three weeks after the unit is out of operation. Reinstall the electrodes at the end of the freezing season.

4.1.9 Non-Freeze Systems

No special testing of non-freeze systems is required, other than an annual check of the specific gravity of the non freeze solution. If the specific gravity indicates a need for replenishing the non-freeze agent, be sure to add the same agent as was previously used.

4.1.10 High Speed Suppression Systems

Full operational testing of high-speed suppression systems is conducted at intervals not to exceed three years, except when mission requirements justify change. A detector or a manual release station must be actuated. Check to be certain that all nozzles are operating. Then, follow these steps to reset the system:

1. Replace pre-prime caps and/or rupture disks.
2. Refill piping with water.
3. If the system uses an explosive valve, replace the firing squib and the squib holder.

4.2.0 Maintenance Requirements

The need for maintenance is shown by periodic inspections. It should include replacement of worn or broken components and cleaning and flushing of systems. A regular schedule of maintenance requirements should be devised. Logs recording accomplished tasks should be maintained as a record of the system's history. Be sure to include manufacturers' manuals for the system components and consult them when making repairs and adjusting or troubleshooting the system.

Test your Knowledge (Select the Correct Response)

2. In a dry-pipe sprinkler system, the entire system should be checked for tightness when air pressure losses exceed what value?

   A. 20 psi
   B. 15 psi
   C. 10 psi
   D. 5 psi

5.1.1 GASEOUS EXTINGUISHING SYSTEMS

Gaseous extinguishing systems are generally found in areas where equipment is installed that would be highly vulnerable to destruction from water or dry chemical extinguishing agents. Computer rooms, electronic gear such as radio receiving and transmitting equipment, and power-generating facilities are examples of areas where gaseous extinguishing system installation would be desirable. In the Navy today, the Utilitiesman will come in contact with two commonly used systems. These are the carbon dioxide and the halogenated gas systems. Each of these systems is discussed in this section.

Gaseous extinguishing systems can be divided into three general categories: local application; total flooding; and hose line systems.

- Local application systems discharge agent onto the burning material and are commonly used for protection of paint dip tanks, restaurant range hoods, and special motors.
- Total flooding systems discharge agent into and fill enclosed space. They are commonly found in flammable liquid storage rooms, computer installations, and transformer vaults containing oil-filled equipment.
- Hose line systems discharge extinguishing agent through manually operated nozzles connected to a fixed supply by piping and/or hoses. At present, carbon dioxide is the only gaseous agent approved for manual hose line systems.

5.1.0 Carbon Dioxide Systems

There are two general methods of applying carbon dioxide to extinguish a fire. One method creates an inert atmosphere in the enclosure or room where the fire is located for a prolonged period of time. This method is called total flooding. The second method is to discharge carbon dioxide to the surface of liquids or noncombustible surfaces coated with liquid flammables. This method is known as local application.

Carbon dioxide is electrically nonconductive. It is used extensively for the protection of electrical equipment. The non-damaging quality of this agent makes it useful as an extinguishing agent for computer rooms and computer tape vaults.

There are two general types of carbon dioxide extinguishing systems: high pressure and low pressure.

5.1.1 High Pressure Systems

In the high-pressure system, high-pressure cylinders are used to store liquid carbon dioxide at ambient temperatures (*Figure 4-24*). Normal cylinder pressure is nominally 600 psi and varies with the ambient temperature of the storage area. Storage area ambient temperatures should not exceed 130°F or be less than 32°F. For safety purposes, high-pressure cylinders have a frangible disk that will burst at 3,000 psi to prevent cylinder rupture as a result of over pressurization.

Figure 4-24 — Typical cylinder arrangement for high-pressure CO_2 system.

5.1.2 Low Pressure Systems

Low-pressure systems have a pressure vessel maintained at 0°F by insulation and refrigeration equipment (*Figure 4-25*). At this temperature, the pressure in the container is approximately 300 psi. Because the container is kept at a low temperature, the container can be filled to 90 to 95 percent of capacity. For safety purposes, a relief valve is installed to bleed off pressure at 341 psi. Another relief valve operates at 357 psi for rapid release of excess pressure. There is also a frangible disk designed to burst at 600 psi should the relief valves fail to control pressure buildups.

Figure 4-25— Refrigerated low-pressure CO_2 storage tank.

5.1.3 Advantages/Disadvantages of CO_2 Systems

There are advantages and disadvantages to each type of carbon dioxide system.

5.1.3.1 Low Pressure Systems

Low-pressure storage units have a liquid level gauge that continuously monitors the amount of carbon dioxide in storage. The smallest low pressure is 750 pounds. Low-pressure systems do not require hydrostatic testing. Low-pressure systems keep the liquid carbon dioxide at 0°F and 300 psi at all times, assuring a uniform discharge rate. Another advantage of low-pressure systems is their ability to allow automatic, simultaneous discharge for more than one hazard area on an engineered basis. Hose reels can also be attached to these systems to operate simultaneously with hazard protection. A reserve supply can be provided by increasing the storage unit size of low-pressure systems. Usually, low-pressure systems require less floor space for storage of equal amounts of carbon dioxide as compared with high-pressure systems. In many instances, low-pressure storage containers may be placed outside the buildings. Low-pressure systems require one large, single area for the refrigerated storage unit.

5.1.3.2 High Pressure Systems

High-pressure systems require weighing the cylinders. High-pressure systems permit storage of almost the exact amount of carbon dioxide required to protect a hazard area because of the flexibility and selection of cylinders in 50-, 75-, or 100-pound sizes. High-pressure systems require refilling and hydrostatic testing every 12 years. Pressures in high-pressure systems vary with the ambient temperature; this affects the discharge rate of the system. High-pressure systems require manifolding and valving arrangements to achieve a reserve supply. Storage of the carbon dioxide is also a consideration in showing advantages or disadvantages of these systems. High-pressure systems require approximately 3 pounds of equipment for every pound. High-pressure systems allow flexibility in space requirements because multiple cylinder banks may be stored in several smaller locations.

5.1.4 Operating Devices

As with all fire protection systems, carbon dioxide systems must have operating devices for discharge of the extinguishing agent and to cause alarms to be actuated. Many of the operating devices discussed earlier in this chapter can be used. Most commonly used are the heat-actuated devices (HAD) or smoke detecting devices. Manual controlling devices are also used in carbon dioxide systems. Whether the agent release is automatic or manual, an alarm at the alarm system control unit should be actuated.

5.1.5 Piping

Carbon dioxide fire protection system pipe and fittings are selected to have suitable low temperature characteristics and good corrosion resistance inside and out. Ferrous metals are galvanized steel, copper, brass, and other materials having similar mechanical and physical properties are acceptable. Copper tubing with suitable flared or brazed connections is also acceptable. Cast-iron (gray) pipe and fittings are not used.

Pipe and fittings for high-pressure systems have a minimum bursting pressure of 5,000 psi. In low-pressure systems, pipe and fittings have a minimum bursting pressure of 1,800 psi.

Between the storage tank and selector valves, black steel pipe may be used because of the larger sizes involved and its air tightness.

The supply piping is usually routed to prevent unnecessary exposure to high temperatures from ovens or furnaces or to direct flame impingement before discharge. Hot piping causes excessive vaporization of carbon dioxide and a resultant delay in effective discharge.

Pressure relief devices or valves that prevent entrapment of liquid carbon dioxide may be installed on sections of piping that can be closed off. On high-pressure systems, relief devices usually operate at 2,400 to 3,000 psi, and on low pressure systems at 450 psi.

5.1.6 Nozzles

Nozzles are of various designs and discharge patterns. Two common types are shown in *Figure 4-26*. Nozzles are marked with a code number indicating the diameter in 1/32-inch increments of a single orifice standard nozzle having the same flow rate. A No. 5 nozzle, for example, has the same flow rate as a 5/32-inch diameter standard orifice. A plus sign (+) after the number indicates a 1/64-inch larger size. Decimals are sometimes used to indicate sizes between the whole numbers.

Figure 4-26 — Types of CO_2 nozzles.

5.2.0 Total Flooding Systems

Total flooding systems are used for rooms, ovens, enclosed machines, and other enclosed spaces containing materials extinguishable by carbon dioxide.

To be effective, the space must be reasonably well enclosed so that the gas can displace the oxygen in the room. There are detectors that activate the system and automatic closing devices that close windows, doors, vents, etc., and set off alarms before the system discharges. A typical arrangement of a total flooding carbon dioxide system is shown in *Figure 4-27*.

Figure 4-27— CO_2 total flooding system.

5.3.0 Local Application Systems

Local application systems are used to protect hazards, such as oil-filled transformers and paint dip tanks. Ventilating fans, conveyors, flammable liquid pumps, and mixers associated with the operation may be interlocked to shut down automatically when the protection system is activated. A typical arrangement of a local application carbon dioxide system is shown in *Figure 4-28*.

Figure 4-28— Local application of CO_2 system.

5.4.1 Halogenated Gas Systems

Several types of halogenated gas systems have been developed for fire protection purposes: Halon 104; Halon 1001; Halon 1011; Halon 1202; Halon 1211; Halon 1301; and Halon 2402. The numbers relate to the chemical formulas of the gases. The first digit identifies the number of carbon atoms in the chemical molecule; the second digit identifies the number of fluorine atoms; the third digit identifies the number of chlorine atoms; the fourth digit identifies the number of bromine atoms; and a fifth digit, if any, identifies the number of iodine atoms present. Primarily, Halon 1301 and Halon 1211 are in general use in the United States today. These two types are recognized by the National Fire Protection Association (NFPA). Standards for their installation and use are published in the National Fire Codes.

Halogenated gas systems are used in the following situations:

- A clean extinguishing agent is needed.

- Energized electrical or electronic circuits are to be protected.
- Flammable liquids or flammable gases are present.
- Surface-burning combustible solids are to be protected.
- Objects or processes have a high value.
- The area to be protected is occupied by people.
- Availability of water or space for other types of systems is limited.

Generally, Halon 1211 and Halon 1301 are used in total flooding applications.

For effective fire-fighting purposes, a minimum concentration of 5 percent is recommended for total flooding systems for surface fires of ordinary combustibles. Deep-seated fires, as in cable insulation, require much larger concentrations and extended holding times.

Halon 1211 is toxic to people when concentrations exceed 4 percent. This prevents its use as a total flooding agent for areas occupied by personnel. Halon 1211 is normally used in portable extinguishers because it is not in enough concentration to be a hazard for people. Equipment for halon fire extinguishing systems is similar to that used for high-pressure carbon dioxide systems. Halon 1301 is stored in a cylinder super-pressurized with nitrogen to 600 psi (at 70°F) to provide an expellant pressure for the agent in excess of the agent's normal vapor pressure.

Because of the high ozone depletion factor of halons, installation of new Halon 1301 systems is prohibited except by special approval from NAVFACENGCOM.

Halon 1301 is the least toxic of the halogenated gases and does not harm personnel when concentrations are below 10 percent. Systems that remain in use are located in computer rooms.

5.5.0 Phase Out of Halons

Because of the high ozone depletion potential of CFCs, HCFCs, and halon gases, the EPA enacted the provisions of the Montreal Protocol into regulations for the United States. This enactment eliminated the production of halons in the year 2000. If you are maintaining a system that contains halon gas, consult engineering for information pertaining to system conversion.

5.6.0 Gaseous Extinguishing System Alarms

There are special considerations for gaseous system alarms because of possible toxic effects on personnel, the need for a reasonably fast response, and reliable operation. Response time for gaseous extinguishing agents is not usually as urgent as foam agents, considering the types of hazards protected. Personnel safety precautions also effect the speed requirement. Heat and /or smoke detectors are frequently used as initiating devices.

Cross-zoning is also frequently used for gaseous extinguishing systems. The first detector (zone) actuation is arranged to cause a local audible and/or visual signal. The second detector (zone) actuation causes a distinctive local signal to warn personnel that the extinguishing agent is about to be released.

Some gaseous extinguishing systems, usually those protecting populated spaces, have an abort feature to avoid unnecessary discharge of an expensive, possibly toxic gaseous agent. Extinguishing systems with the abort feature have a time delay between actuation of the second (or only) detector and release of the agent. The delay may be factory set or adjustable. It is usually set in the range of 15 to 60 seconds, so personnel can leave the area before release of the agent and to allow for manual interruption of the agent release sequence. If the situation is not dangerous, the sequence can be interrupted by a manual abort switch. When the detectors and control unit have been restored to their normal condition, the abort switch can be restored. The abort switch is usually designed to be held in (until the control panel is reset) so that the agent discharge cannot be accidentally impaired when the switch is unattended.

5.6.1 Initiating Devices

Frequently used detectors for gaseous agents are spot-type ionization smoke detectors and rate-compensated heat detectors. Factors affecting detector effectiveness, such as electrical power and air pressure, if pertinent, are supervised.

One or two manual methods for release of the gaseous agent are usually provided.

Manual fire alarm devices are frequently connected to the alarm system control unit to cause immediate discharge of the gaseous agent, regardless of cross-zoning and time delays otherwise provided.

Manual devices may also be connected electrically to cause direct release of the agent, independent of the alarm system.

Direct mechanical release of agent may be by manual actuation of a control valve.

Whether the agent release is caused by an alarm control unit auxiliary output or by an independent manual method, there should be an alarm at the alarm system control unit. Manual release of the gaseous agent usually causes an alarm by actuating a pressure switch that senses the increase in pressure in the gas line or manifold between the release valve(s) and the nozzles.

5.6.2 Sequence of Alarms

The normal circuit arrangement for a building alarm system to release a gaseous extinguishing agent is the same as for a building system with added features, such as cross-zoning, the abort feature, manual release of agent, and other specific auxiliary functions of the alarm system. Alarm systems that release a gaseous extinguishing agent use auxiliary alarm outputs to segregate the protected area and reduce dispersion and dilution of the agent. Typical auxiliary functions are fan shutdown, door (and window) closure, and closure of air-handling system dampers. Gaseous agent-releasing alarm systems applied to computer room installations also shut down computer power at the time the agent is released to eliminate the heat source for possible electrical fires.

A typical sequence of alarm system-initiated events in a computer room installation that includes all the usual features is as follows:

- Detection of fire by first detector in an area causes local and remote alarm indication, fan shutdown, door and damper closure, and other miscellaneous auxiliary functions through interlocks with building systems.
- Detection of fire by second detector in the area (cross-zoned with first detector) causes a distinctive, local, audible signal and initiates a time delay, during which agent release and computer power shutdown may be aborted.

- At the end of an adjustable delay (normally 20 seconds), assuming the release is not aborted, computer power is shut down and the extinguishing agent is released into the protected area.

5.7.0 Inspection, Testing, and Maintenance of Gaseous Systems

Inspection, testing, and maintenance of gaseous fire extinguishing systems are required to be sure they are in proper operating order. Inspection and test frequencies for these systems are summarized in *Table 4-4*.

Table 4-4 — Summary of inspection and test frequencies for gaseous systems.

	Weekly	**Monthly**	**Semi-Annually**	**Annually**
Check CO_2 and Halon nozzles and hand hose lines	X			
Weigh cylinders			X	
Check liquid level in low-pressure CO_2 storage tanks	X			
Check devices and connections of low-pressure CO_2 systems for leakage		X		
Test tank alarm pressure switch and identification device			X	
Conduct actuating and operating tests of CO_2 and Halon system cylinders				X
Hydrostatic test of cylinders and hoses				1
1- See text below for frequency				

5.7.1 Carbon Dioxide High-Pressure Systems

Check hoses and nozzles, cylinders, and cylinder pressure as follows:

- Weekly, check that all nozzles and hand hose lines are clear and in the proper position and that all operating controls are properly set.
- Semiannually, weigh cylinders and replace any that show a weight loss of greater than 10 percent. To weigh cylinders, do the following:
    - Loosen each cylinder support and disconnect each discharge head. Discharge heads are designed to be removed and replaced without tools.
    - Weigh cylinders with a beam scale or with a platform scale. To weigh with a platform scale, remove the cylinders completely from the rack and lift them onto the scale.

Test cylinders and hoses hydrostatically as follows:

- Hydrostatically test cylinders to a minimum pressure of 3,000 psi. The frequency for testing is as follows:
    - If discharged after 5 years from date of last test, perform hydrostatic test.
    - If not discharged after 12 years from date of last test, discharge cylinder and perform hydrostatic test.
- Hydrostatically test hoses to a minimum pressure of 1,250 psi. The frequency of testing is the same as for cylinders.

5.7.2 Carbon Dioxide Low Pressure Systems

Check nozzles, pressure and level gauges, and the system for leaks in all devices:

- Weekly, check to see that all nozzles are clear and in the proper position and that all operating controls are properly set. Check and record the reading on the liquid level gauge of all storage tanks. Refill tanks when the quantity is less than the minimum required to protect the largest single hazard, including any required reserve supply.
- Monthly, check for leaks on all devices and connections under continuous pressure, including valve packing glands, screwed connections, and safety relief valves.
- Semiannually, test the tank-alarm pressure switch and the operation of the alarm bell or light by reducing and increasing the pressure. Perform this test as follows:
  - Close valve on the piping from the vapor space to the alarm pressure switch.
  - Remove the test plug to reduce pressure.
  - Increase pressure by connecting a high-pressure cylinder to the test opening.
  - After testing, disconnect the high-pressure cylinder, replace the test plug, and reopen the valve on the alarm pressure switch piping.
  - If the bell or light fails to operate on the pressure test, repair or replace, and test again.
- Check the liquid level and pressure gauges for accuracy once each year.
- Replace frangible disks on the storage tanks once every 5 years. Maintain refrigeration equipment according to the manufacturer's instructions.

5.7.3 Halogenated Systems

Follow these procedures to test halogenated systems:

- Weekly, check to see that all nozzles are clear, positioned properly and all operating controls are set properly.
- Semiannually, check weight and pressure containers. (See procedures for verifying CO_2 cylinders.) If the container has a loss in net weight of more than 5 percent or a loss in pressure (after adjusting for temperature) of more than 10 percent, you must either refill or replace the container. When a factory-charged, non-refillable container does not have a pressure indicator that shows a loss in net weight of more than 5 percent, you must replace the container.
- Annually, test all actuating and operating devices. Use a cylinder containing carbon dioxide in the place of a halon cylinder or perform a simulated test of pressure-operated devices.

5.7.4 Alarm Systems

You should perform tests and maintenance of detectors, circuits, control units, annunciators, relays, and power supplies as described in *Maintenance of Fire Protection Systems,* NAVFAC MO-117, chapter 3. Some additional steps are required to test cross-zoned detectors, electrically operated releases for gaseous agents, and an abort feature.

5.7.5 Release Devices and Auxiliary Functions

Test electrically operated release devices for gaseous extinguishing systems annually. Combine this test with tests of detectors and the total alarm system. If you cannot perform an actual discharge test, be sure to prevent gas discharge and computer power shutdown, if provided, while observing electrical functions. This may require valve closure or partial disassembly of diaphragm piercing, solenoid plunger-type valves, and manual override of the computer shutdown feature. Refer to system instructions from the equipment manufacturer or installing company. The same method, once determined, is normally used for testing manual devices connected electrically to cause direct actuation of gas release devices. After taking necessary steps to prevent gaseous discharge, you should cause the necessary alarm conditions to activate the extinguishing system by actuating the detectors or manual initiating devices. At the end of the time delay intend, release device actuation should be evident. Verify that relays for auxiliary functions actuate. Take notes on which event relays actuate at the first cross-zoned detector alarm, second cross-zoned detector alarm, and at the end of the timer intend. Note the amount of time delay between the second detector actuation and the delayed functions.

If release devices or auxiliary functions fail, you should replace the control unit in the alarm condition and check appropriate output voltages at the control unit and at the failed device. If voltages are improper, troubleshoot the control unit or circuit as indicated. Cross-zoned systems require an alarm condition on both initiating circuits to actuate release devices and some auxiliary functions. If a timed function fails, check input voltage to the timer and the delayed output voltage from the timer with a voltmeter. Replace the timer if input is proper but output is not. If voltages are proper, check solenoid and relay coil continuities with one side of their respective energizing circuits open to the control unit. (See testing and maintenance for foam systems, *Maintenance of Fire Protection systems,* NAVFAC MO-117, *section 7.3.1.)* Replace defective devices and/or wiring.

5.7.6 Abort Feature

In gaseous extinguishing systems with an abort feature, test the feature annually along with the other elements of the system. To test the abort feature, first determine the timer setting from prior test records or installation data. Then cause first and second cross-zoned detect or alarms. The second detector alarm starts the timed period during which the gaseous agent release and other abortable functions may be activated. Operate the abort switch approximately in the middle of the time interval. Perform this test with the agent release and computer shutdown features disabled. At the end of the time interval, confirm that the aborted functions do not occur. Possible causes of abort failure:

- A defective abort switch,
- A defect in the wiring between the abort switch and the main control unit, or
- An improper abort feature installation or an improper timer setting (low).

During troubleshooting, disable the extinguishing agent release and the computer shutdown feature, if provided. Check the abort timer setting according to the manufacturer’s instructions. If the timer setting is quite low (15 seconds or less) increase the setting to 20 seconds or more (as determined by local authorities to be adequate to prevent unnecessary discharge of the agent).

If actuating the abort switch has no effect, check the switch continuity with an ohmmeter while actuating it disconnected from its wiring. If the switch continuity shows alternating readings of zero ohms and infinite resistance, as it should when being repeatedly actuated, check that the OFF and ON positions of the switch are not reversed. (Such reversal may be caused by connecting the wires to the wrong pair of switch terminals or inverting the switch when mounting it.) If the switch has no defect, check its circuit continuity with an ohmmeter at the control unit and with at least one wire disconnected from the control unit. Observe switch action at the ohmmeter by actuating the switch repeatedly. Correct any circuit defects or wiring errors. Replace the switch if it is defective.

Test your Knowledge (Select the Correct Response)

3. Gaseous extinguishing systems are normally located in which of the following areas?

   A. Computer operation centers
   B. Radio receiver buildings
   C. Power generating facilities
   D. Each of the above

6.0.0 Dry Chemical Extinguishing Systems

Dry chemical extinguishing systems are very similar in construction and operation to gaseous extinguishing systems. There are three general categories of chemical extinguishing systems: total flooding, local application, and hose line systems.

Total flooding systems are arranged to discharge the agent into enclosed spaces. Such systems are used for the protection of flammable liquid storage rooms and paint drying ovens (*Figure 4-29*). Ventilating equipment, conveyors, flammable liquid pumps, and mixers may be interlocked with the dry chemical system and arranged to shut down automatically upon discharge of the system.

Figure 4-29— Total flooding dry chemical system installation.

Local application systems are arranged to discharge dry chemical directly on the hazard, without any enclosure (*Figure 4-30*). Typical local application systems are used for the protection of paint dip tanks and restaurant range hoods. Ventilating fans, conveyors, flammable liquid pumps, and mixers may be interlocked to shut down automatically upon discharge of the system.

Figure 4-30 — Local application of a dry chemical system installation.

Hose line systems discharge dry chemical through manually operated nozzles connected by hose or by piping and hose to a fixed supply (*Figure 4-31*).

Dry chemical used in approved systems is mostly sodium bicarbonate, very finely ground, to which other ingredients have been added to keep it free flowing and to resist caking. Other agents used in dry chemical extinguishing systems include potassium bicarbonate, potassium chloride, and monoammonium phosphate—multipurpose type.

The dangers dry chemicals used in fire extinguishing concentrations cause exposed personnel are temporary breathing difficulty and reduced visibility. In areas using total flooding systems, suitable means should be provided to permit evacuation of personnel. In areas using local application systems where the dry chemical is not confined, there is little hazard to personnel.

Figure 4-31 — Dry chemical cylinder with a hose.

Dry chemical systems are used primarily for extinguishing fires in flammable liquids. Bicarbonate base dry chemical can be particularly effective for extinguishing fire in deep fat fryers caused by overheating. The saponification reaction between the dry chemical and fat or grease prevents re-ignition by turning the fat to soap. Multipurpose dry chemical will not react with the fat or grease and can prevent the saponification reaction between the fat or grease and any bicarbonate base dry chemical subsequently used.

Dry chemical systems are not suitable for fires in materials that contain their own oxygen supply, such as cellulose nitrate. They are not normally used for fires involving delicate electrical equipment, such as telephone switchboards, computers, and certain other electronic equipment, because the dry chemical will insulate the fine and delicate contacts. The contacts will then need complete cleaning.

Monoammonium phosphate and potassium chloride are slightly acidic and, in the presence of moisture, can corrode metals, such as steel, cast iron, aluminum bronze, and titanium. Corrosion can be minimized by prompt cleanup. Most dry chemical agents can be cleaned up by wiping, vacuuming, or washing the exposed materials or surfaces. Monoammonium phosphate will require some scraping and washing if exposed surfaces were hot when the agent was applied.

6.1.1 Types of Systems

There are basically two types of dry chemical systems:

- Gas cartridge systems that use a container of expellant gas that, when released by manual or automatic means, pressurize the container of dry chemical and force the agent through the piping network or hose lines (*Figure 4-32*)
- Stored pressure systems that consist of a container of dry chemicals that is constantly pressurized, usually with nitrogen

Figure 4-32 — Dry chemical and expellant gas storage cylinder.

6.2.0 System Components

Operating devices are used to release the expellant gas from its container for the pressurization of the dry chemical tank or to release the dry chemical if it is stored under pressure.

In fixed systems, expellant gas is released from its container by electrically, pneumatically, or mechanically dropping a weight that opens a cylinder valve or by mechanically releasing a spring that punctures the sealing disk of a gas cartridge. The dry chemical when stored under pressure is released by pneumatically or mechanically dropping a weight that opens the discharge valve. Pressure trips may be used to release the weights of more than one unit for simultaneous discharge of expellant gas. Pressure trips are operated by gas pressure taken from the low-pressure side of the expellant gas regulator.

Hose line systems are actuated at the cylinder by turning a hand wheel or by moving a lever.

The distribution system (piping) should be constructed of standard weight (schedule 40), galvanized steel pipe and standard weight, galvanized steel or malleable iron fittings.

It is important for the piping system to be balanced so the pressure drop to any one nozzle is about the same as to any other nozzle. Although dry chemical suspended in a gas may be homogeneous during flow, certain effects, such as inertia and sudden expansion of the gas, may cause some separation of the two phases. For example, if several nozzles are installed consecutively at right angles to a straight run of pipe, the inertia of the dry chemical carries most of it past the first nozzles. Therefore, these nozzles discharge more gas and less dry chemical than those farther down the piping system. To eliminate this, you can balance all branch piping by the use of tees (the dry chemical enters the side port and leaves through the two end ports).

Nozzles have various designs and discharge patterns. Nozzles used for distributing the dry chemical must be approved for a particular application.

Test your Knowledge (Select the Correct Response)

4. What type of gas is used as a propellant for a dry chemical system?

   A. Hydrogen
   B. Oxygen
   C. Nitrogen
   D. Carbon dioxide

Summary

Fire suppression systems are designed to extinguish fires as quickly as possible to prevent the loss of lives and property. If the components of these systems are not functioning properly, extensive damage or loss of life could occur. You learned how to inspect and maintain many of these systems. If needed, you may have to repair some or all of the components involved to operate properly, and possibly save lives. Although as a Utilitiesman it may not be your direct tasking or responsibility to install or maintain fire suppression systems, it is important to understand the science and operation of these systems, You may be called upon to advise the chain of command on installation or operation capabilities of the plumbing system and like materials.

Review Questions (Select the Correct Response)

1. All automatic sprinkler systems have which of the following characteristics in common?

   A. Water supply
   B. Piping network
   C. Sprinklers
   D. Each of the above

2. In a dry pipe system, the pipes can contain air or what other element under pressure?

   A. Argon
   B. Nitrogen
   C. Hydrogen
   D. Xenon

3. In a differential dry pipe valve system, the air must be maintained at least how many psi greater than the trip pressure?

   A. 20
   B. 15
   C. 10
   D. 5

4. When debris in the water is a problem, you should use what type of dry pipe valve?

   A. Low differential
   B. High differential
   C. Mechanical
   D. Latched clapper

5. What type of automatic sprinkler system should you use in an aircraft hangar?

   A. Wet pipe
   B. Semidry pipe
   C. Water deluge
   D. Semi-wet pipe

6. Pre-prime plugs blow out of the sprinklers at approximately what water pressure?

   A. 25 psi
   B. 20 psi
   C. 15 psi
   D. 10 psi

7. Automatic sprinklers have orifices graduated in what size increments?

   A. 1/2 inch
   B. 1/4 inch
   C. 1/8 inch
   D. 1/16 inch

8. A fusible link sprinkler is kept closed by a two-piece link fused together by what type of metal?

   A. Copper
   B. Aluminum
   C. Solder
   D. Steel

9. A dry pendent sprinkler is used when the system is exposed to which of the following conditions?

   A. High ambient temperatures
   B. Freezing temperatures
   C. Explosive elements
   D. Unstable chemicals

10. A dry pipe alarm system has which of the following characteristics?

   A. It is slow acting.
   B. It is moderate acting only.
   C. It is fast acting only.
   D. It is moderate or fast acting.

11. The retard switch connected to the alarm port of a wet sprinkler system alarm-check valve is normally set within what pressure range?

   A. 10 to 20 psi
   B. 8 to 15 psi
   C. 6 to 15 psi
   D. 4 t0 15 psi

12. In an electronic pressure-drop detector, an overpressure condition of what magnitude can cause a trouble signal?

   A. 250 psi
   B. 200 psi
   C. 150 psi
   D. 100 psi

13. To prevent freezing of water in a fire protection system, a Utilitiesman normally installs a supervisory device in a pipe or reservoir with what low water temperature setting?

    A. 40° F
    B. 32° F
    C. 25° F
    D. 0° F

14. At what interval should you inspect and test the general condition of sprinkler heads and sprinkler systems?

    A. Monthly
    B. Quarterly
    C. Annually
    D. Every 3 years

15. At what interval should you inspect and test water flow alarms?

    A. Weekly
    B. Monthly
    C. Quarterly
    D. Annually

16. At what interval should you inspect and test air and water pressure in dry pipe systems?

    A. Weekly
    B. Monthly
    C. Quarterly
    D. Annually

17. At what interval should you inspect and test general condition of standpipe systems?

    A. Weekly
    B. Monthly
    C. Quarterly
    D. Annually

18. At what interval should you inspect and test general condition of hydrants?

    A. Monthly
    B. Quarterly
    C. Annually
    D. Every 3 years

19. At what interval should you inspect and test water level in tanks?

A. Weekly
B. Monthly
C. Quarterly
D. Annually

20. What minimum distance must be maintained beneath a sprinkler for proper water distribution?

A. 48 inches
B. 36 inches
C. 24 inches
D. 18 inches

21. What type of test should be performed quarterly to test the alarm-check valves?

A. 8-inch drain test
B. 6-inch drain test
C. 4-inch drain test
D. 2-inch drain test

22. When testing a water clapper valve designed to trip at a fixed pressure of 10 to 15 psi, you should maintain what minimum air pressure on this valve?

A. 60 psi
B. 45 psi
C. 30 psi
D. 15 psi

23. When performing a basic inspection of accelerators and exhausters, you should check what pressure?

A. Water
B. Air
C. Centrifugal
D. Atmospheric

24. When testing deluge and pre-action valves, you should perform the 2-inch drain test at what time interval?

A. Weekly
B. Monthly
C. Quarterly
D. Annually

25. When performing a deluge valve dry trip-test in a flammable area, you should use what test in place of the electric test set?

    A. Infrared light
    B. Hot water only
    C. Hot cloth only
    D. Hot water or hot cloth

26. When performing the cathodic protection test with an ammeter, you notice a diminishing current flow. This is an indication of what type of problem?

    A. Failing electrodes
    B. Blown fuses
    C. Frozen electrodes
    D. Broken ground wires

27. Under normal circumstances, full operational testing of high-speed suppression systems should be conducted at intervals not to exceed how many years?

    A. 7
    B. 5
    C. 3
    D. 1

28. What characteristic of carbon dioxide makes it desirable for use on electrical fires?

    A. High-pressure application
    B. Electrical conductivity
    C. Electrical non-conductivity
    D. Low-pressure application

29. What is the normal cylinder pressure in a high-pressure system?

    A. 600 psi
    B. 500 psi
    C. 400 psi
    D. 300 psi

30. In a low-pressure system, liquid carbon dioxide should always be maintained at what constant (a) pressure and (b) temperature?

    A. (a) 300 psi (b) 0°F
    B. (a) 300 psi (b) 32°F
    C. (a) 200 psi (b) 32°F
    D. (a) 200 psi (b) 0°F

31. High-pressure systems require approximately how many pounds of equipment for every pound of carbon dioxide stored?

A. 7
B. 5
C. 3
D. 1

32. Pipe and fittings in a high-pressure system have what minimum bursting pressure in psi?

A. 7,000
B. 5,000
C. 3,000
D. 2,000

33. Pipe and fittings in a low-pressure system have a minimum bursting pressure of how many psi?

A. 3,000
B. 2,800
C. 2,000
D. 1,800

34. What automatic device should be installed along with a total flooding system to conserve carbon dioxide?

A. Closing
B. Venting
C. Door closure
D. Electrical lockout

35. Installation of a new Halon 1301 system is prohibited without special approval from whom?

A. NAVFACENGCOM
B. EPA
C. ROICC
D. Base fire chief

36. Regardless of the method being used, what device must be attached to the releasing mechanism?

A. An auxiliary fan
B. A control valve
C. A light
D. An alarm

37. At what maximum time interval should you replace the frangible disks on low-pressure storage tanks?

A. 12 years
B. 8 years
C. 7 years
D. 5 years

38. What type of system can be used with dry chemicals?

A. Total flooding
B. Local application
C. Hose line
D. Each of the above

39. What is the most widely used dry chemical?

A. Nitrogen
B. Sodium bicarbonate
C. Monoammonium phosphate
D. Potassium phosphate

40. Dry chemicals are used primarily on what type of fires?

A. Flammable liquid
B. Cellulose nitrate
C. Dry wood
D. Delicate electrical equipment

41. Dry chemical distribution systems are constructed of what schedule of pipe?

A. 40
B. 30
C. 20
D. 10

Trade Terms Introduced In This Chapter

Clapper	An assembly inside the alarm check valve that prevents the flow of water when closed
Priming water	A small amount of water over the clapper valve to ensure a tight seal
Accelerator	A device that allows air from the fire system to escape and open the clapper
Exhauster	A device that opens and helps to exhaust the air from the piping system faster, enabling a shorter reaction time to activate the suppression system
Fire flow demand	The water needed to for fire-fighting equipment to sufficiently suppress a fire

Additional Resources and References

This chapter is intended to present thorough resources for task training. The following reference works are suggested for further study. This is optional material for continued education rather than for task training.

Basic Machines, NAVEDTRA 12199, Naval Education and Training Professional Development and Technology Center, Pensacola, FL, 1994.

OSHA Regulations (Standards – 29 CFR)

Naval Construction Force Manual, *NAVFAC P-315*, Naval Facilities Engineering Command, Washington, D.C., 1985.

Engineering Aid Basic, NAVEDTRA 10696-A, Naval Education and Training Professional Development and Technology Center, Pensacola, FL, 1995.

Facilities Planning Guide, NAVFAC P-437, Volumes 1 and 2, Naval Facilities Engineering Command, Alexandria, VA, 1982.

Fluid Power, NAVEDTRA 12964, Naval Education and Training Professional Development and Technology Center, Pensacola, FL, 1994.

National Standard Plumbing Code-Illustrated, National Association of Plumbing- Heating-Cooling Contractors, Washington, DC, 2006.

Plumbing Manual, Volume II, NTTC Course 140-B, NAVFAC P-376, NAVFAC Technical Training Center, Navy Public Works Center, Norfolk, VA, 1965.

Safety and Health Requirements Manual, EM-385-1-1, Department of the Army, U.S. Army Corps of Engineers, Washington, DC, 1992.

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Chapter 5

Water Treatment and Purification

Topics

To hear audio, click on the box.

Overview

This chapter describes the process for obtaining water to support operations in the field. Without a good supply of water, morale can be severely diminished, and illness can be caused and spread by diseases and other chemicals found in the bad water supply.

As a UT, you are responsible for obtaining this good water, treating it if necessary, and getting it from the ground to the facilities and troops that need the water. We will discuss selecting a good water source, how to test it, and how to treat it so it is safe for consumption. We will also discuss how to detect and treat water that has been contaminated with chemical, biological, or radiological agents. Through the chapter, we will talk about different types of water treatment equipment, their processes, and some filters.

Objectives

When you have completed this chapter, you will be able to do the following:

1. Identify the requirements for water source selection.
2. Describe the development criteria for water sources.
3. Describe the results and testing procedures for water contamination.
4. Describe the different types of water treatment equipment.

Prerequisites

None.

This course map shows all of the chapters in Utilitiesman Advanced. The suggested training order begins at the bottom and proceeds up. Skill levels increase as you advance on the course map.

Air Conditioning and Refrigeration	↑	UT ADVANCED
Duct and Ventilation Systems		
Boilers		
Compressed Air Systems		
Sewage Treatment and Disposal		
Water Treatment and Purification		
Fire Protection Systems		
Interior Water Distribution and Interior Waste Systems		
Plumbing Planning and Estimating		
Contingency Support		

Features of this Manual

This manual has several features which make it easier to use online.

- Figure and table numbers in the text are italicized. The figure or table is either next to or below the text that refers to it.
- The first time a glossary term appears in the text, it is bold and italicized. When your cursor crosses over that word or phrase, a popup box displays with the appropriate definition.
- Audio and video clips are included in the text, with an italicized instruction telling you where to click to activate it.
- Review questions that apply to a section are listed under the Test Your Knowledge banner at the end of the section. Select the answer you choose. If the answer is correct, you will be taken to the next section heading. If the answer is incorrect, you will be taken to the area in the chapter where the information is for review. When you have completed your review, select anywhere in that area to return to the review question. Try to answer the question again.
- Review questions are included at the end of this chapter. Select the answer you choose. If the answer is correct, you will be taken to the next question. If the answer is incorrect, you will be taken to the area in the chapter where the information is for review. When you have completed your review, select anywhere in that area to return to the review question. Try to answer the question again.

1.0.0 INTRODUCTION

As a Utilitiesman, you will be responsible for ensuring that an adequate supply of safe water is available for domestic and fire protection uses. In meeting this responsibility, you must consider several factors, such as water source selection, ways to develop the water source, contaminants you may encounter, and methods you can use to remove these contaminants. In this chapter, each of these considerations is discussed.

2.0.0 WATER SOURCE SELECTION

You must consider three factors for a water source: quantity, quality, and reliability.

2.1.1 Source Quantity

Water sources developed for military use are referred to as water points. Water points are classified as follows:

- Surface water (streams, lakes, and rivers)
- Groundwater (wells and springs)
- Seawater
- Rain, snow, and ice

When selecting a water source, you must consider the amount of water available and what the demand is for water.

The amount of water that collects in any surface source depends on the amount of precipitation, the size of the drained area, geology, ground surface, evaporation, temperature, topography, and artificial controls.

The available water at a source can be estimated by using some simple calculations. To calculate the quantity of water (gallons per minute) flowing in a stream, use the following formula:

$Q =$ 6.4 x A x V

$Q =$ Quantity of water in gallons per minute (gpm)

6.4 = A constant – there are 7.5 gallons of water per cubic foot. However, because of error in stream measurement, 7.5 have been reduced to 6.4

$A =$ The area of the stream in square feet obtained by multiplying the width times the average depth of the stream

$V =$ The velocity of the stream in feet per minute obtained by measuring the time it takes a floating object to travel a known distance

An example of this calculation is a stream having an average depth of 2 feet and a width of 16 feet, and a twig is noted to flow at 13.3 feet per minute. To find the amount of water flowing in the stream, you should work the equation as follows:

$Q = 6.4 \times A \times V$

$Q = 6.4 \times (2 \times 16) \times 13.3$

$Q = 6.4 \times 32 \times 13.3$

$Q = 2,723.84$ gpm

To calculate the quantity of water in a lake or pond having little or no runoff, multiply the surface area by the average depth. The answer is in cubic feet. Multiply by 7.5 to obtain gallons at the water source. An example of this is a pond with an average depth of 7 feet and a surface area of 2,864 square feet. It is calculated as shown below:

$Q = A \times D \times 7.5$

$Q = 2{,}864 \times 7 \times 7.5$

Q = 150,360 gallons

Lakes and ponds are usually located within the ***water table*****,** and the hydraulics of the water feeding the lake or ponds are similar to that of wells; therefore, a drawdown test, using a method similar to the one described below for wells, may be used to calculate the quantity of water. To perform the test, you should draw down the ***static water level*** to 1 or 2 feet and then record the recovery time. Also, devise a method to discharge the water being pumped so it does not return to the source during the test.

To calculate the quantity of water that can be supplied from newly constructed or existing wells, you must make a drawdown test. To perform this test properly, you must understand the hydraulics of a well.

Before being pumped, the level of water in a well is the same as the level of the water table in the water-bearing formation in which the well is completed. This is called the static level in the well and in the foundation (*Figure 5-1*). The depth from the ground surface to the static water level should be measured, and this distance is used to describe its position. Thus, if the water in the well is 25 feet below ground, the static water level is said to be 25 feet for this well. Elevation of the static water level above mean sea level can also be used to describe its position.

Figure 5-1 — Static water level.

When a well is pumped, the water level drops. After several hours of pumping at a constant rate, it stabilizes itself in a lower position. This is called the pumping level or dynamic water level for this rate of pumping (*Figure 5-2*).

The distance the water is lowered by pumping is called the drawdown. It is the difference between the static level and the pumping level. The drawdown in the well, resulting from pumping, lowers the water pressure in the well, but the surrounding water-bearing formation retains its original pressure. In response to this difference in pressure, water flows out of the pores of the formation into the well.

Figure 5-2 — Pumping level.

The water-bearing formation does not furnish its water all at once to the well being pumped. The flow of water into the well is held back by the frictional resistance offered by the formation to the flow of water through its pores. The resistance varies in each formation and is developed in direct proportion to the rate of movement or velocity of the water in the formation. The rate of flow, resulting from a given pressure difference, depends on the fictional resistance to flow developed in the formation. The term used to describe this characteristic of a porous material is permeability.

For a particular type of well, the yield of the well for any given drawdown is directly proportional to the permeability of the formation. This property of the formation varies through wide ranges, the value for a coarse sand stratum being several hundred times that of a fine sand stratum of the same thickness. It increases with the coarseness of the sand and decreases with the compactness of the material. It increases where the sand grains are more nearly uniform in size. It decreases when fine sand and silt fill the voids between larger particles. The permeability of a rock formation, such as limestone, varies with the number and sizes of the fractures, crevices, and solution channels.

The measurements that should be made in testing wells include the volume of water pumped per minute or per hour, the depth to the static water level before pumping is started, the depth to the pumping level at one or more constant rates of pumpage, the recovery of the water level after pumping is stopped, and the length of time the well is pumped at each rate during the testing procedure. The testing described in this chapter is essentially the measurement of the hydraulic characteristics of a particular well.

The pump and power unit used for testing a well should be capable of continuous operation at a constant and variable rate of pumpage for a period of over 24 hours. It is important that the equipment be in good condition for an accurate test because it is undesirable to have a forced shutdown during the test. The test pump should be large enough to test to the expected capacity of the well, even though this may be far beyond the amount of water required and may exceed the capacity of the permanent well pump. Pumping by airlift maybe a practical method, provided that meters are not used for measuring the flow. The test should run at least 24 hours. Longer tests, up to several weeks' duration, may be desirable to verify adequacy of the formation.

To determine the safe yield of the well, the pump should be operated at a rate that will cause only about 50 percent of the maximum possible drawdown. The drawdown should not exceed a point 5 feet above the topmost screen slot. For example, a 125-foot well has a static water level of 25 feet and a pumping level of 75 feet or a 50-foot drawdown. The satisfactory pumping level is 50 feet or 50 percent of the maximum drawdown; therefore, a safe well capacity is established and maintained for that condition regardless of the yield. The safe pumping yield is the withdrawal rate that will not cause a lowering of the water table, and should cause no more than 50 percent of maximum drawdown. A chart, similar to the one shown in *Figure 5-3*, should be included in the test report. The complete test report will include the following:

- Initial static water level
- Pumping rates, at least every hour
- Drawdown data, at least every hour
- Rate of recovery

Figure 5-3 — Well chart.

The simplest way to measure the water pumped is to catch it in a steel drum or other tank of known volume. The time required to fill the tank is determined as accurately as possible. The rate of pumpage in gallons per minute is then calculated. For reasonable accuracy, the tank should be large enough to hold the water pumped during a period of at least 2 minutes. This limitation makes the method practical only for relatively small wells because large tanks will not usually be available.

Water meters offer a definite advantage in measuring the water being pumped. The amount of water pumped may be recorded from the meter at desired intervals. The total discharge may be recorded for any individual phase of the drawdown test.

The most accurate way to measure depth to the static level and to the pumping level in a well is with a chalked tape. A steel tape with a weight to make it hang straight is chalked at the lower end with blue carpenter’s chalk and lowered into the well until 1 or 2 feet of the tape is submerged. The proper length to lower the tape may have to be determined by experiment. The wetted length of the tape shows up very clearly on the chalked portion of the tape. This length is subtracted from the total length lowered below the reference point; this gives the depth to water.

The drawdown observed during a well test is the difference in feet between the pumping level and the static water level before pumping was started. The specific capacity of the well is the yield or discharge in gallons per minute divided by the drawdown in feet.

Water needs should be estimated using per capita requirements and other controlling demands as factors in arriving at the estimate. Other controlling demands may be the water requirements for such items as fire protection, industrial uses, lawn sprinkling, construction, leakage, and water delivered to other activities and vehicles. *Table 5-1* shows the per capita daily water requirements for different situations and the daily average requirements for vehicles. *Table 5-2* indicates the requirements that may be needed for construction equipment. Compare the yield of the source with the needs of the activity.

Table 5-1 — Daily Water Requirements in Temperate Zone.

Unit consumer	Conditions of use	Gallons per unit/ consumer per day	Remarks
Man	In Combat:		
	Minimum	½ - 1	For periods not exceeding 3 days, when operational rations are used
	Normal	2	When field rations are used
		3	Drinking plus small amount for cooking or personal hygiene
	March or Bivouac	2	Minimum for all purposes
	Temporary camp	5	Desirable for all purposes (does not include bathing)
	Temporary camp with bathing facilities	15	
	Semi-permanent camp	30-60	Includes allowance for waterborne sewage system
	Permanent camp	60-100	
Vehicle	Level and rolling country	1/8 -1/2	Depending on size of vehicle
	Mountainous country	¼-1	Depending on size of vehicle
Hospital	Drinking and cooking	10 per bed	Minimum does not include bathing or water for flushing
	With waterborne sewage	50 per bed	

Table 5-2 — Quantity and Quality of Water Needed by Construction Equipment.

Equipment	Size	Quantity	Purity of water
Rock crusher	22S-T	60,000 gpd	No special purification; seawater usable
Concrete mixers		18,000 gpd	Potable; minimum of organic matter Acid alkali free; seawater usable but decreases concrete strength by 20%, which may be offset by the use of extra cement
Concrete paver		60,000	
Asphalt plant		1,000 gph	Alkali free, low sulfates
Steam jenny			Potable; low calcium and magnesium
Steam boiler	200 hp w/ receiver	2,000 gph 1,000 gph	
Three car heater (for asphalt plants)		50 gph	
Water distributor	1,000 gal	1,000 gallons per 100 yd of 8 ft road	No special purification of Salt water acceptable
Compaction		Variable	Any available water accepted Seawater actually preferable for certain jobs
Vehicle radiators		Variable	Potable; calcium and magnesium lower than 400 ppm
Asphalt rollers		Variable	Potable; free of organic matter

2.2.0 Source Quality

The quality of water is the ability of water to be potable and palatable (water that is safe to drink, being free of harmful characteristics that could cause odor, foul taste, bad color and/or disease).

Practically all water supplies have been exposed to pollution of some kind. The general growth of population and the increasing use of streams and other bodies of surface water for the disposal of wastes have been detrimental to water sources.

Impurities in water are either suspended or dissolved. The suspended impurities are usually more dangerous to health. They include mineral matter, disease organisms, silt, bacteria, and algae. These must be destroyed or removed from water that is to be consumed. While some of these impurities can be seen by the naked eye, others can be detected by laboratory tests only. *Table 5-3* identifies some of the common impurities in water and summarizes their effect on water quality.

Table 5-3 — Common Impurities in Water.

Suspended Impurities	Organisms		Some cause disease	
	Algae		Causes taste, odor, color, ***turbidity***	
	Suspended solids		Cause murkiness or turbidity	
Dissolved Impurities	Salts	Calcium and magnesium	Bicarbonate	Causes alkalinity, hardness
			Carbonate	
			Sulfate	Causes hardness
			Chloride	Causes hardness; corrosive to boilers
		Sodium	Bicarbonate	Causes alkalinity
			Carbonate	Causes alkalinity
			Sulfate	Causes foaming in steam boilers
			Fluoride	Cases mottled enamel of teeth
			Chloride	Causes salty taste
	Iron			Causes taste, red water, incrustation on metals
	Manganese			Causes black or brown water
	Vegetable dye			Causes color, acidity
	Gases	Oxygen		Causes corrosion of metals
		Carbon Dioxide		Causes acidity, corrosion of metals
		Hydrogen Sulfide		Causes odor, acidity, corrosion of metals
		Nitrogen		No effect

Water samples must be forwarded to a laboratory for complete mineral or bacteriological analysis.

The factors that affect and determine the quality of water, such as physical, chemical, biological, and radiological contamination, are discussed later in this chapter.

2.3.0 Source Reliability

The reliability of a water supply is one of the most important factors in the selection of a water source. The information gathered during the water reconnaissance may indicate a source of sufficient supply only to have the source dry up during periods of no rainfall.

Study the hydrological data to determine the variations that may be expected at the water source.

Geological formations influence the reliability of a groundwater source. The amount of water flowing and the rate of flow may be controlled by geological layers. The amount of water within a water table may be limited by impervious formations, as shown in *Figure 5-4*. It is important that information on the characteristics and properties of the geological formations are considered.

It may be necessary to consider numerous other factors that may affect the reliability of the source. For one example, Lake Bonnie Rose, U.S. Naval Station, Adak, Alaska, is an ample source of cool, clear water being distributed by gravity. However, the relatively high elevation of the lake results in excessive pressure at the station. Pressures are controlled by pressure-reducing valves. The valves sometimes fail in service, resulting in damage to the water system.

Reliability of the source is further increased as the requirements for items that are subject to breakdown decrease (pumps, treatment plants, and so on).

Figure 5-4 — Limitation of water by rock formation.

Legal advice may be necessary when selecting a water source as the laws regulating and controlling water rights may vary considerably. The title to ground and surface water in the United States is usually regulated at the state level. Navigable waters having interstate traffic are under federal control. Some difficulty was experienced in Vietnam by SEABEES in securing water rights to surface streams. These waters were used for flooding of rice fields, and local control denied the use of these sources as water supplies.

Legal advice may also be required in securing the right for waterlines or power lines to cross property. To cite one example, a waterline serving a naval air facility in Sicily was completed, except for a section crossing an irrigation ditch. Final completion of the waterline was delayed for 2 months, waiting to obtain the right for the waterline to cross the ditch.

Test your Knowledge (Select the Correct Response)

1. A total of how many gallons per minute are flowing in a stream that is 10 feet wide and has an average depth of 3 feet when the water is flowing at a velocity of 15 feet per minute?

   A. 3,350
   B. 2,880
   C. 1,920
   D. 960

3.0.0 DEVELOPMENT of WATER SOURCES

Development of a water source includes all work that increases the quantity and improves the quality of the water, or makes it more readily available for treatment and distribution. The development of surface water sources, springs, and seawater sources is considered in this section.

In developing a source, dams, floats, galleries, and similar improvements may be used to increase the quantity and quality of the water. Elaborate developments should be avoided; simplicity brings more rapid results. A temporary water source should not be converted into a permanent one until the area has been reconnoitered for a source requiring less development. All intake hoses or pipes should be equipped with an intake strainer regardless of the clearness of the water source. Suction strainers should be protected from floating debris that may damage, clog, or unnecessarily pollute them. Proper anchorage of suction lines and strainers prevents (1) loss of prime, (2) punctured or kinked lines, and (3) damage to strainers. Water at the intake point should be as clear and deep as possible. The strainer on the suction hose is placed at least 4 inches below the water level. This precaution reduces the possibility of the strainer becoming clogged with floating debris, or the prime being lost because of air getting into the suction line.

3.1.0 Surface Water Development

Of the total amount of rainwater that falls upon the land surface of the earth, only a comparatively small part is absorbed by the soil. By far, the greater part of it runs off the surface of the ground and is carried out to the sea by way of streams and rivers or remains stored in natural lakes and ponds, and in artificial lakes and impounded reservoirs. The methods by which water supply is derived from the surface are (1) by damming of streams or rivers, (2) by using the flow from streams, (3) by pumping directly from surface streams, (4) by collecting water from the roofs of buildings, (5) by providing catchment areas for the collection of rainwater into specially constructed cisterns, (6) by solar distillation, (7) by power distillations, (8) by freezing, and (9) by electrodialysis.

For normal field water supply, surface water is the most accessible type of water source. This source also lends itself readily to the purification equipment common to most engineer units. Surface water is the most easily developed source of water. Methods of constructing intake points for land surface water sources are discussed below.

If the stream is not too swift and the water is sufficiently deep, an intake may be prepared quickly by placing the intake strainer on a rock. This will prevent clogging of the strainer by the streambed and provide enough water overhead to prevent the suction of air into the intake pipe. If the water source is a small stream or shallow lake, the intake pipe can be secured to a post or pile, as shown in *Figure 5-5*.

Figure 5-5 — Direct intake with hose on bottom of water source.

When a stream is so shallow that the intake screen is not covered by at least 4 inches of water, a pit should be dug and the screen laid on a rock or board placed at the bottom of the pit. Pits dug in streams with clay or silt bottoms should be lined with gravel to prevent dirt from entering the purification equipment (*Figure 5-6, Frame*). The screen is surrounded by gravel to prevent collapse of the sides of the pit and also to shield the screen from damage by large floating objects. The gravel also acts as a course strainer for the water. A similar method may be provided by enclosing the intake screen in a bucket, as shown in *Figure 5-6, Frame* .

Figure 5-6 — Methods for securing a surface intake.

The level of the water in small streams can be raised to cover the intake strainer by building a dam. In swiftly flowing streams, a wing or baffle dam can be built to protect the intake screen without impounding the water.

Floats made of logs, lumber, sealed cans, or empty fuel drums can be used to support the intake strainer in deep water. Floats are especially useful in large streams where the quality of the water varies across its width or where the water is not deep enough near the banks to cover the intake strainer. The intake point can be covered by an adequate depth of water by anchoring or stationing the float at the deep part of the stream. The intake hose should be secured to the top of the float, allowing enough slack for movement of the float. If support lines are used to secure the float to the banks, the position of the float can be altered to correspond to changes in depth by manipulation of the lines. The chief advantage of a float intake is the ease with which the screen can be adjusted vertically (*Figure 5-7*).

Figure 5-7 — Float type surface intake.

Water from muddy streams can be improved in quality by digging intake galleries along the bank. A trench is dug along the bank deep enough so that water from the stream percolates into it so it intercepts groundwater flowing toward the stream. The trench is filled with gravel to prevent the sides from collapsing. The intake strainer is placed in the gravel below the water table (*Figure 5-8*). The amount of work required to produce the gallery is justified by a reduction in the amount of chemicals needed to coagulate the water, the elimination of the necessity of frequently backwashing the filter, and the higher quality of water obtained.

Figure 5-8 — Gravel filled gallery intake.

3.2.1 Groundwater Development

Moisture is held beneath the surface of the earth in three zones: (1) the zone of soil moisture, where water is temporarily held in pore spaces by capillary action or other soil conditions; (2) the zone of aeration or zone of percolation beneath the soil layer, where both water and air are present in the pore spaces; and (3) the zone of saturation, where all spaces are filled with water. Groundwater is the term customarily used for the underground water in the saturated zone.

One possible objection to an underground water supply is that the water may be excessively hard. This condition may occur because of the percolation of the water through mineral deposits from which water-hardening constituents are leached or extracted. On the other hand, an underground supply generally has the advantage of requiring less treatment because of the natural removal of impurities as the water passes through various underground soil formations. However, these conditions are general; some mineral deposits do not contribute to hardness, and some underground formations may not be the type that effectively removes objectionable material.

Many times it is advantageous to use shallow groundwater sources or percolated waters adjacent to turbid surface water. Well points are issued in 2-inch diameters and 54-inch lengths. A drive cap is placed over the thread and the well point is driven into the ground with a sledge. Successive sections of pipe, each 5 feet long, are added and driven until the screen is well within the water-bearing media. Several well points may be connected in parallel to supply sufficient water to the raw water pump. In developing drive point sources, it must be remembered that the practical limit of suction lift of the pumps issued with field equipment is 22 to 25 feet at sea level. Thus, suction lift pumps can be used only where the pumping level in the well will be within the limit of suction lift, or 22 to 25 feet below the position of the pump. At 5,000 feet above sea level, the practical limit of suction lift is only 20 feet. It should be noted that since a suction-lift pump must create a partial vacuum in the suction line, it is necessary that the line be absolutely airtight if the pump is to function properly.

Springs yielding 20 gallons of water per minute or more can be used as a source of field water supply if properly developed. Springs may be developed by enlarging the outlet of the spring and by damming and conducting water to storage. To reduce possible pollution, springs should be cleared of all debris, undergrowth, top soil, loose rocks, and sand.

Water that flows from rocks under the force of gravity and collects in depressions can be collected in boxes or basins of wood, tile, or concrete. The collecting box should be large enough to impound most of the flow. It should be placed below the ground level so only the top is slightly above the surface. The box should be covered tightly to prevent contamination and lessen evaporation. The inlet should be designed to exclude surface drainage and prevent pollution. This requires fencing off the area and providing proper drainage. *Figure 5-9* shows a spring inlet protected in this manner. The screen on the overflow pipe prevents the entrance of insects and small animals. Another screen on the intake pipe prevents large, suspended particles from being ingested by the pump used to distribute the spring water. This prevents mechanical failure or reduces it to a minimum.

Figure 5-9 — Protection of spring from surface contamination.

The flow of water from a spring located on a steep slope of loose earth can be obtained by:

- Constructing deep, narrow ditches leading from the spring to the point of collection.
- Constructing pipeline tunnels from the spring to the collecting points. Pipe of large diameter is more suitable for this purpose. The water from the tunnels can be trapped by constructing a dam at the point of collection.

Digging is a more positive and more economical method of developing a spring than blasting. You must proceed with great caution if you use explosives to develop the yield from springs. Blasting in unconsolidated rocks may shift the sand or gravel in such a way as to divert the spring to a different point.

The method used for the development of springs as a water source will depend upon the extent and characteristics of the flow. Thermal (hot) springs should not be developed because their waters are likely to be highly mineralized. Regardless of the type of construction, all springs must be covered. Surplus water should be piped from the structure so surface water cannot enter the spring during periods of flood. It is not necessary to ventilate spring structures; therefore, all openings should be avoided, except for an inspection manhole fitted with a tight, locked cover.

When ground and surface water supplies are inadequate or cannot be used, groundwater supplies are developed by constructing wells. Wells are classified into five types, according to their method of construction. These are dug, bored, driven, jetted, and drilled wells. Each type of well has its particular advantages, which may be ease of construction, type of equipment required, storage capacity, ease of penetration into certain types of formations, or ease of safeguarding against pollution.

In the event of chemical, biological, and radiological operations, it is important to note that groundwater would probably remain essentially uncontaminated by airborne or surface dissemination, in contrast to surface water, which could become severely contaminated. This does not mean that groundwater is always pure and safe to drink. It can be naturally contaminated or could, in some cases, become contaminated with CBR agents. Well water should be thoroughly tested before use.

The production of groundwater involves the method of recovery of water stored in the zone of saturation below the waterline or water table. The groundwater table does not always remain at the same elevation, as it is controlled by rainfall, tides, the pumping rate from wells, and so forth.

A dug well is a large diameter well, seldom less than 3 feet in diameter, excavated with hand tools, and lined with brick, stone, steel, wood cribbing, or tile. That portion of the lining through the water-bearing formation is porous. This shallow type of well is usually dug from 20 to 40 feet deep, depending upon favorable location for water. Because of the large opening and perimeter to be protected against the incursion of surface drainage, dug wells are easily polluted by surface wash.

Bored wells are constructed in soft water-bearing formations that will not cave in while the hole is being bored. They are usually bored with hand or powered earth augers to a depth ranging from 25 to 60 feet without caving in.

Jetted wells are suitable in soft, unconsolidated, alluvial deposits. The well consists of an inner tube, which is a drilling or jetting tube, and an outer tube, which is the well casing. A power-driven pump with suitable hose attachments supplies continuous water pressure during drilling. One type of rig uses a block and tackle or a tripod for controlling the tools and casing. Larger rigs have a mast and hoisting block and use engine power for handling casing, drive weight, and pump. Water is led into the well through a small-diameter pipe and forced downward through the drill bit against the bottom of the hole. The stream loosens the material, the finer portion of which is carried upward and out of the hole by the ascending water. During the drilling, the jet or drill is turned slowly to ensure a straight hole. Casing is sunk as fast as drilling proceeds. In softer materials, by using a paddy or expansion drill, a hole may be made somewhat larger than the casing. The casing then may be lowered a considerable distance by its own weight. Ordinarily, a drive weight is needed to force it down. As a rule, one size of casing is used for the entire depth of the well. It is difficult to drive a single string of casing beyond 500 to 600 feet by this method. If a well is sunk much deeper, an additional string of smaller size must be used. In fine-textured material, the hole often may be jetted to the full depth and the casing inserted afterward. The wall of the hole becomes puddled by the muddy water so it will stand alone.

A driven well is constructed by driving a pointed screen, or drive point, and attached pipe directly into a water-bearing formation. The finished well consists of a series of lengths of pipe fitted at the upper end with a pump and the lower end with a sand screen through which the water is admitted. The drive point consists of a perforated pipe with a mild steel point at its lower end to break through pebbles or thin layers of hard material. As the drive point is driven down, succeeding sections are screwed into place. These sections continue until the water-bearing formation is reached. The pump then is attached, and after the well has been developed, it is ready for use. Drive point wells usually range in diameter from 1 1/4 to 2 inches, but larger sizes up to 4 inches also are made. The larger sizes, although of greater weight and more difficult to drive, have the advantage of using deep-well pumps, when necessary. The smaller sizes, because of their lesser weight and greater portability, are valuable for determining the depth of water-bearing formations and for test yields at shallow depths. The depth of the well is limited by the formations encountered and by the type of pump available. For small wells, the groundwater level must be within 25 feet of the surface because suction pumps generally are used. If small, self-priming, centrifugal pumps are used, the lift must be less than 25 feet. If 2-inch or larger pipes are used, it is possible to lift water from a greater depth by installing a cylinder-type pump near the water level.

The following conditions are necessary for successful driven wells. The formation into which the point is being driven must not be too hard and compact. The distance to groundwater must not exceed the lift of the pumps available. The water-bearing formations must have moderately high permeability to provide adequate yields in small diameter wells. The wells must be developed properly to obtain sufficient water.

Chief disadvantages against general use of driven wells are as follows. Construction is laborious and slow when tightly compacted soils are encountered. Driving is destructive to well equipment; points frequently are stripped of mesh; pipe is bent and broken. Couplings frequently are belled by the force of the hammer blows. Belled joints always leak air and either render the well useless or seriously impair the yield of water. Yields are small from any one well point. As many as five points connected in series may be required to operate a power pump to capacity.

Successful construction of driven wells depends upon close observation and correct interpretation of events (occurring while driving) by the well driver. Accurate interpretation of such details as the penetration made with each blow, the drop and rebound of the monkey, the sound of the blow, and the resistance of the pipe to rotation enables the experienced well driver to determine the character of the materials being penetrated. An approximation of the geological section of the well can be obtained by recording these observations. Study of the logs for successive wells, coupled with a study of the results obtained from each well, assists in developing trained well drivers with each successive well.

Although a well site may have been properly selected, the strata correctly interpreted, and the presence of water accurately judged, wells may fail to yield water merely because they have not been pumped to clear the fine sediment from around the screen. When the presence of water is suspected, a simple test is to pour water into the well. If the screen is in dry sand, the water sinks downward and seeps into the formation, but if the screen is in saturated sand, the level of the added water remains nearly stationary or quickly sinks to a static level. Also, the quantity of water that can be poured into the well is an index of the well capacity when pumping; when saturated, the sand yields its contents as freely as it absorbs water. Often the raising or lowering of the pipe a foot or more brings a greater length of the screen into contact with the water-bearing stratum and results in a great increase in yield.

There are two methods of drilling wells. One method is the hydraulic rotary and the other is the cable tool percussion. Drilled wells tend to be the most complicated and require a lot of equipment. In most cases, Equipment Operators will be called upon to place drilled wells. The Utilitiesman may be called upon to install pumps and plumbing when the drilling is complete. Alpha types commonly perform the duties as water well drillers; however, UTs can also qualify as Drillers. Development of this type of well will then proceed in a similar manner as any other type of well.

3.3.1 Alternative Water Sources

In some regions of the world, there is not enough surface or groundwater available to support the demands for domestic and fire protection water needs. In these areas, it may be necessary to develop alternate sources of water. Rainwater, snow, seawater, water barges, and mobile tanks are a few of the alternate water sources that may be considered.

In tropical regions, there is an abundance of rainwater with a rapid rate of surface runoff. The construction of collection surfaces can be a solution to water needs.

For temporary or emergency water supplies, collecting surfaces may be constructed by the use of tarps, wooden platforms, metal surfaces, and so forth. However, surfaces constructed for other purposes, such as building roofs, may be used.

More permanent rainwater catchment areas will be cleared, graded, and given an application of cement or other impervious mixture. The catchment area should be located at least 100 feet from any source of subsurface contamination (septic tanks, cesspools, and so on), and as far from other sources of pollution (dust, soot, and so on) as possible. The catchment area and impounding basin should be enclosed by a fence.

Collected waters should be carried by gravity or pumping to closed stowage reservoirs. As rain falls toward the earth, it absorbs dust and such gases as carbon dioxide and oxygen, and must therefore be considered unsafe for consumption until treated. Filtration and disinfection are the minimum required treatment.

In some locations, water may be so hard to obtain or polluted that it is not be economical to develop any source. In this case, water barges or mobile tanks may be used. Barges or mobile tanks can be filled from ships, tank trucks, or other well points located some distance away. It is important to note that all mobile containers are a temporary water source. Disinfection of their surfaces that will come in contact with potable water is required.

In northern arctic areas, where deep wells cannot be sunk through the thick layers of permafrost and the surface sources are frozen solid, water must be obtained by melting snow or ice. Ice is preferred to snow because it will yield more water for a given volume. Snow or ice may be contaminated; therefore, all melt produced should be treated before drinking. Approximately 5 cubic feet of snow are required to yield 1 cubic foot of water. In emergencies, personnel can eat small quantities of snow. This snow should be placed in the mouth rather than being sucked, to prevent chapped or cut lips. Only small quantities of snow should be consumed in this manner because consumption of large quantities will reduce the body temperature.

Seawater is vastly different in its characteristics (as well as in the methods of purification used) from other surface sources. The chemical characteristics of seawater are such that normal coagulation and filtration are ineffective as treatment processes.

In developing seawater sources, consideration must be given to such factors as surf action, saltwater corrosion, suspended sand and silt in the water, living organisms, surface oil along beaches, and the rise and fall of the water level with the tides. If the equipment is located on sheltered bays, harbors, lagoons, or estuaries, it can be supplied by intakes built in the same way as freshwater surface intakes. On small islands where there is insufficient surface and groundwater, and on or near open beaches, intakes for equipment can be built as follows:

1. Saltwater wells. Beach wells should, if possible, be used in preference to offshore intakes. Wells can be dug to tap fresh or salty groundwater. This eliminates the problems caused by tides, surf, and shallow water close to shore. Such wells have an added advantage in that they can be built back of the shoreline under natural overhead concealment. Driven and jetted wells may also be used effectively at beach locations.
2. Offshore intakes. Offshore intakes are sometimes required because of lack of time, personnel, or equipment or because of coral conditions that prohibit well construction. Intakes of either the rigid pipe or float type may be used but they should be located in deep water beyond the surf. They must be positioned vertically and be off the bottom but still beneath the water surface at low tide. In this way, foreign materials in the water that might cause excessive wear on equipment will be largely excluded. The rigid pipe intake can be placed on timber supports and anchored securely in position by piling or riprap. Floats securely anchored can support the intake screen in much the same manner as in surface waters. A rubber suction hose can be used to connect the rigid pipe on the sea bottom to the pipe supported beneath the float.

Test your Knowledge (Select the Correct Response)

2. The strainer on a suction hose should be placed a total of how many inches under the water level?

   A. 6
   B. 8
   C. 4
   D. 3

4.1.1 WATER CONTAMINATION

Water takes on various characteristics and properties as it passes over and through the earth. These characteristics and properties vary and are dependent on the materials encountered. These materials may be natural or manmade and are classified according to their means of detection.

- Physical—detected by one or more of the human senses
- Chemical—detected by chemical analysis
- Biological—detected by testing for chloroform organisms
- Radiological—detected by radiac equipment and special laboratory field tests

4.1.1 Physical Impurities

Physical impurities in water are either suspended or dissolved. The suspended impurities are usually more dangerous to health. They include mineral matter, disease organisms, silt, bacteria, and algae. They must be destroyed or removed from water that is to be consumed by humans.

The most important physical characteristics are turbidity, color, odor, taste, and temperature. Valuable information can be obtained by observing the water with any of the five human senses and using commonsense judgment on the following characteristics:

- Color
- Turbidity
- Odor
- Taste (use with caution)
- Temperature
- Condition of vegetation around source (dead or mottled vegetation can indicate the presence of chemical agents)
- Presence of dead fish, frogs, and so forth

Before starting any treatment to remove color, turbidity, taste, or odor, you should take several preventive measures.

You must prevent the formation of algae in raw water supply points. Algae can be controlled with copper sulfate, chlorine, or activated carbon. Before deciding which method or combination of methods may be most effective, consider the following factors:

- Volume of water to be treated
- Time of year
- The effects of treatment on fish life
- Type of secondary water treatment in use
- Equipment available
- Cost of treatment

You must also prevent the raw water source from becoming polluted by drainage from industrial waste and surface drainage from farms, mines, and watersheds. The above conditions usually cause water to take on color due to the presence of colored substances in solution, such as vegetable matter dissolved from roots and leaves. Dissolved humus, iron, and salts could also be included. True color is due to substances in true solution; apparent color includes true color and substances suspension rather than dissolved. Color may also be caused by industrial wastes and turbidity. Color as such is harmless but objectionable because of its appearance and the taste and odors sometimes associated with it.

Turbidity is a muddy or unclear condition of water caused by particles of sand, clay, or organic matter being held in suspension. Clay and silt remain suspended in water for the longest period of time because of their particle size and specific gravities. The removal of turbidity is essential to the production of potable water. Removal reduces water contamination, extends the time between backwashing of filters, decreases chlorine demand, improves disinfection, and enhances user acceptability of the finished water. Proper water treatment requires turbidity removal because suspended particles often contain organisms that may cause diseases.

Turbidity is removed by coagulation and sedimentation. Since the physical characteristics of raw water vary widely in different locations, dosages of coagulant chemicals must be determined at each water point to ensure maximum efficiency with minimal waste of chemicals. After coagulation and settling, the water should not have more than 20 percent of the original turbidity. Daily jar tests will help check the optimum chemical dosage required to meet this standard.

4.2.0 Coagulation Chemicals

The type of chemicals that should be used for coagulating raw water can be determined by using the results from jar tests, plant tests, or by using the data shown in *Table 5-4*. Theoretically *Table 5-4* is correct; however, these values can be misleading when applied to some types of raw water. The chemical content of water may have a considerable influence on the optimum pH range for the various coagulants. The term *pH* is used to describe the acid or base properties of water solutions. A scale from 0 to 14 has been established where pH value of 7 is neutral. A pH value less than 7 is acidic. A pH value above 7 is alkaline or basic. A pH value less than 7 in the wastewater plant influent may indicate septic conditions of wastewater. The pH values less than 5 and more than 10 usually indicate that industrial wastes exist and are not compatible with biological wastewater operations. Pretreatment of these wastes at the source is usually required since extreme pH values may damage biological treatment units.

For example, coagulation with ferrous sulfate is usually best accomplished at relatively high pH values in the alkaline zone. With soil and colored waters, ferric coagulant may sometimes be used with considerable success at pH values of 4.0 or less. Because of this wide variation in the optimum pH range of coagulant (caused by individual characteristics of the raw water), the coagulant dosage and the optimum zone for ***floc*** formation should be determined by jar tests rather than by just relying on *Table 5-4*.

Table 5-4 — Optimum pH Ranges for Common Coagulant.

Coagulant	pH
Aluminum Sulfate	5.0 to 7.0
Ferrous Sulfate	9.5 and above
Chlorinated copperas	4.0 to 6.5 and above 9.5
Ferric Chloride	4.0 to 6.5 and above 9.5
Ferric Sulfate	4.0 to 10.0

4.3.1 Jar Test

The jar test is the most common method of determining proper coagulant dosages. When there is a question as to which chemical should be used as a coagulant, it is often necessary to run more than one series of jar tests. Different coagulant chemicals and pH ranges should be used to determine which one produces the most satisfactory results at the lowest cost. The step-by-step procedures for a jar test are as follows:

1. Prepare a standard solution of each coagulant selected for trial by adding 10 grams of coagulant to 1 liter of distilled water.

2. Correct the pH of a sample of raw water to within the optimum range for the coagulant being tested (only if the pH is to be adjusted to the same extent in actual plant operation). Divide the raw water into six 1-liter samples,
3. Add 0.5 ml of standard coagulant solution to one sample of raw water, 1.0 ml to the second sample, 2.0 ml to the third sample, 3.0 ml to the fourth sample, 4.0 ml to the fifth sample, and 5.0 ml to the sixth sample. The result is a dosage of 5, 10, 20, 30, 40, and 50 mg/1, respectively.
4. Agitate samples in the jar test apparatus at a velocity about equal to the treatment equipment you are using and for the same length of time as the treatment equipment mixing time.
5. Keep the samples at the same temperature as water passing through your treatment equipment.
6. After stirring, let the samples settle for 30 minutes.
7. Siphon off a sample of the water and determine the turbidity by using a turbidometer.
8. The smallest amount of coagulant that produces the lowest turbidity represents the optimum dosage. Multiply the coagulant dosage in mg/1 (step 5 above) by 8.33 to get the correct chemical feed in pounds per million gallons.
9. Repeat the steps for each chemical used until satisfactory results are obtained.

As to acceptability, the taste and odor of water must be considered from the user's point of view. Tastes and odors of water are most commonly caused by algae, decomposing organic material, dissolved gases, or industrial wastes. Potability is not fleeted by the presence of odors and tastes. On the other hand, palatability is frequently affected, particularly when a substance, such as bone or fish oil, is present. Tastes and odors that make water unpalatable must be removed. Use of free available chlorine, ***aeration***, and activated carbon can do much to prevent or remove unacceptable tastes and odors from treated water.

The use of free available chlorine is advantageous because most odors and tastes are removed and rigorous disinfection is assured.

Activated carbon is the most widely used single process for taste and odor removal. Aeration and copper sulfate treatment are also used. All three methods are described below. The method used depends upon the substance or substances to be removed and the equipment available.

Activated carbon is an excellent absorbing agent to use in ridding water of unpleasant tastes and odors. It is also an effective agent for removal of organic color. It is insoluble and tends to float unless all particles are wetted thoroughly by being made into a slurry before being added to the water. When continuous flow equipment is being used, the activated carbon should be added to the limestone feeder and added to the water with the limestone slurry. When the batch type of equipment is being used, the activated carbon can be added along with other chemicals in the coagulation tank. Being insoluble, activated carbon does not affect the pH value or chemical characteristics of water. One ounce of activated carbon per 1,000 gallons of water is usually adequate. However, dosages up to 1 pound per 1,000 gallons can be used, depending upon the kind and degree of impurities present. Use of activated carbon in much higher dosages for removal of chemical agents is discussed later in this chapter.

NOTE

Treatment with activated carbon should always be made ahead of, or part of, the coagulation process so the activated carbon and the various impurities absorbed by it are removed.

Aeration treatment consists of adding oxygen by exposing the water to air. The process has a two-fold action. Volatile odor-producing materials are released to the atmosphere, and the action of the air upon readily oxidizable materials causes a precipitation of insoluble oxides and hydroxides. Removal of hydrogen sulfide is an example of the formal action, while removal of iron is an example of the latter action. The aeration of water to rid it of the taste and odor of decomposing vegetable matter generally involves both actions.

Copper sulfate controls tastes and odors caused by small living organisms. This treatment is most frequently used in lakes and reservoirs. The copper sulfate is applied by towing a porous sack containing copper sulfate crystals behind a boat or by spraying a copper sulfate solution over the surface of the water. The amount of copper sulfate you should use depends on the type and concentration of organisms present. Dosages must be controlled because amounts greater than 2.0 parts per million (ppm) kill fish in the water. The amount necessary to remove microorganisms has no detrimental effect on human beings. Copper sulfate treatment is rarely used in field water supply for several reasons:

1. The advantage to be derived from treating an entire lake or reservoir frequently does not warrant the expense of the treatment when the length of time the water source is to be used is taken into consideration.
2. The amount of copper sulfate used entails considerations of wildlife, medical effects, and total water chemistry, which are beyond the water supply technician's area of operation.
3. Superchlorination and dechlorination with activated carbon are effective for short periods, although they are expensive for extended operations.

Temperature must be considered in the treatment of water. Lowering the temperature of water suppresses odors and tastes and therefore increases its palatability. In the summer, the temperature of deep lakes and reservoirs decreases sharply from top to bottom. By shifting the depth of intake, it may be possible to draw relatively cool water even during hot weather. Water should be drawn from the lower depths when possible. Cool water is more viscous than warm water and thus is more difficult to filter. Cool water is more difficult to coagulate and chlorinate effectively than warm water because of slower reactions. Water treatment rates should be reduced when water temperatures are less than 45°F.

4.4.0 Chemical Characteristics of Water

The most important chemical characteristics of water are its acidity, alkalinity, hardness, and corrosiveness. Chemical impurities can be either natural, manmade (industrial), or be deployed in raw water sources by enemy forces.

Some chemical impurities cause water to behave as either an acid or a base. Since either condition has an important bearing on the water treatment process, the pH value must be determined. Generally, the pH influences the corrosiveness of the water, chemical dosages necessary for proper disinfection, and the ability to detect contaminants.

4.4.1 Hardness

Hardness is caused by the soluble salts of calcium, magnesium, iron, manganese, sodium, sulfates, chlorides, and nitrates. The degree of hardness depends on the type and amount of impurities present in the water. Hardness also depends on the amount of carbon dioxide in solution. Carbon dioxide influences the volubility of the impurities that cause hardness.

The hardness caused by carbonates and bicarbonates is called carbonate hardness. The hardness caused by all others (chlorides, sulfates, and nitrates) is called noncarbonated hardness.

Alkalinity is usually equivalent to the carbonate hardness. Sodium, however, also causes alkalinity. In natural waters, sodium is not normally present in appreciable amounts.

In natural waters, the alkalinity is therefore equal to the carbonate hardness. After water has been softened, a large amount of sodium remains in the treated water. In softened water, the total alkalinity is the sum of the carbonate alkalinity plus the sodium alkalinity. Hardness is undesirable in that it consumes soap, makes water less satisfactory for cooking, and produces scale in boilers and distillation units.

The following minerals cause hardness in ground and surface waters:

- Calcium carbonate is alkaline and only lightly soluble; causes carbonate hardness and alkalinity in water.
- Calcium bicarbonate contributes to the alkalinity and carbonate hardness of water. Calcium bicarbonate, when heated, produces carbon dioxide and calcium carbonate. This calcium carbonate precipitates as scale in boilers and distillation units.
- Calcium sulfate or gypsum causes noncarbonated hardness in water. Being more soluble in cold water than in hot, it separates from the water in boilers and forms scale on the boiler tubes.
- Calcium chloride causes noncarbonated hardness in water. In steam boilers and distillation units, the presence of calcium chloride causes chemical reactions that can pit metallic tubing.
- Magnesium carbonate (magnesite) and magnesium bicarbonate act the same in water as calcium carbonate and bicarbonate.
- Magnesium sulfate (epsom salts) adds to the noncarbonated hardness of water and causes boiler scale. In amounts greater than 500 parts per million in drinking water, it acts as a laxative.
- Magnesium chloride has the same properties and effects as calcium chloride. However, the magnesium will contribute to the formation of magnesium hydroxide scale on boilers and evaporators.
- Iron is undesirable because it imparts a rusty color and objectionable taste to water. It also forms crusts in plumbing and piping. When iron is present in water, organisms whose life processes depend on iron compounds may also be present. These organisms may cause tastes and odors and create what is called red water.
- Manganese, while not encountered as often as iron, is found in both surface and groundwater. Its presence in water normally causes a grey or black color. The

total concentrations of iron and manganese in potable water should not exceed 0.3 ppm.

Iron and manganese removal is not normally required in the production of field drinking water. Oxidation by aeration, followed by sedimentation and filtration, is the most common method of removing iron and manganese. They are oxidized to insoluble ferric oxide and manganese oxide by this process. The same methods may generally be used to remove both iron and manganese, although when they are present together in water, removal is more difficult. Combinations of iron and manganese with organic matter may require aeration in trickling beds containing coke, followed by sedimentation and filtration. In some cases, superchlorination followed by sedimentation and filtration will in itself remove these two substances. The addition of lime, $Ca(OH)_2$, followed by sedimentation and filtration, is another method for removal of these substances.

The concentration of chemical substances present in water for military water supply should not exceed the values shown in *Table 5-5*. If local conditions or short-term requirements make the use of water containing higher chemical concentrations necessary, authorization must be obtained from the medical officer.

Table 5-5 — Maximum Chemical Allowances for Water Source.

Chemical Substances	Maximum values
Copper	1.0 ppm
Iron	0.0 ppm
Manganese	0.05 ppm
Zinc	5.0 ppm
Magnesium	125.0 ppm
Chlorides	250.0 ppm
Sulfates	250.0 ppm
Phenolic compounds	0.001 ppm
Lead	0.05 ppm
Hexavalent Chromium	0.05 ppm
Fluoride	1.5 ppm
Turbidity (silica scale)	5.0 units
Color (platinum-cobalt scale)	15.0 units
Nitrate-Nitrogen	10.0 ppm
Total solids	500.0 ppm

Water softening. Water softening is the term used to identify the process of treating water supply hardness. Water softening is most likely necessary when water is being supplied to laundries and heating units involving boilers and steam equipment.

Lime-Soda Process. Lime-soda ash softening consists of the application of these materials to the raw water. Lime, Ca(OH)2, reacts with the soluble calcium and magnesium bicarbonates and forms insoluble calcium carbonate and magnesium hydroxide. Soda ash, Na2CO3, reacts with the soluble noncarbonated compounds of calcium and magnesium to precipitate insoluble calcium and magnesium compounds but leaves sodium compounds in solution. The physical operation of adding lime-soda ash and removing the precipitates is similar to that in the conventional coagulation-filtration process for bacteria and turbidity removal.

Zeolite Process. Zeolites used in water softening are complex compounds of sodium, aluminum, and silica, which have the faculty of exchanging bases. They are often called *green sand* because of the color of natural zeolite. Synthetic zeolites are also available. When water containing calcium and manganese compounds passes over the zeolite, the calcium and manganese are exchanged for the sodium in the zeolite. In this way, the water is softened and its sodium content increased. When the sodium of the zeolite is exhausted, it is regenerated by applying a sodium chloride solution. Another exchange is made, and the resulting concentrated solution of calcium and magnesium chloride is discharged to waste. The operating rate varies directly with the thickness of the zeolite bed. The time between regenerations depends on the characteristics of the water and the total amount of water applied. The need for regeneration will be evident when hardness is no longer removed. The zeolite process can only be used on water that has been treated for removal of turbidity.

Ion Exchange. The ion exchange unit, when run on the sodium cycle, will significantly soften water. The ion exchange unit will also remove such undesirable ions as those of manganese and lead.

4.4.2 Dissolved Gases

The concentration of a gas in water is directly proportional to the concentration, or partial pressure, of the gas in the atmosphere in contact with the water surface. In general, this involves the water temperature, its salinity, and the altitude. The gases of primary interest to water supply are as follows:

- Oxygen. Large amounts of dissolved oxygen are found in rainwater. The amounts in surface water vary greatly, depending on the amount and type of pollution, the degree of self-purification, the action of algae, and the temperature of the water. Polluted water will exhaust the oxygen supply, while clean water will contain much dissolved oxygen. Cold water contains larger amounts of dissolved oxygen than warm; as water temperature rises, the dissolved oxygen is released to the atmosphere. Decreased pressure on water has the same effect, releasing oxygen to the atmosphere. Dissolved oxygen causes the solution of metals and, especially in the presence of carbon dioxide, causes many metals to corrode.
- Carbon Dioxide. The presence of carbon dioxide in water contributes to the degree of hardness and acidity of the water. Water acquires this gas in four ways: from the air by natural movements of water in contact with the air, such as currents and wave action; by contact with decomposing vegetation, which gives off carbon dioxide freely; by the reaction of ferric chloride and limestone in the coagulation process; and by contact with the gas in underground deposits. A high carbon dioxide content usually makes water more corrosive to metals.
- Hydrogen Sulfide. Hydrogen sulfide in solution lends a disagreeable taste and rotten-egg odor to water. Groundwater absorbs sulfides by passing over sulfur-bearing rocks. Hydrogen sulfide is also responsible for the destruction of cement and concrete as well as the corrosion of metals. In small amounts, it is

unpleasant but not dangerous. In large amounts, it is harmful. Water that smells of hydrogen sulfide should be treated.

Dissolved gases are removed by means of aeration or the use of activated carbon. Aeration exposes as much water as possible to the air. This will release dissolved gases, such as hydrogen sulfide and carbon dioxide, into the atmosphere. Liberating the dissolved gas from the water by aeration permits the oxygen in the air to come in contact with the finely divided water particles, thereby increasing the dissolved oxygen content of the water. This increase of oxygen content removes the offensive taste and odor imparted by the dissolved gases. Aeration raises the pH by eliminating the carbon dioxide, but increases corrosiveness by increasing the amount of dissolved oxygen. One type of aerator consists of trays containing slats or coke over which the water is sprayed. Other methods of aeration include spraying water up over a shallow receiving basin and forcing air into a basin with diffusers or mechanical pump-type aerators similar to those used in sewage treatment. Operation of most aerators is practically automatic; operators' duties consist essentially of making sure that pipes, slots, and surfaces are not clogged and that air has free access to the water. If the water is not to be filtered after aeration, aerators must be screened to keep out insects and other foreign matter.

Activated carbon is a specially treated granular powdered carbon. It absorbs or attracts large quantities of dissolved gases. It is extremely effective in taste and odor control when the

- type of activated carbon used meets minimum standards,
- dosage is correct,
- carbon is mixed intimately with the water, and
- carbon is in contact with the water for an adequate period.

Acceptable commercial preparations of activated carbon should meet the following minimum specifications:

- It does not contain any soluble mineral injurious to health.
- Moisture content is not over 8.0 percent.
- It is in powdered form that wets down and goes into suspension readily, does not settle too rapidly, and does not float on the surface when applied.
- At least 99 percent of the carbon in water suspension passes a 100-mesh sieve and 95 percent passes a 200-mesh sieve.
- It has enough adsorption capacity to reduce a concentration of 0.1 milligrams per liter (mg/l) phenol in distilled water to 0.01 ppm.

Because of the wide range in waters, no general rule can be given for activated carbon dosage. The dose required at each water plant must be determined by periodic laboratory tests. The test is made by preparing a number of samples of raw water, adding the standard amount of treating chemicals and varying amounts of carbon to each sample, allowing plant contact time, filtering, and making odor tests. Numerical comparison can be made with the threshold odor test. A carbon dose of 3 ppm removes most tastes and odors from water. However, dosages can vary from 3 to 15 ppm, depending upon the odor of the water. Laboratory tests will determine the dosage.

Activated carbon is fed into the water by dry feeders. It must be handled more carefully than coagulant because it is a fine powder; therefore, the feeder must be an approved type and designed to prevent the spreading of the carbon dust and causing fires. In addition, inhaling of the dust by personnel, even in low concentrations, can affect their lungs. The dry feeder room should have explosion-proof electrical equipment. A spark or pilot flame can create an explosion. Dry carbon will float on the surface of the water for a long time; therefore, it is important that the carbon be wetted thoroughly and mixed by agitation using a paddle wheel, swirling action, a spray, or so forth, in a small tank. Some dry feeders have a mixing chamber in which the carbon is wetted by the swirling action of the water.

Activated carbon may be applied to the water at one or several points, depending on the results desired. Carbon is added at one or more of the following points:

- In the raw water, as early as possible after it enters the plant. This point of application is not recommended for extremely turbid waters.
- In the mixing basin. When added before sedimentation, activated carbon not only removes foreign matter from the water, but the carbon that settles in the sedimentation basin continues to absorb products of sludge decomposition, thus preventing formation of secondary tastes and odors. Black alum is premixed activated carbon and coagulant that can be used in special situations both as a coagulant and for taste and odor control.

4.5.1 Chemical, Biological, and Radiological (CBR) Contamination

Should chemical or biological agents or nuclear weapons be employed during conflicts, the water supply of the area involved would, in all likelihood, become contaminated. A water source contaminated with a chemical, biological, or radiological agent can cause incapacitation or death to a consumer. Effective means for determining the presence of CBR agents, followed by proper decontamination procedures, can reduce or eliminate the hazards caused by these agents.

In the event that you are assigned to supervise or manage a field water supply point, you will be responsible for the detection and removal of CBR contaminants. The supervisor of a water point crew must be sure the crew is trained in the identification of CBR contamination by recognizing the various indications of CBR contamination of their water point as follows:

- An unusual taste or odor
- Dead fish and animals in unusually large numbers
- A sudden drop in normal pH values or a pH value of less than 6.0
- High readings on radiac equipment
- Personnel developing fevers, diarrhea, cramps, vomiting, and so forth
- Burning sensation of skin, eyes, and nose
- Runny eyes, nose, and mouth

If CBR contamination of a water source is suspected, have your crew don appropriate protective clothing and equipment before they start tests for determining the type and extent of the problem. For example, water contaminated with a nerve agent should not be allowed to come in contact with the skin nor should the vapors be inhaled; therefore, wearing a protective mask and gloves is necessary before checking for nerve agent contamination.

4.5.1 Chemical Contamination

Chemical agents are classified in seven categories: nerve, blister, blood, choking, vomiting, irritant, and incapacitating. The nerve agents, blister agents, and agents containing cyanide are most dangerous because they are highly poisonous. Some agents are soluble in water and either are slow to decompose in solution or remain poisonous after decomposition. Water supplies are likely to become contaminated as an incidental result of widespread chemical attack rather than as a result of direct attack on the water supply. Chemical agents are colorless, odorless, and tasteless. The first indication of their use could be the appearance of casualties. The chemicals affect people, animals, and plants but leave homes, factories, and other facilities untouched.

4.5.2 Biological Contamination

Water is a carrier of many organisms that cause intestinal disease. An epidemic of one of these diseases among troops can be more devastating than enemy action and can cause great damage to morale as well as health. A heavy responsibility thus rests upon the Utilitiesman, and vigilance over water purification equipment and procedures should never be relaxed. It is emphasized that water treatment methods to be used when certain chlorine-resistant organisms are encountered should be prescribed by a representative of the medical officer. The representative will recognize or anticipate the presence of these organisms and recommend such additional chlorination or other treatment methods as may be necessary.

A waterborne disease rarely produces symptoms in its victim immediately after the victim has consumed the contaminated water. A period of time, known as the incubation period, must pass before the victim comes down with the disease. During this incubation period, the disease organisms are growing and multiplying. Absence of symptoms for several days after untreated water has been consumed is therefore no guarantee that the water is safe. Also, absence of disease among the local inhabitants is no assurance of safety because they may have developed immunity.

Types of waterborne diseases include typhoid fever, paratyphoid fever, cholera, bacillary dysentery, amebic dysentery, common diarrhea, infectious hepatitis, and schistosomiasis. Biological water contamination causes little, if any, change in the chemical and physical characteristics of water, such as pH, alkalinity, and color. This makes it difficult to test a water source for contamination. However, when the water has an excessive chlorine demand, it should be viewed with concern. The excessive demand could be due to microorganisms. Other indicators are as follows: aircraft dropping or spraying of unidentified material; unusual types of bombs, particularly one which bursts with little or no blast; smoke and mist of an unknown substance: unusual increase in insects, such as mosquitoes, ticks, or fleas; increased occurrence of sick or dead animals; increased incidents of troop sickness and disease; or intelligence reports indicating enemy use of a biological contaminant.

4.5.3 Radiological Contamination

Although nuclear weapons have been used in combat, there are no reliable data as to the effect of nuclear explosions on field water supplies. However, available fallout data leave no doubt that contamination of water supplies by this means must be considered. Since radiation is not detectable by human senses, you should use instruments and laboratory tests to determine its presence.

A nuclear attack over or near a source of water supply will probably cause its contamination with radioactive materials. A nuclear explosion could cause contamination by any of the following (listed in the decreasing order of importance to the water point operator):

- Fallout of fission products
- Induced activity in the water and surrounding soil
- Blow-in or wash-in of radioactive dust
- Fallout of unfissioned uranium or plutonium

The magnitude of contamination depends upon the yield of the weapon, the location of the detonation with respect to the water source, and whether it is air, surface, or subsurface burst.

4.6.0 Treatment of CBR Contamination

If chemical, biological, or radiological agents, or any combination of these are used, the field water supply will inevitably be involved. It is impossible to foresee what type of agent will be used, but effective security measures can decrease and counteract the hazards of all three types of agents.

Effective security involves prompt and accurate detection. Contamination by chemical agents usually, although not always, leaves significant signs that should arouse immediate suspicion. Such signs include a drastic lowering of the pH value of the water, characteristic odors and tastes, and dead fish. If chemical contamination is suspected, the medical officer will have medical personnel test the water with the Chemical Agent Water Testing Kit M272. A complete technical and operational breakdown of this kit can be found in Army TM-3-6665-319-10.

Advice and guidance from the medical officer must be sought and followed carefully when water contaminated by CBR agents must be treated and used. Specialized training of personnel in the latest means of detection and treatment will aid water supply technicians in safeguarding the lives and health of personnel.

If contamination of any type, by CBR agents or poisonous industrial wastes, is detected, every effort must be made to find an uncontaminated water source before considering treating and using water known to be contaminated.

When an uncontaminated water source is not available for use, permission must be secured from proper medical authority to proceed with treatment of the contaminated water. Water is considered CONTAMINATED AND UNSAFE for treating if one or more of the following results are obtained from competent testing in *Table 5-6*.

Table 5-6 — Presence of Contaminates in Water Test.

Test	Result
Arsenic test	Positive
Mustard test	Positive
pH test	pH below 6.0
Chlorine demand test	Positive
Nerve agent test	Positive
Taste and odor test	Positive

Water is considered safe for treatment by the usual methods if the pH is above 6.0 and all other contamination tests are negative.

When contamination by a CBR (chemical, biological, and radiological) agent has been determined to be present in your water source, the Reverse Osmosis Water Purification Unit (ROWPU) may be used.

The ROWPU will successfully remove 99 percent of CBR contamination from a water source. A post-treatment system in conjunction with the ROWPU will remove a total of 99.9 percent of CBR contamination.

4.6.1 Post Treatment

The 600-gph ROWPU post-treatment system consists of two CBR cylinders. One cylinder is for nuclear and the other is for chemical. The types of contamination present will determine what cylinder you should use. The CBR cylinder filters are capable of decontaminating water for up to 100 operating hours. The cylinder marked “nuclear” contains resin beads that absorb certain ions present on the nuclear battlefield. The cylinder marked “chemical” contains activated carbon that absorbs agents found on the chemical battlefield.

4.6.2 Nuclear Agent Removal

The ROWPU removes the majority of ions without post treatment. The reverse osmosis (RO) removal characteristics for nuclear warfare agents are as follows:

- 95.5% of iodine, leaving the nuclear cylinder to remove 4.5%
- 99.7% of strontium, leaving the nuclear cylinder to remove 0.2%
- 98% of cesium, leaving the nuclear cylinder to remove 1.2%

4.6.3 Chemical Agent Removal

The ROWPU also removes large amounts of chemical agents . Removal characteristics for various chemical warfare agents are as follows:

- GB-99.1%, leaving the chemical cylinder to remove 0.7%
- VX-99.9%, leaving the chemical cylinder to remove 0.1%
- BZ-99.9%, leaving the chemical cylinder to remove 0.1%
- GD-99.7%, leaving the chemical cylinder to remove 0.3%

4.6.4 Biological Agent Removal

The ROWPU also removes biological agents from a water source. Reverse osmosis removal characteristics for various chemical agents do not exist. Any biological agent that is not removed by the ROWPU will be eliminated by the chlorine residual maintained in the product water.

Test your Knowledge (Select the Correct Response)

3. What is the purpose of a jar test?

   A. To aid in the removal of turbidity
   B. To indicate what chemical is necessary for coagulation
   C. To determine whether the water is turbid
   D. To provide sedimentation of the contents in the jar

5.0.0 WATER TREATMENT EQUIPMENT

The Utilitiesman may be called upon to select and set up various types of field water treatment equipment. You must be familiar with the theory of operation, the capabilities, the installation considerations, and the maintenance requirements of this equipment. This section covers four types of water treatment equipment. They are distillation, reverse osmosis, filtration, and disinfection units.

5.1.0 Distillation

In areas where a satisfactory freshwater source cannot be located and existing water treatment facilities are not usable, the distillation process can be used to obtain fresh drinking water from brackish water, seawater, or water containing excessive amounts of dissolved solids. Distillation is effective for removing radioactive contaminants from water. Since the output of distillation equipment is limited and the process is expensive, its use is restricted to situations in which no other process is adequate. Continuous flow or batch type of water purification equipment is used whenever possible.

5.1.1 Theory of Operation

Distillation consists of heating water to form steam, separating the steam from the remaining water, and then cooling the steam so it becomes water again (*Figure 5-10*). As the water is heated to form steam or water vapor and the vapor is separated and then cooled, solids dissolved in the water do not vaporize but remain behind in the raw water. A large amount of heat that is not evidenced as a rise in temperature is required to change (vaporize) boiling water into steam. The process whereby latent heat is removed and steam becomes water is called condensation.

Figure 5-10 — Distillation in its simplest form.

Heat flows through the bottom of the evaporator, enters the water, and changes the water to steam. The steam is condensed in the condenser, its latent heat of vaporization being transferred to the water surrounding the tubes. A portion of the cooling water that has picked up heat in passing through the condenser is used as feed water for the evaporator. All dissolved solids remain in the equipment, and noncondensable gases are vented to the air so the resulting distillate is almost pure. Thus, the distillation process is useful in producing water that is extremely high in purity and low in total solids.

Despite this high degree of purity, all distilled water must be disinfected before being consumed because of the possibility of recontamination during handling, In thermocompression distillation, the latent heat of vaporization of steam is again used to produce additional steam. The pressure and temperature of the steam generated in the evaporator are raised by compressing the steam. The compressed steam passes to the condenser section, where it condenses, giving up its latent heat and causing more steam to form in the evaporator. This steam is then compressed and the cycle repeated. The use of combination evaporator-condenser with a steam compressor creates a closed heat cycle, permitting the continued reuse of the latent heat of vaporization. The compressor is driven by a gasoline or diesel water-cooled engine.

Figure 5-11 shows the operation of a simple thermocompression distillation unit. Cold raw water flows through heat exchangers, where it is heated almost to boiling by the outgoing streams of distillate and brine and by water from the engine that drives the compressor. The hot raw water flows into the evaporator-condenser and is changed to steam by the steam condensing in the tubes. This involves the transfer of latent heat. The steam in the evaporator is drawn into the compressor, where it is compressed and its temperature is raised (from 212°F to 222°F). The compressed steam flows back through the coils in the evaporator-condenser, where it transfers its latent heat through the walls of the coil into the water in the evaporator section. This transfer of latent heat causes the steam to condense in the coils and changes the water in the evaporator into steam. This cycle will continue as long as the compressor runs.

Figure 5-11 — Flow diagram-thermocompression distillation.

5.1.2 Installation

At permanent naval activities, the installation of distillation equipment will be designed by engineers, and improvements to the system can be made over a long period of time. In the tactical field environment, it will be the Utilitiesman supervisor who must consider various factors for the installation of distillation equipment. These factors are as follows:

- Potable water demand
- Site location
- Site drainage
- Security
- Fire protection

The demand for potable water will determine the number of distillation units, the need for storage facilities, operating hours, and so forth. You must determine the population you will be serving. Keep in mind that your water point may supply many units in an area, not just your organization.

The site location for distillation equipment must be upstream of any source of contamination. You must consider ocean currents that may change with wind direction, weather conditions, the season of the year, or tidal action. It is not efficient use of personnel or equipment if you have to relocate because the wind changed direction.

The site must also be relatively flat with a gradual slope toward the ocean. You also must allow for maximum tidal action. In many areas, the tide may rise and fall several feet, depending on the season of the year. Build low platforms to keep your equipment out of the sand and to allow air to circulate underneath tanks to prevent rot. These platforms also prevent punctures of the storage tanks by sharp objects and provide a stable working area for operating personnel.

The importance of providing adequate drainage at any water point cannot be overemphasized. Wastewater from filters, leakage from tanks, and spillage from distribution points can render a water point inoperable as well as create an unsanitary condition.

Your water point may or may not be located in the vicinity of friendly forces. Denying the enemy information about your water point by using overhead concealment and camouflage may be as necessary as guarding against ground attacks and sabotage with a defensive plan. Any adverse effect, from thirst to disease, that the enemy can have on a water point will affect the well-being of the force using it. It will be considered in the plans of the enemy.

Distillation equipment cannot produce water quickly enough to be used for fire protection. Do not permit your treated water to be used for this purpose except in extreme emergencies. Raw water should be used whenever possible.

5.2.0 Reverse Osmosis

The use of reverse osmosis water purification equipment by the military has produced potable water from the sources available in a combat field environment. The reverse osmosis water purification unit (ROWPU) is capable of treating freshwater, brackish water, and seawater. Additionally, the unit is capable of treating water contaminated with chemical, biological, and radiological warfare agents. When using the unit to treat water contaminated by CBR agents, you must use the equipment in conjunction with auxiliary ion exchange and carbon adsorption units.

The ROWPU used by the NCF is capable of producing 600 gph of product water from freshwater sources and 400 gph of product water from seawater at 70°F. The rate of water production in the ROWPU depends upon the operating pressure, normally 350 to 550 psig for freshwater and 750 to 950 psig for seawater. Temperature affects the rate of flow. Cold water decreases the flow, while warm water increases the flow.

NOTE

Maximum operating water temperature of the ROWPU feed water is 120°F. Water temperatures above this figure may damage the membranes within the reverse osmosis modules.

Reverse osmosis (RO) is a purification process in which filtered water is pumped through a semi-permeable membrane under great pressure. The membrane allows product water to pass through while rejecting impurities, both dissolved and suspended.

You must use an extremely high pressure for a useful volume of water to pass through a unit membrane. The RO process is shown in *Figure 5-12*. Reverse osmosis may appear to be nothing more than a filtering process, but there are distinct differences. In filtration, the entire liquid stream flows through the porous filter medium and no chemical changes take place between the feed and the filtrate. In RO, the feed flows parallel to the semi-permeable membrane with a fraction of it passing through a given membrane area; dissolved ionic and organic substances are rejected by the membrane and, in this case, drained off as a brine.

The following explanation is the flow process through the 600 gph ROWPU. As you read through this section, refer to the flow diagram in *Figure 5-13*. Water is delivered to the ROWPU through the raw water pump. Upon entering the unit, it goes through the multimedia filter. This filter removes small and large solids. From the multimedia filter, the water is picked up by the booster pump that pushes the water through the cartridge filter. The cartridge filter takes out suspended solids that passed through the multimedia filter. From the cartridge filter, the water is picked up by the RO pump that pushes the water under high pressure through the pulse dampener and into the RO elements. The RO elements remove dissolved minerals and other bacteria that passed through the filters. The product water leaving the last element receives enough chlorine to kill any remaining bacteria.

Figure 5-12 — Reverse osmosis process.

Figure 5-13 — Water flow through the 600 gph ROWPU.

5.3.0 Filtration

Filtration consists of passing the water through some porous material to remove the suspended impurities. Filtration is one of the oldest and simplest procedures known to man for removing suspended matter from water and other fluids.

It is a common misconception that filtration removes suspended solids by a simple straining process, whereby particles too large to pass through openings in the filter media are retained on the media. The mechanism involved in removing suspended solids by filtration is very complex. While straining is important at the filter media surface, most solid removal in deep granular filters occurs within the filter bed. Flocculation and sedimentation in the pore spaces between filter media particles are important removal mechanisms that are also used for the absorption of particles onto the filter media surfaces. Additional straining between media particles within the filter also contributes to overall solids removal.

The simplest form of water filter is the sand filter. This filter resembles a small reservoir, whose bottom is a bed of filter sand that rests on a bed of well-graded aggregate, with the largest size aggregate being at the bottom. An underdrain system of tile or brick is provided beneath the gravel to collect the water from the filter area. The underdrain system consists of a header or main conduit extending across the filter bed. Means are provided for regulating the flow of water out of the filter through this header and also for controlling the rate of flow onto the filter. This allows the filter to be operated at controlled rates that should not exceed 3.0 gph per square foot of filter area. An average filter bed consists of about 12 to 20 inches of gravel and 20 to 40 inches of sand. The depth of water over the sand bed varies from 3 to 5 feet.

The cartridge filter basically comes in two types of cartridge filtration: (1) depth filtration, where solid particles become trapped within the filter medium; and (2) surface filtration, where solid particles form a cake on the surface of the filter medium. Wound fiber cartridges function primarily as depth filters are the standard cartridge used in the 600 gph ROWPU. (See cartridge filter in *Figure 5-14, Frame 1*) The most effective filtration system ever devised and one of the most effective portable systems in existence is the diatomite filter unit.

In the diatomite filter (*Figure 5-14, Frame 2*), water is passed through a layer of diatomaceous silica (also called diatomaceous earth). It consists of skeletal remains of minute algae (diatoms) found in marine deposits that have lifted above sea level.

The diatomite filter accomplishes highly efficient filtration. Properly operated diatomite filters are capable of removing amoebic cysts, the cercariae

Figure 5-14 — Types of cartridge filters.

of schistosomes, and approximately 90 percent of the bacteria from coagulated and settled water. They also produce water with less than one unit of turbidity.

Before filtering, water is normally pretreated by passing it through sedimentation basins or holding tanks. This process removes heavier suspended solids that may cause rapid clogging of the filter. This water is brought onto the filters as the next step in the purification process. This water contains very finely divided, suspended matter, such as minute particles of floc, clay, and mud that have not settled, and bacteria and microscopic organisms that have not been removed by sedimentation. The purpose of the filter is to remove this suspended matter and give the water a clear, sparkling, and attractive appearance.

There are basically three types of filters. These are slow sand filters, rapid sand filters, and pressure filters.

Slow sand filters contain fine-grain sand and have low filtration rates. They are usually used when coagulation is not included in the treatment process. Their capacity is about 2 to 10 million gallons per day (mgd) per acre of filter surface. Use of slow sand filters has been practically discontinued because of their high cost per unit of capacity and the labor required to clean them. Rapid sand filters are now universally used in modern water treatment plants. There are two types: gravity and pressure. Gravity filters (*Figure 5-15, Frame 1*) are essentially open-top, rectangular concrete boxes about 10 feet deep. An underdrain system at the bottom is covered by gravel, which, in turn, supports a 24- to 30-inch layer of fine filter sand (*Figure 5-15, Frame 2*). Gravity filters are usually designed to filter about 2 gpm per square foot of filter-bed area. However, in an emergency, up to 4 gpm per square foot can be obtained if prior treatment by flocculation and sedimentation produces very low turbidity and pre-chlorination and post-chlorination or both are effectively disinfecting the water. Approval must be obtained from the major command to operate filters at rates in excess of 2 gpm per square foot. Pressure filters (*Figure 5-16*) have the filter bed enclosed in a pressure vessel. Water is either pumped into the vessel and forced through the filter or is drawn into the vessel and through the filter by a pump. The diatomite filter is classified as a pressure filter.

Figure 9-15 — Types of gravity filters.

Figure 5-16 — Pressure-type water filter.

5.4.1 Disinfection

Besides coagulation, sedimentation, and filtration, water must undergo an additional treatment step: disinfection. This is necessary because no combination of the other three steps can be relied upon to remove all disease-producing organisms from water and because there is a danger of recontamination during handling before consumption. Residual disinfection using chlorination is the final step in all water treatment processes (including distillation). Under emergency or field conditions, water may be disinfected with iodine or by boiling.

The most satisfactory means of water disinfection and provision of a residual is by use of a chemical disinfectant. The efficiency of the disinfection process is dependent upon numerous factors. These factors include the chemical used, the contact time, the type and concentration of microorganisms, the pH and temperature of the water, the presence of interfering substances, and the degree of protection afforded organisms from the disinfecting solution by materials in which they are imbedded. Various concentrations of disinfectant are required, depending upon the local environmental conditions and the amount of particle removal effected.

Chlorine is the most commonly used chemical for disinfection of water. It is used in field water supply in the form of calcium hypochlorite, a standard item in the supply system (commercially known as HTH powder). When the calcium hypochlorite is dissolved, the chlorine goes into solution and a calcium carbonate sludge settles out. The chlorine is present in the solution as hypochlorous acid or hypochlorite ion (depending on the pH). Both forms are powerful oxidizing substances. The chlorine available in either form rapidly oxidizes the organic and inorganic matter, including the bacteria in the water. In this reaction, the chlorine is converted to chloride and is no longer available as a disinfectant. The organic matter, along with material such as iron and manganese, consumes the chlorine. The use of chlorine makes it possible to introduce an accurately measured dosage to ensure the destruction of disease-producing organisms and provide a readily measured residual to safeguard against recontamination during further handling.

Chlorine dosage is the amount of chlorine added to water to satisfy the chlorine demand as well as to provide a residual after a specified time. The amount required to disinfect water varies with the organic content and pH value of the water, the temperature, the time of contact, and the chlorine residual required. The dosage is usually stated in terms of parts per million (ppm) or milligrams per liter (mg/l).

The chlorine demand of water is the difference between the quantity of chlorine applied in water treatment and the total available residual chlorine present at the end of a specified contact period. The chlorine demand is dependent upon the nature and the quantity of chlorine-consuming agents present and the pH value and temperature of the water. (High pH and low temperatures retard disinfection by chlorination.) For comparative purposes, it is imperative that all test conditions be stated. The smallest amount of residual chlorine considered to be significant is 0.1 ppm. The relationship of the demand to the length of the contact period is discussed below.

Some of the chlorine-consuming agents in the water are nonpathogenic (nondisease-causing organisms), but this bears no relationship to the fact that they contribute to the total chlorine demand of the water. Navy policy requires that for field water supplies, the chlorine demand must be satisfied and chlorine residual must be present.

Residual chlorine is the amount of unreacted chlorine remaining at a specified time after the chlorine compound is added. Chlorine in aqueous solution is highly unstable. It may change quantitatively and qualitatively under numerous conditions, including the presence of other elements or compounds. The total residual chlorine in the water can be chemically divided into several types:

- Total available residual chlorine is the sum of the free available chlorine and the combined available chlorine.
- Free available chlorine refers to hypochlorous acid and hypochlorite ion present in water. These are the most effective disinfection forms of chlorine. The free available chlorine is a rapid-acting type, important because it can be relied upon to destroy bacteria relatively quickly, and thus is active during the period immediately following chlorination. The relative amount of each present in the water is dependent upon the pH value of the water. It is important to remember that when the pH is raised, the quantity of free available chlorine required to kill the same number of microorganisms increases. With decreasing temperature, the same situation of increasing dosage to maintain the same kill is encountered. If the contact time is varied, then the dosage applied must also be changed. For example, to shorten the contact time, the dosage has to be increased.
- Combined available chlorine results from the presence of ammonia or organic nitrogen that will react to form simple chloramines. Thus, the term combined available chlorine arises from the fact that the chlorine has combined with another substance. Chloramines are a slower-acting and less active form of disinfectant; therefore, a much higher concentration than that of free available chlorine is needed to produce the same germ-destroying effect. The specific chloramines present are also a function of pH.

Chlorine demand in most water is likely to be largely satisfied 10 minutes after chlorine is added. After the first 10 minutes of chlorination, disinfection continues but at a diminishing rate. A standard period of 30 minutes' contact time is used to assure that highly resistant or high disease-producing organisms have been destroyed, providing a high enough dosage has been applied.

The efficiency of the chemical disinfection process is dependent upon numerous factors. They include the type and concentration of microorganisms, the pH and temperature of the water, the presence of interfering substances, and whether or not the organisms are protected from the disinfection solution by being embedded in tissue cells, clumps of tissue cells, or other material; therefore, various concentrations of disinfectants are required. Minimum concentrations of disinfectants are prescribed below. Higher concentrations may frequently be prescribed by the medical officer on the basis of his knowledge of endemic disease or local environmental conditions.

Seabee-operated mobile and portable water treatment units use coagulation and filtration as a part of the treatment process. They are capable of a high degree of removal of particulate material. When those units are used, sufficient chlorine will be added to the water, preferably before coagulation, so the residual in the finished water after 30 minutes of contact will be at least as much as that indicated by the following amounts in *Table 5-7*.

Table 5-7 — 30 Minute Free Chlorine Test.

pH	Residuals in mg/l
5	.075
6	.075
7	1.00
8	3.00
9	5.00
10	5.00

If adequate provisions are not made for accurate and frequent measurement of pH, 5.00 mg/l must be used. The following guidelines were used in developing the above table:

- The water to be treated is natural surface or groundwater of average composition and not grossly or deliberately contaminated.
- Water temperature is above the freezing point.
- Treatment consists of coagulation, sedimentation, and filtration through diatomaceous earth. Water plant operators are well trained and dependable.
- The prescribed concentrations of free chlorine should provide a reasonable margin of safety for all bacteria and viruses pathogenic to man. Parasitic ova (eggs) would have been removed in the coagulation and filtration steps of the treatment process.

5.5.0 Emergency Treatment Methods

Emergency treatment methods using water sterilizing bags, canteens, and other water containers do not provide for removal of impurities by coagulation and filtration. The entire reliance for rendering the water safe for consumption is placed on the disinfection process. Sufficient chlorine is added to the water so the residual, after 30 minutes of contact, will be at least 5 ppm of total chlorine. Under certain conditions, such as the presence of highly resistant disease-producing microorganisms or adverse environmental conditions, the medical officer will designate such higher residuals as may be necessary.

Boiling is a quick means of disinfecting small quantities of water by individuals in the field. It is likely that all bacteria that produce diseases in man are killed by pasteurization temperatures. There are some resistant organisms, principally viruses (such as infectious hepatitis), for which water must be boiled to achieve inactivation. A practical minimum standard for altitudes from sea level to 25,000 feet is to bring the water to a rolling boil for 15 seconds. Longer boiling times may be prescribed by the medical officer on the basis of evidence that the minimum is not inactivating all pathogenic microorganisms. Upon cooling, the boiled water should be kept in a covered, uncontaminated container. Boiling is obviously a difficult way to disinfect large quantities of water.

Breakpoint chlorination is the application of chlorine to produce a residual of free available chlorine with no combined chlorine present. As chlorine is added, the total residual increases gradually after the initial demand of the water has been satisfied. At some residual concentration, depending on the water treated, free available chlorine reacts with the remaining oxidizable substances (including combined chlorine), and the residual drops sharply. When all combined chlorine has been oxidized by reaction with free available chlorine, the residual, now consisting only of free available chlorine, rises again and continues to increase in direct proportion to increased dosage. The point at which the residual again begins to increase is the breakpoint.

Figure 5-17 shows four typical breakpoint chlorination curves. Note that the curve rises at almost a 45-degree angle after the breakpoint is reached. Reactions are most rapid at pH from 6.5 to 8.5 and with increasing temperatures.

Curve 1 shows a typical breakpoint for water containing a considerable amount of ammonia. During the initial upward rise, chloramines are first formed. The curve rises until sufficient free available chlorine is developed to react with chloramine; then it falls until a point where all ammonia compounds have been oxidized.

With less organic matter in the water, as in curves 2 and 3, free available chlorine is formed sooner, destroying chloramines formed at the early stage. This results in lower combined chlorine residuals and flatter curves before breakpoint.

With practically no organic matter, curve 4 shows the chloramines are neutralized at an early stage by the upswing of the curve.

For some waters containing complex organic compounds, several intermediate breakpoints occur.

Advantages of breakpoint chlorination are high bactericidal efficiency, long-lasting residuals, and low odor and taste characteristics. It can be used only if detention periods are long enough to develop free available chlorine residual. This varies with the organic content of water. In some cases, the treated water must be open to the air to permit escape of chloroorganic gases formed.

Figure 5-17 — Breakpoint chlorination curves.

Tests for ammonia nitrogen will assist in determining the breakpoint. In practice, 10 to 25 times as much chlorine as ammonia nitrogen content may be needed to reach the breakpoint. Breakpoint chlorination, before instead of after filtration, has been found desirable. In surface water supplies with widely varying ammonia nitrogen content, the breakpoint chlorination should not be used unless trained assistance is available to make frequent tests for the breakpoint. With such water quality, the breakpoint curve can change radically in a short time.

Superchlorination is the application of more chlorine than needed for the chlorine residual essential to marginal chlorination. The surplus, which is used to control odors and tastes, is later removed by dechlorination. This method is particularly valuable in surface waters with variable ammonia and organic content. Sulfur dioxide reacts with chlorine to form acids that are neutralized by the natural alkalinity of the water. Sulfur dioxide is fed by equipment similar to that used for chlorine feeding. Activated carbon absorbs the excess chlorine, while aeration removes it by dissipating it to the atmosphere.

5.5.1 Water Purification System (3000D)

The 3000D Water Purification System (*Figure 5-18*), was developed to provide a fully self-contained water purification unit for purifying turbid and bacteria-polluted water. The design of the unit allows for increased efficiency, mobility, and cost effectiveness. The unit provides trouble-flee water purification at the rate of 3,000 gph.

There are four modular components located within a single frame: diesel-powered pump, chlorinator control, filter, and supplies to produce 20,000 gallons of potable water. Subsequent water processing requires only diatamatious earth, chlorine, and diesel fuel. Each module may be operated independently in or out of the frame by one person.

Figure 5-18 — 3000D water purification system.

Test your Knowledge (Select the Correct Response)

4. Water produced by distillation equipment should NOT be used for what purpose?

   A. Fire protection
   B. Vehicle washing
   C. Galley scrubbing
   D. Personal cleanliness

Summary

Water is the most important substance on earth. Everybody requires water to stay alive, and you are responsible to provide it to them. Vehicles need it to stay in good operating order. Water is essential for cleanliness and cooking. You, the UT, have learned how to develop the water for field operations, treat it, filter it, and previously, pipe it to the customer. This chapter enabled you to become a better UT and provide water to others that need it.

Review Questions (Select the Correct Response)

1. What term is used to describe a water source developed for military use?

   A. Water source
   B. Water point
   C. Water well
   D. Water outlet

2. Compute the quantity of water in a lake that is 100 feet long, 20 feet wide, has an average depth of 6 feet, and no run off.

   A. 30,000 gallons
   B. 60,000 gallons
   C. 90,000 gallons
   D. 120,000 gallons

3. Which of the following types of sand provides the greatest rate of flow during drawdown?

   A. Fine sand with grains irregular in size
   B. Fine sand with grains nearly uniform in size
   C. Coarse sand with grains irregular in size
   D. Coarse sand with grains nearly uniform in size

4. The pump and power unit used for testing a well should be capable of continuous operation for a minimum of how many hours?

   A. 96
   B. 72
   C. 48
   D. 24

5. What are the two classifications of water impurities?

   A. Suspended or bacteria
   B. Suspended or dissolved
   C. Dissolved or silt
   D. Dissolved or bacteria

6. What data, if any, should you study to determine the variation in reliability that may be expected at a water source?

   A. Geological
   B. Hydrological
   C. Bacteriological
   D. None

7. A temporary water source should not be converted into a permanent water source until after what activity has taken place?

A. A title search for water rights
B. An area search for a source requiring less development
C. An impurities examination by the medical officer
D. An inspection by the public works officer for additional free-flowing springs

8. For a normal field water supply, what type of water source is the most accessible?

A. Well
B. Spring
C. Subsurface
D. Surface

9. In a swiftly flowing stream, what type of dam can be constructed to protect an intake screen without impounding the water?

A. Wing only
B. Baffle only
C. Wing or baffle
D. Ripple or wing

10. The quality of water from a muddy stream can be improved in which of the following ways?

A. By sinking shallow wells
B. By digging intake galleries
C. By filling unneeded trenches
D. By digging outtake galleries

11. Moisture is held beneath the surface of the earth in what total number of zones?

A. Four
B. Three
C. Two
D. One

12. In a driven well, the sections of well pipe are delivered in lengths of what size?

A. 20 feet
B. 15 feet
C. 10 feet
D. 5 feet

13. When developed properly, springs yielding a minimum of how many gallons per minute can be used as a source of field water?

A. 20
B. 15
C. 10
D. 5

14. There is a total of how many classifications of wells?

A. Nine
B. Seven
C. Five
D. Three

15. A well that is dug is usually 3 feet in diameter or more and within what depth range?

A. 25 feet to 50 feet
B. 20 feet to 40 feet
C. 15 feet to 40 feet
D. 10 feet to 30 feet

16. A well can normally be bored within what maximum depth without fear of a cave-in?

A. 60 feet
B. 50 feet
C. 40 feet
D. 30 feet

17. When jetting a well, you turn the jet or frill slowly for what purpose?

A. To ensure the hole is straight
B. To assist in sinking the casing
C. To remove mud and sand
D. To extract muddy water

18. When a well is driven, the drive points are within what size range?

A. 1 inch to 3 inches
B. 2 1/4 inches to 3 inches
C. 3 inches to 4 inches
D. 1 1/4 inches to 2 inches

19. To guard against subsurface contamination, you should locate rainwater catchment areas at what minimum distance from possible sources of contamination?

A. 100 feet
B. 75 feet
C. 50 feet
D. 25 feet

20. What minimum treatment is required for collected rainwater that is to be used as a water source?

A. Filtration only
B. Disinfection only
C. Filtration and disinfection
D. Aeration and filtration

21. A total of how many cubic feet of snow is required to produce 1 cubic foot of water?

A. 9
B. 7
C. 5
D. 3

22. Which of the following chemicals can be used to prevent the formation of algae in raw water supply points?

A. Chlorine
B. Copper sulfate
C. Activated carbon
D. Each of the above

23. What term accurately describes a muddy or unclear condition of water caused by sand, clay, or organic matter?

A. Suspension
B. Turbidity
C. Backwashing
D. Coagulation

24. To treat 1,000 gallons of water, you should use approximately how many ounces of activated carbon?

A. 1,000
B. 100
C. 10
D. 1

25. When you are using copper sulfate to treat a lake, concentrations of organisms should never exceed how many parts per million to protect the lives of fish?

A. 5
B. 3
C. 2
D. 1

26. You should reduce the water treatment rate when the outside temperature reaches what level?

A. 45°F
B. 32°F
C. 20° F
D. 0°F

27. The total concentration of manganese in potable water should not exceed how many parts per million?

A. 0.1
B. 0.3
C. 0.5
D. 0.7

28. The ion exchange unit removes which of the following undesirable properties of water?

A. Asbestos and chemicals
B. Chemicals and radioactive particles
C. Manganese and lead
D. Hexavalent chromium and fluoride

29. Dissolved gases can be removed from a water supply by what means?

A. Aeration
B. Chlorination
C. Coagulation
D. Ion exchange

30. A water source with a pH value less than what number is an indication of possible CBR contamination?

A. 6.0
B. 5.0
C. 3.5
D. 1.5

31. What water test kit does medical use to check a water source for chemical contamination?

A. M678
B. M474
C. M272
D. M222

32. What is the name of the process whereby latent heat is removed and steam becomes water?

A. Evaporation
B. Distillation
C. Vaporization
D. Condensation

33. The compressor in a thermal compression distillation unit raises the temperature of the steam from 212°F to what temperature?

A. 229°F
B. 226°F
C. 222°F
D. 220°F

34. What type of treatment is used in residual disinfection as the final step in the water treatment process?

A. Coagulation
B. Chlorination
C. Activated carbon
D. Soda ash

35. What minimum amount of residual chlorine is considered significant?

A. 0.4 ppm
B. 0.3 ppm
C. 0.2 ppm
D. 0.1 ppm

36. What standard period of contact time is required for disinfection purposes to kill disease-producing organisms?

A. 40 minutes
B. 30 minutes
C. 20 minutes
D. 10 minutes

Trade Terms Introduced In this Chapter

Water table	The level at which the groundwater pressure is equal to atmospheric pressure; may be conveniently visualized as the 'surface' of the groundwater in a given vicinity
static water level	The water level of the water table before any pumping occurs
Turbidity	Muddy or unclear water caused by particles of sand, clay, or organic matter being held in suspension
Floc	A process in which chemicals are added to the water to bring the nonsettling particles together in larger, heavier masses of solids
Aeration	The process by which air is circulated through, mixed with, or dissolved in a liquid or substance

Additional Resources and References

This chapter is intended to present thorough resources for task training. The following reference works are suggested for further study. This is optional material for continued education rather than for task training.

OSHA Regulations (Standards – 29 CFR)

Naval Construction Force Manual, *NAVFAC P-315*, Naval Facilities Engineering Command, Washington, D.C., 1985.

Facilities Planning Guide, NAVFAC P-437, Volumes 1 and 2, Naval Facilities Engineering Command, Alexandria, VA, 1982.

Maintenance and Operation of Water Supply , Treatment and Distribution Systems, NAVFACMO - 210 , Naval Facilities Engineering Command, Alexandria, VA, 1984.

Fluid Power, NAVEDTRA 12964, Naval Education and Training Professional Development and Technology Center, Pensacola, FL, 1994.

Water Purification Unit , Reverse Osmosis 600 – GPH Trailer Mounted, TM-5-4610-215-24, Department of the Army, Washington, DC, 1983.

Water Supply Point Equipment and Operation, FM-10-52-1, Headquarters Department of the Army, Washington, DC, 1991.

Plumbing Manual, Volume II, NTTC Course 140-B, NAVFAC P-376, NAVFAC Technical Training Center, Navy Public Works Center, Norfolk, VA, 1965.

Safety and Health Requirements Manual, EM-385-1-1, Department of the Army, U.S. Army Corps of Engineers, Washington, DC, 1992.

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Chapter 6

Sewage Treatment and Disposal

Topics

To hear audio, click on the box.

Overview

Sewage is the wastewater of community life. In composition it includes dissolved and suspended organic solids that are liable to become putrid and decay. Sewage contains countless numbers of living organisms, bacteria, and other microorganisms whose life activities cause the process of decomposition. When decay proceeds under anaerobic conditions (an absence of dissolved oxygen), offensive conditions result and odors and unsightly appearances are produced. When decay proceeds under aerobic conditions (a presence of dissolved oxygen), offensive conditions do not result and the process is accelerated.

It is important to remove sewage and other wastes to an area away from the center of activity. It is only by such practices that the environment can be maintained in an acceptable and safe condition. Among the waste products of life are the disease-producing (pathogenic) bacteria and viruses that can be readily transferred by sewage from sick individuals to well ones. Procedures for proper disposal of sewage are necessary to protect the health and comfort of the people and to maintain the cleanliness of the environment.

The degree of treatment used for sewage depends on two main considerations: (1) health protection for individuals in the command and community and (2) prevention of water pollution. State and local authorities with statutory authority in pollution control have established standards of purity that are necessary to prevent pollution of natural waters. Accordingly, when a Navy installation discharges liquid waste into controlled waters, the standards set by state and local authorities must be maintained. As a Utilitiesman you may be involved in the installation, operation, and maintenance of systems designed to meet the above requirements. This chapter discusses the major sources of sewage along with sampling and testing procedures and monitoring of sewage disposal ***influents***. In addition to these subjects, septic tanks, cesspools, and leaching fields are also discussed.

Objectives

When you have completed this chapter, you will be able to do the following:

1. Identify the sources of raw sewage.
2. Identify the characteristics of sewage.
3. Describe the procedures associated with sewage sampling.
4. Describe the procedures associated with sewage testing.
5. Describe the procedures utilized for disposing and monitoring sewage effluents.
6. Describe the purpose of septic tanks, cesspools, and leaching fields.

Prerequisites

None.

This course map shows all of the chapters in Utilitiesman Advanced. The suggested training order begins at the bottom and proceeds up. Skill levels increase as you advance on the course map.

Air Conditioning and Refrigeration	↑	U T
Duct and Ventilation Systems		
Boilers		
Compressed Air Systems		
Sewage Treatment and Disposal		A D V A N C E D
Water Treatment and Purification		
Fire Protection Systems		
Interior Water Distribution and Interior Waste Systems		
Plumbing Planning and Estimating		
Contingency Support		

Features of this Manual

This manual has several features which make it easier to use online.

- Figure and table numbers in the text are italicized. The figure or table is either next to or below the text that refers to it.
- The first time a glossary term appears in the text, it is bold and italicized. When your cursor crosses over that word or phrase, a popup box displays with the appropriate definition.
- Audio and video clips are included in the text, with an italicized instruction telling you where to click to activate it.

- Review questions that apply to a section are listed under the Test Your Knowledge banner at the end of the section. Select the answer you choose. If the answer is correct, you will be taken to the next section heading. If the answer is incorrect, you will be taken to the area in the chapter where the information is for review. When you have completed your review, select anywhere in that area to return to the review question. Try to answer the question again.
- Review questions are included at the end of this chapter. Select the answer you choose. If the answer is correct, you will be taken to the next question. If the answer is incorrect, you will be taken to the area in the chapter where the information is for review. When you have completed your review, select anywhere in that area to return to the review question. Try to answer the question again.

1.0.0 SOURCES of RAW SEWAGE

The major sources of raw sewage are domestic sewage, industrial sewage, and storm water.

1.1.0 Domestic Sewage

Domestic sewage consists of waste from toilets, lavatories, urinals, bathtubs, showers, home laundries, and kitchens. It also includes similar wastes from medical dispensaries and hospitals.

1.2.0 Industrial Sewage

Depending upon the source, industrial sewage has characteristics that are different from domestic sewage. Some of these wastes are dangerous to plant operators as well as to the treatment plant and collection system. Industrial waste sources include, but are not limited to, laundry and dry-cleaning plants, metal-cleaning and plating processes, paint spray booths, aircraft and vehicle cleaning racks, boiler plants, photographic processing systems, and fire-fighting activities. Industrial waste systems commonly require pretreatment or a completely separate facility.

Industrial wastes can also be very high or low in pH because of acids and/or bases used in their processes. You may expect intense colors in wastes from painting areas. Grit, salt, and dirt levels may be high from vehicle wash racks.

Radioactive wastes must never be dumped into regular collection systems. They must be handled separately and, in most cases, very carefully.

Explosive or flammable liquids can often enter the system from fuel storage areas. These liquids also create a dangerous fire hazard in a sewage treatment plant.

1.3.0 Storm Water

Storm water should be excluded from the sewage collection system as much as possible. Heavy input of storm water can disturb the operation of a treatment plant by sending it too much water, a problem called hydraulic overloading.

This situation may force diverting or bypassing effluent from the treatment plant. Bypassing is normally a violation of National Pollutant Discharge Elimination System (NPDES) permits. These permits are controlled by the Environmental Protection Agency (EPA). Bypassing can result in releasing bacteria, heavy metals, and other dangerous contaminants into receiving waters. It is to be avoided whenever possible.

Very large paved or roofed areas should not be drained into the sanitary collection system. Maintenance personnel should prevent storm water infiltration as much as possible by ensuring manholes are sealed, pipes are not cracked or broken, and all leaking joints are repaired.

1.4.0 Source Quantity Variables

Each military installation has different wastewater flows depending upon the types or sizes of industrial activities. Normally, 80 to 120 gallons per day per permanent resident and 30 to 50 gallons per day per transient and community labor personnel can be used as a rough volume estimate for flow.

1.5.0 Patterns of Flow

The amount of wastewater a treatment plant receives fluctuates from hour to hour. Changing seasons also affect the pattern flow. Peak flow of domestic wastes normally reaches a plant just after breakfast and for several hours in the early evening. Industrial wastes may reach the plant during the industry's period of operation. If the industry has two or three shifts, flow will be more constant.

The size and topography of the area served by a treatment plant also affects the flow pattern. Small plants may have large differences between peak and low flow periods. Larger plants normally have more uniform rates of flow. The period of lowest flow is usually between 2400 and 0500 hours. Unusual flow patterns help operating personnel identify and correct abnormal surges in flow in the wastewater system.

2.0.0 CHARACTERISTICS of SEWAGE

Sewage is composed of many materials that are broken down into three general areas. These areas are the physical, chemical, and biological characteristics of wastewater. This section will aid you in identifying these various characteristics.

2.1.0 Wastewater Composition

The concentrations of most materials in wastewater are expressed in milligrams per liter (mg/l) and denote the strength of the wastewater. The higher the concentration, or mg/l, the higher the strength. *Table 6-1* lists the most important materials that compose wastewater.

Table 6-1 — Characteristics of Typical Wastewater Generated at Military Facilities.

Parameter	Weak	Medium	Strong
Total solids	330	700	1,200
Total volatile solids	240	420	810
Suspended solids	100	200	400
Total dissolved solids	230	500	800
Volatile suspended solids	70	130	220
Settleable solids*	2	4	6
Biochemical oxygen demand (5 day)	100	200	400
Total nitrogen as N	10	20	40
Ammonia nitrogen as N	4	10	20
Total phosphorus as P	6	10	20
Grease	50	100	150
Chemical oxygen demand	300	450	600
*All the above are measured in milligrams per liter (mg/l) except settleable solids, which are measured in milliliters per liter (ml/l).			

2.2.0 Physical Characteristics

The physical characteristics of wastewater include those items that can be detected using the physical senses. They are temperature, color, odor, and solids.

2.2.1 Temperature

The temperature of wastewater varies greatly, depending upon the type of operations being conducted at your installation. Wide variation in the wastewater temperature indicates heated or cooled discharges, often of substantial volume. They have any one of a number of sources. For example, decreased temperatures after a snowmelt or rainfall may indicate serious infiltration. Changes in wastewater temperatures affect the settling rates, dissolved oxygen levels, and biological action. The temperature of wastewater becomes extremely important in certain wastewater unit operations such as sedimentation tanks and recirculating filters.

2.2.2 Color

The color of wastewater containing dissolved oxygen (DO) is normally gray. Black-colored wastewater usually accompanied by foul odors, containing little or no DO, is said to be *septic. Table 6-2* provides wastewater color information.

Table 6-2 — Significance of Color in Wastewater.

Unit Process	Color	Problem Indicated
Influent of Plant	Gray	None
	Red	Blood or other industrial wastes or TNT complex
	Green, Yellow, Other	Industrial wastes not pretreated (paints, etc.)
	Red or other soil color	Surface runoff into influent, also industrial flows
	Black	Septic conditions or industrial flows

2.2.3 Odor

Domestic sewage should have a musty odor. Bubbling gas and/or foul odor may indicate industrial wastes, anaerobic (septic) conditions, and operational problems. Refer to *Table 6-3* for typical wastewater odors, possible problems, and solutions.

Table 6-3 — Odors in Wastewater Treatment Plant.

Odor	Location	Problem	Possible Solutions
Earthy, musty	Primary and secondary units	No problem Normal	None required
Hydrogen sulfide (H_2S) rotten eggs	Influent	Septic	Aerate, chlorinate, oxonizate
	Primary clarifier	Septic sludge	Remove sludge
	Activated sludge Aeration tanks Trickling filters	Septic conditions (anaerobic)	More air or less BOD, recirculation rate HTH, flood
	Secondary clarifier		Remove sludge and/or grease
	Chlorine contact tank		Remove sludge
	General plant		Practice good housekeeping
Chlorine-like	Chlorine contact tank	Improper chlorine dosage	Adjust chlorine dosage controls
Industrial odors, general	Plant	Inadequate pretreatment	Enforce sewer use regulation

2.2.4 Solids

Wastewater is normally 99.9 percent water and 0.1 percent solids. If a wastewater sample is evaporated, the solids remaining are called total solids*.*

The amount of solids in the system has a significant effect on the total solids concentration in the raw sewage. Industrial and domestic discharges also add solids to the plant influent*.* There are many different ways to classify solids. The most common types are dissolved, suspended, settleable, floatable, colloidal, organic, and inorganic solids.

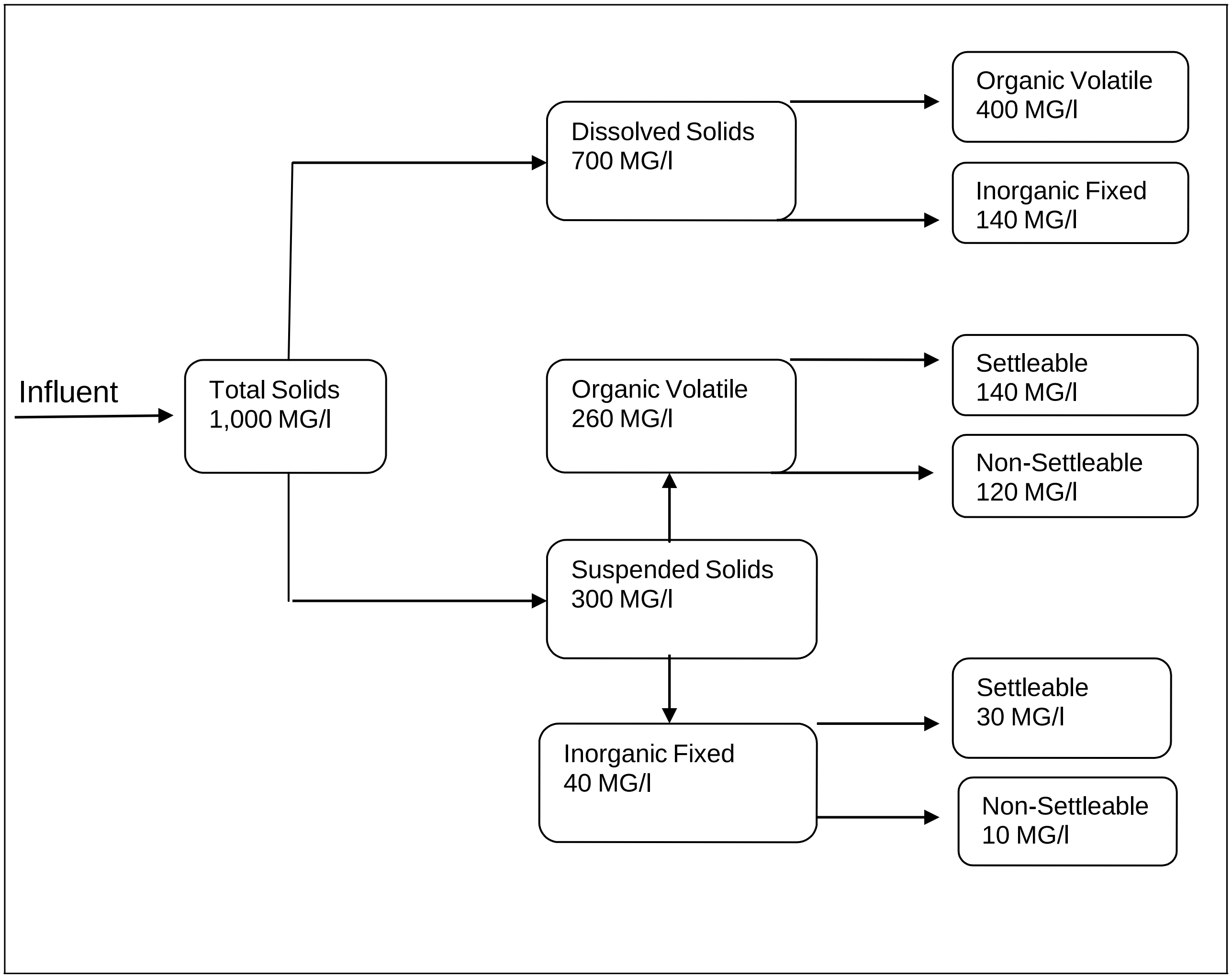
Part of the total solids are dissolved in wastewater. Much like sugar dissolves in coffee, many solids dissolve in water. Dissolved solids pass through a fine mesh filter. Normal wastewater processes using settling or flotation are designed to remove solids but cannot remove dissolved solids. Biological treatment units such as trickling filters and activated sludge plants convert some of these dissolved solids into settleable solids that are then removed by sedimentation tanks.

Those solids that are not dissolved in wastewater are called ***suspended solids**.* When suspended solids float, they are called ***floatable solids*** or scum. Those suspended solids that settle are called settleable solids, grit, or ***sludge**.* Very small suspended solids that neither float nor settle are called ***colloidal particles**.* Colloidal particles are often removed in the biological treatment units. They may also be removed by chemical treatment followed by sedimentation.

All the solids discussed above may be either organic or inorganic. *Organic solids* always contain carbon and hydrogen and when ignited to high temperatures (500°C to 600°C) burn to form carbon dioxide, water, and sometimes various other compounds. The burning or volatilization of organic solids has led to the term volatile solids*.* All solids that burn or evaporate at 500°C to 600°C are called volatile solids. These solids serve as a food source for bacteria and other living forms in a wastewater treatment plant. Most organic solids in municipal waste originate from living plants or animals.

Those solids that do not burn or evaporate at 500°C to 600°C but remain as a residue are called *fixed solids.* Fixed solids are usually inorganic in nature and may be composed of grit, clay, salts, and metals. Most inorganic solids are from nonliving sources. *Table 6-4* summarizes the types and amounts of the solids discussed in the preceding paragraphs.

Table 6-4 — Solids of a Typical Domestic Wastewater.



2.3.0 Chemical Characteristics

The chemical characteristics of wastewater of special concern to the Utilitiesman are pH, DO (dissolved oxygen), oxygen demand, nutrients, and toxic substances.

2.3.1 pH

The term *pH* is used to describe the acid or base properties of water solutions. A scale from 0 to 14 has been established where pH value of 7 is neutral. A pH value less than 7 is acidic. A pH value above 7 is alkaline or basic. *Figure 6-1* lists pH values for some common materials. A pH value less than 7 in the wastewater plant influent may indicate septic conditions of wastewater. The pH values less than 5 and more than 10 usually indicate that industrial wastes exist and are not compatible with biological wastewater operations. Pretreatment of these wastes at the source is usually required since extreme pH values may damage biological treatment units.

2.3.2 Dissolved Oxygen

Dissolved oxygen (DO) in wastewater has a great effect on the characteristics of the water. Wastewater that has DO is called aerobic or fresh. Aerobic raw sewage is usually gray in color and has a musty odor.

Wastewater that has no DO is called anaerobic or septic. Anaerobic raw sewage is usually black and has an offensive hydrogen sulfide or rotten egg odor.

2.3.3 Oxygen Demand

Oxygen demand is the amount of oxygen used by bacteria and other wastewater organisms as they feed upon the organic solids in the wastewater. Chemical tests such as the BOD (biochemical oxygen demand), the COD (chemical oxygen demand), the ODI (instantaneous oxygen demand or oxygen demand index), and the TOC (total organic carbon) measure the “strength” of sewage. These tests are discussed in detail later in this chapter. It is important that organic wastes be removed to protect the receiving body of water into which the wastewater plant is discharging. Sludge deposits, odors, and fish kills may occur if removal is not adequate.

Figure 6-1 — Common substance pH values.

2.3.4 Nutrients

Nutrients are life-supporting nitrogen and phosphorus. They stimulate excessive growths of algae and other aquatic plant life. They are always present in domestic wastewaters and are not removed during conventional primary and secondary treatment. Removal is accomplished by processes in addition to normal wastewater treatment or tertiary treatment, when specific reuse requirements require it.

2.3.5 Toxic Chemicals

Most military and industrial installations use various types of toxic chemicals, the discharges of which can be harmful to wastewater treatment processes. These toxic chemicals should be pretreated or removed before the wastewater enters the collecting system. *Table 6-6* lists some examples of these types of wastes.

Table 6-6 — Chemicals and Discharges Commonly Found at Military Installations.

Physical	Chemical	Biological
Solids from: Paint Photo lab Sandblasting Grease –valve, etc. Oils Cutting oils Heavy metals Rust Fiber (bacterial slime) Misc. solids (trash) Grit-rocks-sand Color-dyes Metal sulfides	Heavy metals (in solution)- chromium, nickel, lead, zinc, copper, iron oxide chlorine, aluminum, mercury cyanides Phenols Acids- sulfuric, hydrochloric, nitric Base-caustic soda, lime Salts-alum, brine, copper sulfate Ship chemicals Gases Pesticides Germicides Solvents Detergents Adhesives	Bacteria-fecal coliforms Iron and sulfur bacteria Special slimes, fungi, and oil-related growth Algae-green and blue-green Snails and clams Viruses

2.4.0 Biological Characteristics

The three biological organisms present in wastewater are bacteria, viruses, and parasites.

2.4.1 Bacteria

Sewage consists of vast quantities of bacteria, most of which are harmless to man. However, pathogenic (disease-causing) organisms such as typhoid, dysentery, and other intestinal disorders may be present in wastewater. Tests for total coliform and fecal coliform nonpathogenic bacteria are used to indicate the presence of pathogenic bacteria. Because it is easier to test for coliforms, fecal coliform testing has been accepted as the best indicator of fecal contamination. Fecal coliform counts of 100 million per 100 milliliters may be found in raw domestic sewage. Detectable health effects have been found at levels of 2,300 to 2,400 total coliforms per 100 milliliters in recreational waters. Disinfection, usually chlorination, is generally used to reduce these pathogens. Breakdown or malfunctions of chlorination equipment will probably result in excessive discharge of pathogenic organisms and can seriously affect public health.

Bacteria can also be classified according to their dissolved oxygen requirement. Aerobic bacteria are bacteria that require dissolved oxygen to live. Anaerobic bacteria cannot live if dissolved oxygen is present. Facultative bacteria can live with or without dissolved oxygen.

2.4.2 Viruses

Wastewater often contains viruses that may produce diseases. Outbreaks of infectious hepatitis have been traced through water systems because of wastewater entering the supply. Sedimentation, filtration, and disinfection, if used efficiently, usually provide acceptable virus removal.

2.4.3 Parasites

There are also many species of parasites carried by wastewater. The life cycle of each is peculiar to the given parasite. Some are dangerous to man and livestock, particularly during certain stages of the life cycle. Amoebic dysentery is a common disease caused by amoebic parasites. Chlorination, chemical precipitation, sedimentation, or sand filtration is used to ensure protection against parasites.

Test your Knowledge (Select the Correct Response)

1. What term is used to describe wastewater that contains dissolved oxygen?

   A. Anaerobic
   B. Aerobic
   C. Raw sewage
   D. Treated sewage

3.0.0 SEWAGE SAMPLING

Samples of sewage are taken to find out how well a treatment plant is working and what operating changes may need to be made. Some samples show how much the plant is reducing pollutants like BOD, solids, and so forth. Raw sewage entering the plant must be tested as well as the effluent from the plant and the receiving stream above and below the discharge point to determine how well the plant is removing pollutants. Since wastewater flows often change a great deal, daily sampling is suggested.

3.1.0 Representative Sampling

A sample should be taken in a way that will represent the wastewater being treated. No matter how good the lab analysis is, if the sample is not correctly collected, the lab data will not be correct. With the large changes in composition and flow rate, getting a representative sample can be very hard. Careful thought, planning, and training must be used to develop and carry out a good sampling program.

Samples may be taken by hand or automatically. Taking samples by hand may be as simple as tying an open bottle to a pole that can be lowered into the wastewater. *Table 6-7* explains some of the things that should be done when taking samples by hand. The automatic samplers may be purchased or made by the operator.

Table 6-7 — Procedures for Manual Wastewater Sample Collection.

Procedures	Special Cautions
Take samples where wastewater is well mixed.	Weirs are not good sampling points since settling of solids is enhanced upstream, and greases and oils build up downstream from the weir.
Take the samples from the center of the flow channel. To avoid floating scum, hold the mouth of the container below the liquid surface.	Solids often build up near the sides and bottom of the flow channel.
Take a representative sample.	Raw wastewater should be sampled after screening and grit removal. Deposits or nonrepresentative materials such as grease or scum should be excluded from the sample. Particles larger the 0.25 inch (6mm) in diameter should be excluded.
When compositing samples into other containers, thoroughly mix the contents of each before pouring.	If dissolved gases or volatile substances are to be tested, turbulence may be produced by gentle stirring.
Ensure that the sampling containers and sampling devices are clean and uncontaminated and suitable for the planned analysis.	Before the sample is taken, the container should be rinsed several times with the wastewater.
Ensure that the sampling places are easy to reach and that safety precautions are observed.	Proper sampling equipment should be available.

3.2.0 Grab Sampling

A grab sample is a single sample of wastewater taken over a short span of time, usually less than 15 minutes. This type of sample yields data about the wastewater at one time and place. The grab sample should be used where the wastewater does not change suddenly or change a great deal. For example, grab samples may be used to determine pH and temperature. Grab samples are also used when a batch dump or discharge is seen.

3.3.0 Composite Samples

A composite sample yields data about the wastewater over a longer span of time. A series of grab samples may be taken over a certain amount of time and combined to form a composite sample. These samples should show the time and frequency of the sample, for example, an 8-hour composite of 30-minute grab samples. The composite sample is used to find BOD, COD, suspended solids, and nutrients.

3.4.0 Flow Proportional Samples

The composite may be flow proportional. For this type of sample, the volume of the sample changes in proportion to the flow. The flow sludge proportional composite sample is most often run for 24 hours with a 2-hour interval between each collection. To collect this kind of sample, the volume needed for the tests and the average daily flow for the plant must be known. *Table 6-8* shows the volumes required for some tests. The following formula may be used to find the volume of sample to be taken at each interval.

$$\text{Liters required} = \frac{\text{Flow at sampling time}}{\text{Average flow}} \times \frac{\text{Total sample size}}{\text{Number of samples}}$$

For example, to collect an 8-hour composite sample with a 2-hour interval, five samples would be needed. If a total sample of 2 liters was needed, the average daily flow was 60,000 gallons (227 cubic meters), and the flow at the first sample time was 45,000 gallons per day (170 cubic meters), then the milliliters required for the first sample could be figured like this:

$$\text{Liters required} = \frac{45{,}000\ \text{gal/day}}{60{,}000\ \text{gal/day}} \times \frac{2\ \text{liters}}{5\ \text{samples}}$$

$$\text{Liters required} = \frac{170\ \text{cubic meters/day}}{227\ \text{cubic meters/day}} \times \frac{2\ \text{liters}}{5\ \text{samples}}$$

Liters required = .30

Milliliters required = (Liters required x 100) = 300

NOTE

264 gallons = 1 cubic meter (m^3)

Gallons x 0.003785 = cubic meters (m^3)

1 liter = 1,000 milliliters

Table 6-8 — Recommendation for Sample Volume and Preservation of Sample.

Measurement	Type of Sample	Vol. Req. (ml)	Container	Preservative	Holding Time
Acidity	G*	100	P, G**	Cool, 4°C***	24 hr
Alkalinity	G	100	P, G	Cool, 4°C	24 hr
Arsenic	PC****	100	P, G	HNO3 to pH 2	6 mo
BOD	PC	1,000	P, G	Cool, 4°C	6 hr
Bromide	G	100	P, G	Cool, 4°C	24 hr
COD	PC	50	P, G	H2SO4 to pH 2	7 days
Chloride	G	50	P, G	None req.	7 days
Chlorine	G	50	P, G	Cool, 4°C	24 hr
Color	G	50	P, G	Cool, 4°C	24 hr
Cyanides	G	500	P, G	Cool, 4°C NaOH to pH 12	24 hr
Dissolved Oxygen					
Probe	G	300	G only	Det. on site	No holding
Winkler	G	300	G only	Fix on site	No holding
Fluoride	G	300	P, G	Cool, 4°C	7 days
Hardness	G	100	P, G	Cool, 4°C	7 days
Iodine	G	100	P, G	Cool, 4°C	24 hr
MBAS	G	250	P, G	Cool, 4°C	24 hr
Metals					
Dissolved	PC	200	P, G	Filter on site	6 mo
				HNO3 to pH 2	
Suspended	PC			Filter on site	6 mo
Total	PC	1,100		HNO3 to pH 2	6 mo
Mercury Dissolved	PC	100	P, G	HNO3 to pH 2	38 days (glass)
				Filter HNO3 to pH2	13 days (hard plastic)
Nitrogen					
Ammonia	G	400	P, G	Cool, 4°C H2SO4 to pH 2	24 hr2
Kjeldahl	PC	500	P, G	Cool, 4°C H2SO4 to pH 2	24 hr2
Nitrate	PC	100	P, G	Cool, 4°C H2SO4 to pH 2	24 hr2
Nitrate	G	50	P, G	Cool, 4°C	24 hr2
NTA	PC	50	P, B	Cool, 4°C	24 hr
Oil & Grease	PC	1,000	G only	Cool, 4°C H2SO4 to pH 2	24 hr
Organic Carbon	PC	25	P, G	Cool, 4°C H2SO4 to pH 2	24 hr
pH	G	25	P, G	Cool, 4°C Det. on site	6 hr

Table 6-8 — Recommendation for Sample Volume and Preservation of Sample con't.					
Measurement	Type of Sample	Vol. Req. (ml)	Container	Preservative	Holding Time
Phenolics	G	500	G only	Cool, 4°C H3PO4 to pH 4 1.0 g CUSO4/1	24 hr
Phosphorus					
Orthophosphate, dissolved	G	50	P, G	Filter on site Cool, 4°C	24 hr[2]
Hydrolyzable	G	50	P, G	Cool, 4°C H2SO4 to pH 2	24 hr[2]
Total	PC	50	P, G	Cool, 4°C	24 hr[2]
Total, dissolved	PC	50	P, G	Filter on site Cool, 4°C	24 hr[2]
Residue					
Filterable	PC	100	P, G	Cool, 4°C	7 days
Nonfilterable	PC	100	P, G	Cool, 4°C	7 days
Total	PC	100	P, G	Cool, 4°C	7 days
Volatile	PC	100	P, G	Cool, 4°C	7 days
Settleable Matter	PC	1,000	P, G	None req.	24 hr
Selenium	PC	50	P, G	HNO3 to pH 2	6 mo
Silica	PC	50	P only	Cool, 4°C	7 days
Specific Conductance	G	100	P, G	Cool, 4°C	24 hr[3]
Sulfate	PC	50	P, G	Cool, 4°C	7 days
Sulfide	G	50	P, G	2 ml zinc acetate	24 hr
Temperature	G	1,000	P, G	Det. on site	No holding
Threshold Odor	G	200	G only	Cool, 4°C	24 hr
Turbidity	G	1,000	P, G	Cool, 4°C	7 days
*Type G sample = Grab.			**P, G = Plastic or Glass.		
***4°C = 4 Celsius.		****PC = Proportional Composite.			
1. If samples cannot be returned to the lab in less than 6 hours and holding time exceeds this limit, the final reported data should show the actual holding time.				2. Mercuric chloride may be used as an alternate preservative at a concentration of 40 mg/1, especially if a longer holding time is required. However, mercuric chloride should not be used if something better is available.	
3.If the sample is stabilized by cooling, it should be warmed to 25°C for reading, or temperature correction made and results reported at 25°C.				Note: It has been shown that certain samples properly preserved may be held beyond the recommended holding time. Consult designated authority.	

3.5.0 Sample Stowage

To get the best results, samples should be analyzed as soon as possible after they are collected. Some tests, such as DO, temperature, and pH, must be performed at the time of collection since the results can change while the sample is being carried to the lab. Some other tests may be delayed if the sample is properly stored. The most common means of preserving a sample is to cool it to 2°C to 10°C. *Table 6-8* shows some ways to preserve the sample.

3.6.1 Identifying samples

After the sample is collected, it should be identified with a label. The label should include the following information:

- Where the sample was taken
- Date and time of collection
- Type of sample (grab or composite, with the appropriate time and volume information)
- Anything that might change before laboratory testing, such as temperature, pH, and appearance
- Initials or name of the person who took the sample

Test your Knowledge (Select the Correct Response)

2. For proper storage, you should maintain the sample within what temperature range?

   A. 18°C to 26°C
   B. 10°C to 18°C
   C. 2°C to 10°C
   D. -2°C to -10°C

4.0.0 SEWAGE TESTING

Laboratory reports are useful in the operation of a wastewater treatment plant. The operator can use laboratory test results to keep the plant working at its best and to give early warning of operating problems. Laboratory testing programs vary with the type of treatment, size of the plant, local water quality requirements, and the NPDES permit requirements. Some of the most common laboratory tests for wastewater treatment plants are shown in *Table 6-9*. They are discussed later in this chapter. Laboratory tests required by NPDES are determined for each treatment plant and are cited in the discharge permit. The normal procedures for these tests are given in *Standard Methods for the Examination of Water and Wastewaters* and *Methods of Chemical Analysis of Water and Wastes*, published by the EPA.

Table 6-9 — Important Laboratory Tests.

Test to be Performed	Sampling Point	Recommended Means of Collection	Recommended Frequency of Collection
Settleable solids	1. Influent 2. Final effluent	Grab or composite	Daily
Suspended solids	1. Influent 2. Final effluent	Proportional composite	Weekly
BOD5 or COD	1. Influent 2. Effluent 3. Stream—above & below discharge	Proportional composite	Weekly
Dissolved oxygen	1. Influent 2. Final effluent 3. Stream—above & below discharge	Grab	Daily
pH	-----	Grab	Daily
Fecal coliform	Final Effluent	Grab	Weekly
Alkalinity	1. Final effluent 2. Digester	Proportional composite or grab	Daily
Chlorine residual	Final effluent	Grab	Daily (at least)

4.1.0 Laboratory Equipment

Examples of the various types of laboratory equipment are shown in *Figures 6-2* and *6-3.* In order for the operator to conduct accurate sewage tests, the laboratory must be equipped with a minimum of equipment. *Table 6-10* lists the types of equipment needed for some of the basic laboratory tests.

The operator should always maintain this equipment in a high state of repair and cleanliness. Any contamination of the test equipment may adversely affect the results. Refer to the manufacturer's instructions for the proper maintenance procedures for each piece of equipment. *Table 6-11* gives some basic guidelines for the maintenance and use of various types of laboratory equipment.

Safety should be vital to all personnel conducting sewage tests. Good housekeeping is essential in a laboratory to prevent mishaps and damage to expensive equipment. Each piece of equipment should be cleaned and returned to its proper place after being used.

When conducting sewage tests, it is always wise for the operator to avoid actual contact of the hands with the sewage samples or other filth. Hands must be kept out of the nose, mouth, and eyes. It is particularly important to use gloves when the hands are chapped or burned, or the skin is broken from any wound. Operators should thoroughly wash their hands with plenty of soap and hot water before eating.

Figure 6-2 — General laboratory equipment.

Figure 6-3 — General laboratory equipment.

Table 6-10 — Types of Equipment Needed for Various Laboratory Tests.

	Equipment Needed*																												
Constituents to be Analyzed	Atomic Absorption	600^0C Muffle Furnace	103^0C Drying Oven	Analytical Balance	Imhoff Cone	pH Meter	Lamotte Kit	BID Incubator	Vacuum Pump	Hot Plate	Kjedahl Unit	Condenser/Extract. Eq.	DO Meter & Probe	Autoclave	Amperometric Titrat.	35^0C Incubator	Gas Analyzer	Steam Bath	Magnetic Stirrer	Blender	Turbidity Meter	Carb. Adsorp. Unit	Desecrator	Spectrophotometer	Stirring Equip.	Vibrating Shaker	Total Org. Carb. Analy	Purity Meter	Water Still
Volatile Solids		x	x	x																			x						
Total Solids			x	x																			x						
Settleable Solids					x																								
pH						x																							
Total Sulfides							x																						
BOD								x																				x	x
COD										x		x								x								x	x
Suspended Solids				x	x				x														x						
Dissolved Oxygen													x																
Chlorine Residual															x														
MPN Coliform**																													
Volatile Acids										x		x																x	x
Alkalinity						x													x										
Gas Analysis																	x												
Grease				x	x				x	x		x						x											
Total Organic Carb.																											x		
Turbidity																					x								
Volatile SS		x	x	x					x														x						
Total Phosphorus																													
MBAS***																									x				
Sludge Filterability						x		x																					
Ash Analysis		x		x																									
Jar Test																									x				
Apparent Density				x																						x			
Isotherms			x	x					x												x					x			
Calcium Content				x																			x						
Ammonia Nitrogen										x		x																	
Organic Nitrogen										x	x	x																	
Nitrate Nitrogen																								x					
Heavy Metals	x																												

Table 6-11 — Maintenance Guide.

Equipment	Function	Used for	Instructions*
ANALYTICAL BALANCE	Precision weighing.	Preparation of standards. Weighing samples of total and suspended solids, sludge moisture, oils, and grease.	Install on heavy shockproof table away from vibration and extreme temperature variations. Keep level at all times.
TRIP BALANCE	Course weighing.	Weighing samples of MLSS, wet sludge filter cake, grit, and chemicals.	Maintain and use according to manufacturer's instructions.
pH METER	pH measuring.	Analysis of wastewater, industrial waste, and determining endpoints of alkalinity, acidity and ammonia tests, also streams, surface water, and various solutions.	Calibrate frequently with buffers at pH 4.0, 7.0, and 10.0. Be sure buffers are fresh. Immerse electrodes in distilled water while not in use. Discard electrodes with broken tips and deep scratches. Keep electrode reservoir filled. Rinse electrodes with distilled water after each operation. Keep sample mixed during test. Observe temperature of sample and adjust meter.
DRYING OVEN	Controlling drying of samples. Drying samples and glassware.	Drying samples suspended and dissolved solids and sludge. Also drying chemicals and glassware.	Equip with accurate thermometer. Be sure temperature controls are working properly. Keep doors fitted tight to prevent heat loss. Clean the oven frequently. Arrange samples to prevent cross-contamination. Locate away from heat-sensitive equipment.
MUFFLE FURNACE	Igniting (burning) volatile substances.	Determining amount of volatile and fixed solids in suspended, total, activated, and digested solids and/or sludge samples. Igniting barium sulfate precipitates in sulfate testing.	Be sure the furnace is equipped with an accurate temperature control. Keep heat chamber clean. Check frequently for deposits of soot and ash. Be sure that fumes are properly exhausted. Locate away from heat-sensitive equipment.

Table 6-11 — Maintenance Guide, Continued.

Equipment	Function	Used for	Instructions*
DESICCATOR	Providing moisture-free atmosphere for temporary storage of glassware, chemicals, and samples.	Drying chemical powders. Cooling glassware and samples before reweighing.	Check doors or lids for tight seal. Keep closed at all times except when inserting or removing materials. Be sure desiccant material is active. Replace or replenish inactive desiccant.
BOD INCUBATOR	Providing constant light-free temperature for BOD samples.	Incubating BOD samples at 20°C for 5 days.	Check temperature controls for accuracy. Be sure proper temperature is maintained at all times. Be sure door closes and seals properly. Keep chamber clean and free of biological growths.
WATER DISTILLATION UNIT	Distilling water to laboratory standards.	Providing high-quality water for chemical solutions, BOD dilution, bacteriological and chemical analyses. Also water for rinsing analytical glassware.	Check temperature control for accuracy. Be sure boiler, condenser coils, and tubing are free of deposits and scale. Clean frequently. Use borosilicate glass storage containers with tight covers to exclude airborne dust, gases, and organisms. Test pH and conductivity frequently to help ensure purity.
DEIONIZER	Purifying water by ion exchange rather than by distillation.	Same as for water distillation unit.	Use ion exchange cartridges of proper type. Discard cartridges at once when exchange capacity is exhausted. Be sure water feed rate is not exceeded. Store deionized water same as distilled water.
CALORIMETER OR SPECTROPHOTOMETER	Quantatively measuring water quality by calorimetric method.	Testing for phosphorus, nitrate, nitrite, hexavalent chrome, color, sulfate by turbidity method, phenols, residual chlorine, and others.	This equipment is delicate. Handle with care. Keep adequate stock of replacement parts. Be sure the equipment is properly calibrated before use for transmittance or absorbance readings. Be sure to use proper filter for test being performed.

Table 6-11 — Maintenance Guide, Continued.

Equipment	Function	Used for	Instructions*
REFRIGERATOR	Low temperature storage.	Storage of wastewater and sludge samples at 4°C. Also storage of unstable chemicals.	Check temperature controls for accuracy. Keep interior clean and free of biological growths. Provide refrigerator(s) with adequate capacity for laboratory needs.
AUTOCLAVE	Sterilization by steam.	Sterilization of dilution water, glassware, sample media, and related items for bacteriological testing.	Check time, temperature, and pressure controls for accuracy. Confirm sterilization by use of test strips or other indicators. Be sure sterilized materials are properly wrapped, sealed, and stored to prevent contamination.
HOTPLATE OR HEATER	Healing liquids and solids.	Preparing analytical solutions. For evaporation concentration, hydrolysis digestion, and other analytical operations.	Check temperature controls for accuracy. Be sure units are adequate for laboratory needs. If controls are manual, do not leave hotplates unattended.
DISSOLVED OXYGEN ANALYZER	Instrumental measuring of dissolved oxygen.	Testing wastewater, industrial waste, streams, and BOD samples for dissolved oxygen.	Check accuracy of instruments frequently. Recalibrate, if necessary, using approved standards. Store probe in water or in moisture-saturated air. Keep probes clean. Change membranes and replace electrolytes as recommended by manufacturer.
BACTERIA INCUBATOR	Providing constant temperature during incubation of samples.	Coliform and other bacteriological tests.	Check accuracy of temperature controls. Keep storage chamber clean and free of spillage and bacteriological growths. Check doors for proper closing and sealing. Locate unit where not exposed to extreme temperature changes.
WATER BATH INCUBATOR	Providing constant temperature for water bath incubation of samples.	Testing coliform and nitrate samples. Also digestion of wastewater samples.	Check accuracy of temperature controls. Keep storage chamber clean and free of rust, scale, and sediment. Check cover and seal for proper fit. Maintain bath water at correct level.

Table 6-11 — Maintenance Guide, Continued.

Equipment	Function	Used for	Instructions*
CONDUCTIVITY METER	Measuring electrical conductance/resistance of a solution.	Testing distilled water, water, and wastewater samples.	Calibrate frequently against known reference. Keep electrode clean and stored in distilled water between tests. Observe between tests. Observe sample temperature and make necessary adjustment.
TOTAL ORGANIC CARBON ANALYZER	Analyzing carbon fractions by combustion/infrared methods.	Rapid analysis of total inorganic and organic carbon in water and wastewater samples.	Due to the complexity of this unit, problems should be referred to specially trained technicians.
ATOM ABSORPTION SPECTROPHOTOMETER	Analyzing metal ions by atomic absorption/emission method.	Testing samples for heavy metal or toxic metal ions.	Be sure the unit is properly installed with fume exhaust system. Problems with the unit should be referred to a specially trained technician.
*Always follow manufacturer's instructions for maintenance and operation.			

4.2.0 Dissolved Oxygen Test

The DO test finds the milligrams per liter (mg/l) of oxygen that are dissolved in water or wastewater. Oxygen exists as a gas and can dissolve in water in only a limited amount. Pure water at 20°C at sea level can hold a maximum of 9.17 mg/l of DO. Raising the temperature, salt content, or altitude will lower the DO level in the water. An important thing to remember is that this test should be run as soon as possible after the sample is taken. It must always be run as a grab sample. It is best to test several samples taken at different times during the day because the DO content of wastewater may vary. If incoming wastewater has no DO, it is septic. Most wastewater treatment plants are not built to treat septic wastewater. A great deal of plant and animal life that lives in water and wastewater, including necessary microorganisms, needs DO just as we need oxygen from the air. If the DO is used up, aerobic organisms will die and the water will become anaerobic or septic, and foul odors will develop. If this occurs, you should check for flow problems within the sanitary system upstream of the treatment plant.

4.3.0 Hydrogen Ion Concentration (pH Value) Test

The measure of acidity or basicity (alkalinity) of something is called the pH. The effect of pH on some parts of wastewater treatment makes it an important test. A low pH of domestic wastewater may mean that the wastewater is septic, or it can mean that industrial or commercial acid wastes are entering the system. A pH of 6.5 to 8 is about right for treatment plant influent. Test results showing a very high or low pH may mean someone is breaking sewer use regulations. Sudden changes of 0.5 or more on the pH scale may mean that operating problems are starting. Grab samples should be taken for pH tests.

4.4.0 Settleable Solids Test

The settleable solids test on wastewater can tell the operator a lot about what kind of wastewater is coming into the plant and how the solids are settling. Also, the settleable solids test can help the operator estimate the volume of sludge to be expected in the clarifier.

Either grab or composite samples will work for this test. The test is done using an Imhoff cone. The Imhoff cone (*Figure 6-3*) can be either glass or plastic. It can hold 1 liter and is marked off in milliliters (ml).

Before running the test, you should allow the sample to settle for 45 minutes. After 45 minutes, you should run a glass or plastic rod gently down the inside of the cone and turn it to loosen solids clinging to the sides. Settling should then continue for another 15 minutes. The depth of the solids in the bottom is then read from the scale and recorded as milliliters of settleable solids per liter of wastewater.

4.5.0 Activated Sludge Settleability Test

The settleability test is often used with all kinds of activated sludge plants to find the amount of solids in aeration units. The results help the operator to decide when to waste sludge and to find the rate of sludge return. The activated sludge settleability test can be run in a 1,000 ml graduated cylinder or in any clear, wide-mouthed container. The container should be ruled off into 10 units, such as centimeters, milliliters, or inches. The sample is poured into the cylinder or jar up to the top mark and allowed to settle. Readings are taken from time to time to find settling rates. The sample should be allowed to settle for about 30 minutes.

4.6.0 Five Day Biochemical Oxygen Demand (BOD_5) Test

The BOD_5 test is the most important test for finding the polluting strength of a wastewater. It is the most widely used way to check how the treatment plant is running. The BOD_5 test indirectly measures the amount of organic material in the sample. Either grab or composite samples may be used for this test.

NPDES permits often state that influent and effluent flow-proportional composite samples be taken for the BOD_5 test. Normal domestic wastewater coming into the plant should be in a 200 to 300 mg/l BOD_5 range. The effluent must comply with the plant's NPDES permit.

To run the test, the amount of oxygen is measured in a portion of diluted wastewater, and another portion like the first one is stored at 20°C for 5 days. The glass bottles shown in *Figure 6-3* are used for this test. During the 5 days, the microorganisms eat the organic matter in the wastewater and use oxygen at the same time. At the end of 5 days, the amount of oxygen consumed by the microorganisms times the dilution factor of the sample gives the sample's 5-day BOD. The dilution factor is the number of milliliters of dilution water added to a given number of milliliters of sample.

4.7.0 Chemical Oxygen Demand (COD) Test

Like the BOD5 test, the chemical oxygen demand (COD) test finds the amount of oxygen required to consume the organic matter in a wastewater sample. The COD test does not measure the amount of oxygen used by the microorganisms. It uses a strong chemical--concentrated sulfuric acid silver sulfate solution. It is a good operating control test because the results can be obtained in as little as 1 hour. COD test results are equal to or greater than BOD5 test results. The chemical used in the COD test attacks more organisms in the wastewater than the slower BOD5 organisms. BOD5 data can often be related to COD data by a multiplying factor. For instance, the 200 to 300 mg/l BOD5 of normal wastewater influent is about two-thirds of its usual 300 to 450 mg/l COD value. If such a factor can be figured for a certain kind of wastewater, COD data can be used to predict BOD 5 test results that will not be known for 5 days.

4.8.0 Total Suspended Solids Test

Total suspended solids are those solids in wastewater that can be taken out with a filter having a specified pore size. Suspended solids are made up of settleable solids and nonsettleable solids. Suspended solids tests can be run with either grab or composite samples, but flow proportional composite samples are the best for this test. Influent wastewater may have as much as 400 mg/l of suspended solids.

4.9.0 Mixed Liquor Suspended Solids Test

The suspended solids test that is run on the aeration tank mixed liquor is called the mixed liquor suspended solids test or MLSS test. It is used as a control test to help find out whether to increase or decrease the rate of sludge return and when to waste sludge. The very high solids content of mixed liquor requires a larger diameter filter (11 centimeters instead of 2.4 centimeters) to prevent rapid clogging.

4.10.0 Chlorine Residual Test

When chlorine is used to disinfect the effluent, tests are needed to see if the chlorine residual requirement has been met. The chlorine residual test may be run using the *iodometric* or *amperometric* methods. Since grab samples are used for these tests, most states suggest that the test be run within 30 minutes after taking the sample.

4.11.0 Fecal Coliform Test

The fecal coliform test is an indicator of harmful bacteria in the wastewater. Both the membrane filter and most probable number (MPN) can be used to run the test. If the sample is not prepared for the test on the site, it should be cooled to 4°C within 30 minutes and then tested within 6 hours.

4.12.0 Alkalinity

The alkalinity test can tell the operator a lot about the wastewater in the plant. A very high alkalinity in the wastewater may mean that an alkaline industrial waste has entered the system. The alkalinity test is often used to see how the anaerobic sludge digesters are working. The alkalinity in treatment lagoons usually goes down as the lagoon becomes septic. The alkalinity usually shows a 20 to 30 mg/l change before there is a change in pH.

4.13.0 Laboratory Records

Records can be used to find the best operating controls for a wastewater plant, problems that might arise in the plant, and the future needs of the plant. Records may also be used in court if a lawsuit is filed against the treatment plant.

The treatment plant should keep three kinds of records: physical records that describe in detail all areas of the plant itself, maintenance records that show what repair and cleaning have been done or needs to be done, and performance records that show the plant's operating data.

Physical records include operation and maintenance (O&M) manuals, actual plans and blueprints for the plant, shop drawings, O&M guides from equipment manufacturers, costs for all units, a hydraulic profile showing the height of water in all treatment units, and an equipment record. Under Public Law (PL) 92-500, consulting engineers are required to provide operation and maintenance (O&M) manuals for the treatment plants they design. These O&M manuals must meet the requirements of *Considerations for Preparation of Operation and Maintenance Manuals,* EPA, Washington, D.C., 1974.

Preventive maintenance in the treatment plant can reduce costly repairs and downtime on equipment. One of the key steps in a good maintenance program is keeping records. These records include the data needed to make a maintenance schedule, to estimate a maintenance budget, and to build up enough spare parts.

A record of all equipment in the plant must be made. This can be done on index cards. Each piece of equipment should be given a number based on where it is located in the plant. This number is written on an index card with the name of the equipment, its location in the plant, the name and address of the manufacturer or supplier, the cost, and the date of installation. The card should also have the type, model, serial, and any other code numbers, along with the capacity or size rating. The same card or another set of cards should include the type of maintenance required and how often it is needed, the special lubricants or coatings needed, and a record of all work done on the unit, including the labor, parts, and total cost. This data should be considered when planning to buy new equipment and making a maintenance schedule.

Making a maintenance schedule requires careful thought. Good records can serve as a guide. Some large treatment plants now use a computer to plan maintenance schedules and keep records up-to-date. Preventive maintenance should be scheduled so it can be done during good weather and not during times of peak load at the plant. Also, the schedule must leave time for repair work. A large chart showing what needs to be done daily, weekly, monthly, quarterly, semiannually, and annually can help in setting up a work schedule.

A spare parts inventory should be established. The command supply procedures should be followed but these steps may assist you if needed. Many spare parts must be ordered several days or weeks before they are delivered. These spare parts should be stocked at the treatment plant so the plant will not have to be shut down until the part arrives. A list or inventory of spare parts makes reordering simpler. A written record of parts used and replaced should be kept. The operator should record the date an item was ordered, the date delivered, its cost, and the name of the supplier each time a part is ordered and delivered.

In addition to the above records you must also maintain performance records. There are three types of performance records: laboratory records, operator's log, and NPDES forms.

A complete set of laboratory records should be kept for all laboratory tests. The laboratory record should have the date and time the sample was taken, the method used to take the sample, the name of the person who took the sample, the place where the sample was taken, the test performed on the sample, and the results of the laboratory test. These records should be kept in a bound notebook so they can be used as a part of legal testimony about the operation of the plant if need be. A monthly or quarterly report is also required at most plants.

A monthly report is required for all wastewater plants on a military installation. Since no two treatment plants are exactly the same, the operator will find that a special log designed for the treatment plant is helpful. The operator should report on special features of the treatment plant under the blank columns in the log. Operators at each treatment plant are required to complete the log. Navy plant operators use the *Wastewater Treatment Plant Operating Record,* NAVFAC 11340/1 (6-75).

Finally, every treatment plant that discharges to a body of water must get an NPDES permit from the EPA or the designated state agency. The permit lists standards for the effluent, tests required, frequency of running the tests, and the sampling method of each test. The treatment plant must submit a monthly or quarterly report to the EPA or the designated state agency with all the laboratory tests required by the permit. These reports and laboratory records must be kept for at least 3 years.

Use performance records to check the plant. The performance records at a treatment plant can provide good process control data to the operator. Results of laboratory tests that differ a lot from previous records may show an equipment breakdown, an industrial waste discharge, or a break in the collection system. *Table 6-12* shows some changes from normal values and some causes for these changes.

Table 6-12 — Variations in Performance and Some Common Causes.

Variation	Possible Cause	Solution
BOD_5 (or COD): Increase	Increased organic loading. Population growth. Industrial expansion.	Identify source of increase. If overloading is permanent, adjust treatment plant processes for maximum efficiency. Require adequate pretreatment. Enforce sewer use regulations if violations are found. Install holding tanks (ponds) if feasible. Modify or expand treatment units.
	Septic influent.	Freshen by aeration or chlorination.
	Septic conditions in treatment plant units.	Check on detention time and sludge pumping schedule. See if dissolved oxygen requirements of aerated units are being met.
BOD_5 (or COD): Decrease	Decrease in organic loading.	No problem.
	Wastewater organisms killed by toxic waste.	Find source of toxic waste. Require neutralization or exclude from treatment facility by enforcing sewer use regulations. When toxic waste is found, immediately notify appropriate military and regulatory authorities. Immediately seek advice from qualified specialists as to disposal of toxic waste remaining in the plant. Disposal after neutralization and/or dilution may be no problem.
Suspended Solids: Increase	Industrial expansion or population increase. Changes in industrial processes.	Generally, same procedure as for BOD_5 increase, unless growth and expansion are the causes. Check pretreatment for operation. Also check for industrial “dumping.” Enforce sewer use regulations, if applicable.
Suspended Solids: Decrease	Collection sewers blocked (clogged).	Inspect, clean, and flush if needed.
	Broken or completely blocked sewer resulting in bypassing.	Clean and flush sewer if clogged. Repair or replace if sewer is broken or settled out of position. If wastewater is bypassing, treat with chlorine at once.

pH: Increase	Industrial discharge. Inadequate pretreatment.	Try to find source of alkaline (basic) discharge and require pH adjustment before discharge to collection system. Check on operation of pretreatment units.
pH: Decrease	Industrial discharge. Inadequate pretreatment.	Try to find source of acidic discharge and proceed as suggested above.
	Septic influent.	Check sewers for low velocity (flat grades) and blockage (clogging). Clean and flush sewers. Chlorinate if necessary. Check lift station wet wells for proper detention time (not more than 30 minutes in warm weather). If the cause cannot be remedied, then freshen the septic wastewater at the head of the treatment plant by using aeration and/or chlorine. If the pH remains too low for satisfactory operation, adjust by applying alkaline chemical such as lime or soda ash.
Wastewater Flow: Increase	Population and industrial expansion	Consider installing holding ponds or tanks. Consult with industry to prevent "dumping" during high flow periods. If increased flow is expected to be continually above treatment plant design capacity, plant expansion and/or modifications should be considered.
	Infiltration-Inflow.	Check collection system for unauthorized storm and surface water connections. Enforce sewer use regulations. Repair or replace broken or cracked pipes and leaky joints. Raise or provide good surface drainage for manhole covers in low areas. Install holding ponds or tanks.
Wastewater Flow: Decrease	Bypassing leakage (exfiltration).	Check collection system for leaks and bypassing. Make necessary repairs. Notify appropriate regulatory officials at once. Request their advice.
	Decreased water use.	Recirculate enough of the treatment plant effluent to primary clarifier, trickling filter (or other unit) to prevent excessive detention time and provide better operation.
Temperature Influent: Increase	Discharge of hot wastes.	Enforce sewer use regulations if temperature is high enough to hinder operation.
Temperature Influent: Decrease	Infiltration—inflow of storm water.	Locate points of entrance. Repair if needed. Enforce sewer use regulations, if applicable.
Chlorine Demand: Increase	Inefficient operation due to septic conditions, poor settling, and other operating problems.	Check on efficiency of each treatment unit. Adjust controls to secure maximum efficiency. Check sludge-pumping schedule and rate, recirculation of effluent, aeration rate, trickling filter operation, and return of digester supernatant. Check for proper detention time in clarifiers and aeration tanks.
	Industrial discharges. Slug loading or "dumping."	If possible, secure cooperation of industry in controlling time and rate of discharging strong waste.
	Chlorine feed equipment not properly working.	Check accuracy of dosing equipment. The problem could be improper dose instead of increased chlorine demand. Find out if chlorine and wastewater are being properly mixed.
	Temperature.	Wastewater with high temperature usually requires more chlorine to satisfy the chlorine demand.

5.0.0 DISPOSING of and MONITORING SEWAGE EFFLUENTS

The wastewater treatment process includes taking the solids out of the wastewater, getting rid of the solids, and getting rid of the treated wastewater or effluent in a way the federal and state regulating agencies approve.

All plants that discharge an effluent must have NPDES permits issued by the EPA or by a state agency for the EPA. Before these permits are given to the plant, officials make a careful survey of the water use nearby that might be hurt by the effluent of the treatment plant. The permit may list top, bottom, or average limits for some kinds of pollutions. It may also state in what way the plant can dispose of its effluent. If the plant does not meet the limits on the permit, the operator should contact the regulating agency at once. The permit can be changed or revoked by the agency. Sometimes the plant may be allowed to discharge more than the limit on the permit, but that is up to the regulating agency. The purpose of the permit is to protect human health and natural resources. All operators should know the permit limits and make every effort to ensure that the treatment plant complies with them.

5.1.0 Effluent Discharge Methods Laboratory Equipment

The two major methods of discharging effluent are continuous discharge and intermittent discharge.

Most treatment plants discharge an effluent to a receiving water all the time. The effluent may go to an ocean, gulf, bay, lake, or stream. The point of discharge may be above or below the surface of the receiving water. Continuous discharge is often cheaper than other methods because it takes less manpower, equipment, and storage to operate. However, a very good monitoring program must be used to make sure toxic waste is not discharged. After a toxic waste is discharged, there is no practical way to stop or isolate the toxic substance.

Intermittent discharge means that the effluent is not discharged all the time, but only from time to time. This type of discharge requires a place to store the effluent. It is not often used at large plants. But it does work well at lagoons and small treatment plants that have holding or “polishing” ponds.

Intermittent discharge lets the operator choose the time and rate of discharge. A controlled amount of effluent can usually be discharged without hurting the quality of the receiving water if the operator picks the right time for all discharges. In some cases, the receiving water has even been improved. Intermittent discharge may cost more to build, but it does not require as costly a monitoring program. When there is no discharge, there is no effluent to be tested.

A special type of intermittent discharge is seasonal discharge. This type of discharge is often used to protect high-quality streams, especially during the season when the stream is used a great deal for recreation. More storage is needed for seasonal discharge because there are usually only two discharges, one in spring and one in autumn. The effluent is discharged under controlled conditions approved by the regulating agencies.

5.2.0 Methods of Disposing and Monitoring Sewage Effluents

Several methods of disposing of sewage effluents are used today. All methods must conform to the NPDES permit requirements and must be closely monitored. This section discusses these methods as well as troubleshooting problems with sewage effluent quality.

5.2.1 Direct Discharge to Receiving Water

Most treatment plants discharge effluent right into the receiving water. The abilities of the receiving water to dilute and accept the effluent is shown in the NPDES permit limits. The NPDES permit also considers the use of the receiving water. The effluent may come from a final clarifier, a disinfection contact basin, a lagoon, a polishing pond, or a storage pond. However, it must pass through some type of outfall sewer to the point of discharge.

The outfall sewer may be an enclosed pipe or an open channel or some of both. It is used to transport the effluent from the final treatment or storage unit to the point of discharge. The outfall sewer may be built to include cascades or stair steps, channels, mechanical aerators, or a filter bed of coarse rock. The purpose of these aerators is to increase the DO content of the effluent.

The NPDES permit requires that certain tests be made on the effluent on a regular schedule. Effluent testing may include, but is not limited to, flow measurement, temperature, BOD or COD, suspended solids, pH, DO, coliform count, and chlorine residual. Test results must be reported to the regulating agency. Along with the required tests, operators should check the receiving water, especially on small streams and lakes. Laboratory tests and visual checks may show that a problem exists in the receiving water and that something needs to be done. Plant operators cannot usually test large rivers, bays, lakes, and gulfs.

If an effluent containing a toxic substance is accidentally discharged to a receiving water that is used downstream as a drinking water supply, for recreation, or for livestock watering, operators must call the regulating agency and the downstream water users at once. Regulating agencies can then help curb the problem, and drinking water suppliers will have enough time to close their water intake lines until the problem is stopped. This will also warn people in recreation areas and give farmers and ranchers time to move livestock to a safe water supply.

5.2.2 Discharge to Recycling

In some areas where there is a shortage of water, wastewater effluent is recycled for industry, recreation, irrigation, and fire control use. Many industries can use treated wastewater for cooling and cleaning. Often this is cheaper for the industry than using potable (drinking) water. Lakes for fishing and boating have been maintained with recycled wastewater. Records show that these man-made lakes are often no more hazardous to the users than natural lakes. Recycled wastewater is seldom used as a drinking water supply.

Monitoring of effluent discharged for recycling is very important. Only by monitoring can the operator be sure that the effluent is good enough to be used. Recycling units may include extended settling and biological stabilization in holding ponds, sand filtering, and disinfection. Quality control is a must since the recycled water must be safe.

5.2.3 Evaporation and Percolation Basins

Evaporation and percolation basins are used to dispose of wastewater effluent by letting it evaporate and by letting it percolate or seep into the soil. The correct use of these ponds depends on the area of the basin compared to the amount and kind of the wastewater effluent to be processed. The larger the surface and bottom of the pond, the faster the wastewater evaporates and percolates. The climate and kind of soil are important in finding out whether this type of disposal can be used in a given area. This kind of system can be a good and cheap way to dispose of wastewater effluent.

It is often better to build two basins or one basin with a dike that separates it into two parts. After a time, suspended solids will change to settleable solids and build up in the pores or openings of the soil. Percolation will slow down and sooner or later will stop. To get the basin back in working order, it must be drained, dried, and cleaned. Scars must be cut in the bottom. With two basins, one can be kept in service while the other is being restored. The bottoms of the ponds should be sloped for quick and complete draining. The berms or dikes must be checked often for erosion and rodent damage. The dikes and surrounding areas should be mowed often to keep vegetation at a maximum height of 6 to 10 inches (15 to 25 centimeters). This will help keep rodents out of the area. The area should be fenced to keep out larger animals.

Signs should be built to show that the ponds are wastewater treatment plants and are dangerous. As with wastewater lagoons, trees should not be allowed to grow within about 500 feet (150 meters) of the pond. There must be enough surface drainage around the edge of the pond to keep surface water from entering the unit.

Since there is no discharge from the system, there is no need for testing the pond effluent. All bodies of surface water and all wells in the area should be tested often to see if they have been polluted by the pond. Too many suspended solids discharged to the pond will stop up the unit. A suspended solids test should be performed daily to find out if the treatment plant units are working well or if operative controls need to be changed. The ponds should be checked each day. Any changes in the way the plant looks or smells or any changes from normal operation need to be checked out. Laboratory tests may help find the problem and suggest ways of correcting it.

5.3.0 Troubleshooting

Table 6-13 describes some problems and solutions for these problems with wastewater effluent. Refer to manufacturers' manuals for more specific troubleshooting and operating guides for various types of treatment plants. Effluent quality usually depends on the operation and maintenance of upstream process units.

Odors and unsightly conditions are the most common subjects of complaints. Toxic wastes and wastes with high fecal coliform count are more dangerous but are more difficult to detect. Therefore, fewer complaints are made regarding these two hazards.

Complaints must be received with courtesy and investigated at once to see if the complaint is valid. Be sure to inform the complaining person(s) as to your findings, what can be done or what is being done to remedy the problem. A careful investigation may show that the source of the problem is not related to the wastewater treatment plant.

If the treatment plant is the source of the problem, use all available operating controls to obtain maximum plant efficiency. Notify designated regulatory officials at once as to the nature of the problem. If the solution to the problem appears to be beyond operator control, request advice and/or assistance.

Table 6-13 — Troubleshooting Effluent Disposal.

Indicator	Likely Causes	Actions to Take
Effluent BOD or COD too high.	1. Organic overload.	1. Control organic loading by sewer use regulations. Improve plant upkeep. Use all available operating control.
	2. Septic conditions in plant units and the collection system.	2. Check sludge pumping schedule for proper removal. Inspect pumps to see if they are working. Inspect sludge pipes and valves for clogging, check for sludge deposits (pockets) that are not being pumped out of the clarifiers. Inspect all plant units whether primary or secondary for proper operation. Refer to manufacturer's instructions for process information. Inspect the collection system, including lift stations, for septic conditions.
	3. Not enough aeration.	3. Maintain the recommended DO level in all aerated units, usually about 2 mg/1. Inspect air diffusers for even distribution of air and good mixing.
Effluent settleable solids content too high.	1. Hydraulic overload.	Try to control hydraulic loading by maintaining the collection system. Install holding ponds or tanks to handle peak load. Check on wastewater flow rate often to see if plant capacity is exceeded. Inspect settling tanks for short circuiting (channeling).
	2. Sludge collection and removal equipment not working right.	
Effluent suspended solids content too high.	1. Secondary units organically overloaded.	1. Keep organic loading of secondary units within design capacity if reasonably possible. Carefully inspect aerated units for DO content and mixing.
	2. Hydraulic overload.	2. Same action as for too many settleable solids in the effluent due to hydraulic overload.
Effluent pH too low or too high.	1. Industrial discharges not properly pretreated.	1. Inspect and sample the wastewater from the collection system to find the source. Require or provide proper pretreatment.
	2. Septic conditions in collection system or in the treatment plant.	2. Inspect both collection system and plant for detention time in sewer pipes, wet well, and clarifiers. Clean and flush clogged or partly clogged sewers. Aerate and/or chlorinate the influent wastewater for temporary relief.
Wastewater organisms killed, very little treatment being provided.	Toxic material leaking or being discharged to the collection system.	Immediately notify downstream users and regulatory authorities, giving all available information as to type and quantity of toxic substance, also time of release. If the operator has advance warning of a spill or discharge of toxic waste, then all available storage should be used to contain the toxic material instead of letting it pass through the plant. If it cannot be contained, use all available methods to neutralize and/or dilute the toxic waste. Try to find the source of the toxic material and use every reasonable means to prevent its discharge to the system.
Coliform count above permit requirement.	1. Not enough chlorine being applied.	1. Test several times daily for "free" chlorine residual, especially during and immediately after peak flows. Adjust dose of chlorine according to test results. Inspect chlorine feed pump for working condition. If chlorine compounds such as HTH and others are being used, be sure of its percentage of

		chlorine content when adjusting the feed rate (dose).
	2. Chlorine not well mixed with the wastewater.	2. Inspect mixing equipment to be sure the chlorine and wastewater are well mixed immediately. Test for free chlorine residual in several areas of the contact tank to be sure of proper mixing.
	3. Contact time too short.	3. Carefully check the contact (detention) time of the tank to be sure that 15 to 30 minutes' contact time is provided. Remove sludge deposits, if any are present, from the contact tank.

Test your Knowledge (Select the Correct Response)

3. For a wastewater plant that discharges effluent to a body of water, what type of permit must be obtained from the EPA or designated state agency?

   A. NPDES
   B. Operating
   C. Discharge
   D. COD

6.0.0 SEPTIC TANKS, CESSPOOLS, and LEACHING FIELDS

Septic tanks, cesspools, and leaching fields are used for sewage treatment processes where common sewers are not available. These facilities are for the most part underground receptacles. If properly designed, constructed, located, and operated, these receptacles work without objectionable odors over long periods of time with a minimum amount of attention.

6.1.0 Septic Tanks

Septic tanks may be used to serve small or scattered installations where the effluent can be disposed of by dilution, leaching wells or trenches, subsurface tile, or artificial subsurface filter systems (*Figure 6-4*).

The septic tank capacity should equal a full day's flow plus an additional allowance of from 15 to 25 percent for sludge capacity. The minimum acceptable size of a septic tank is 1,000 gallons. *Table 6-14* outlines the minimum tank capacities required by the *National Standard Plumbing Code*. Septic tanks are constructed of reinforced concrete. The length of the tank should not be less than two or more than three times the width.

Figure 6-4 — Septic tank.

The liquid depth should not be less than 4 feet for the smaller tanks and 6 feet for the larger ones. Manholes should be provided over the inlet and outlet pipes and over the low points in the bottom of hopper-bottom tanks. The roof of the tank may be covered with earth, but access openings should extend at least to the ground surface. Although ells or tees may be used at inlet and outlet connections, straight connections are better for rodding. Instead of ells, wooden baffles, located approximately 18 inches from the ends of the tank and extending 18 inches below and 12 inches above the flow line, are provided. Elevations should permit free flow into and out of the tank. The bottom of the inlet sewer should be at least 3 inches above the water level in the tank. The inlet and outlet connections should be sufficiently buried or otherwise protected to prevent damage by traffic or frost.

Table 6-14 — Capacity of Septic Tanks.

Single family dwellings Number of bedrooms	Multiple dwelling units or apartments One bedroom each	Other uses Maximum fixture units served	Minimum septic tank capacity in gallons
1-3		20	1,000
4	2 Units	25	1,200
5 or 6	3	33	1,500
7 or 8	4	45	2,000
Extra bedroom 150 gal. ea.	5	55	2,250
Extra dwelling units over 10,250 gal. ea.	6	60	2,500
Extra fixture units over 100, 25 gal. per fixture unit.	7	70	2,750
	8	80	3,000
	9	90	3,250
	10	100	3,500

When a tank will discharge into a leaching field greater than 500 feet in length, a dosing tank and siphon should be incorporated into the system (*Figure 6-5*). The rush of sewage that occurs when the siphon discharges results in better distribution throughout the leaching field. While the dosing tank is refilling, the resultant resting period is favorable to maintaining aerobic conditions in the receiving soil. The dosing tank should have a capacity about 60 to 75 percent of the interior capacity of the leaching pipe to be dosed at one time and should automatically dose once in 3 to 4 hours. Double the amount of dosing siphons for each additional 500 feet of leaching tile or pipe.

Figure 6-5 — Septic tank with dosing siphon.

Although properly designed septic tanks require little operating attention, they must be inspected periodically. The frequency is determined by the size of the tank and the population load. The minimum frequency should be once every 2 months at periods of high flow. The inspection should assure that the inlet and outlet are free from clogging, that the depth of scum and sludge accumulation is not excessive, and that the effluent passing to subsurface disposal is relatively free from suspended solids. A high concentration of suspended solids in the effluent quickly clogs subsurface disposal facilities. Sludge and scum accumulation should not exceed one-fourth the tank capacity. It should not be assumed that septic tanks liquefy all solids, that they never need cleaning, and that the effluent is pure and free from germs. Perhaps 40 to 60 percent of the suspended solids are retained and the rest are discharged in the effluent. Separating sludge and scum from the liquid in septic tanks is difficult. In small tanks these wastes are customarily mixed, and the entire contents are removed when the tanks are cleaned. The material removed contains fresh or partially digested sewage solids. It must be disposed of without endangering public health. Disposal through manholes in the nearest sewer system, as approved by local authorities, or burial in shallow furrows on open land is recommended. A diaphragm type of sludge pump is best suited for removing the content of the tank. The contents should be transported in a watertight, closed container.

When installing a septic tank system for sewage treatment, you must take into consideration the location with respect to wells or other sources of water supply, topography, water table, soil characteristics, area available, and maximum building occupancy. Building occupancy is a key factor in determining tank size. *Table 6-15* shows common sewage uses based on type of facility and gallons per person per day of usage.

Table 6-15 — Sewage Flows According to Type of Establishment.

Type of Establishment	Gallons used
Schools (toilet and lavatories only)	15 gal per day per person
Schools (with above plus cafeteria)	25 gal per day per person
Schools (with above plus cafeteria and showers)	35 gal per day per person
Day workers at schools and offices	15 gal per day per person
Day camps	25 gal per day per person
Trailer parks or tourist camps (with built-in bath)	50 gal per day per person
Trailer parks or tourist camps with central bathhouse	35 gal per day per person
Work or construction camps	50 gal per day per person
Public picnic parks (toilet wastes only)	5 gal per day per person
Public picnic parks (bathhouse, showers, and flush toilets)	10 gal per day per person
Swimming pools and beaches	10 gal per day per person
Country clubs	25 gal per locker
Luxury residences and estates	150 gal per day per person
Rooming house	40 gal per day per person
Boardinghouses	50 gal per day per person
Hotels (with connecting baths)	50 gal per day per person
Hotels (with private baths--two persons per room)	100 gal per day per person
Boarding schools	100 gal per day per person
Factories (gallons/ person per shift)	25 gal per day per person
Nursing homes	75 gal per day per person
General hospitals	150 gal per day per person
Public institutions (other than hospitals)	100 gal per day per person
Restaurants (toilet and kitchen wastes per unit of serving capacity)	25 gal per day per person
Kitchen waste from hotels, camps, etc. serving 3 meals per day	10 gal per day per person
Motels	50 gal per bed space
Motels with bath, toilet, and kitchen wastes	60 gal per bed space
Drive-in theaters	5 gal per car space
Stores	400 gal per toilet room
Service stations	10 gal per vehicle served
Airports	3-5 gal per passenger
Assembly halls	2 gal per seat
Bowling alleys	75 gal per lane
Churches (small)	3-5 gal per sanctuary seat
Churches (large with kitchens)	5-7 gal per sanctuary seat
Dance halls	2 gal per day per person
Laundries (coin operated)	400 gal per machine
Service stations	1,000 gal, 500 gal (each add. bay)
Subdivisions or individual homes	75 gal per day per person
Marinas—Flush toilets	36 gal per fixture per hr
Urinals	10 gal per fixture per hr
Washbasins	15 gal per fixture per hr
Showers	150 gal per fixture per hr

The physical location of a septic tank in relation to wells must be no closer than 100 feet from a shallow well and no closer than 50 feet from a deep well. In general, a shallow well is less than 100 feet in depth and a deep well is more than 100 feet in depth. *Figure 6-6* shows a typical septic tank system layout with minimum distances noted. Keep in mind that septic tanks, cesspools, and leaching fields must be located downhill from any water source.

Figure 6-6 — Minimum distances for private disposal system.

6.2.0 Cesspools

Sewage from private dwellings and farmhouses in outlying areas may discharge into cesspools if a common sewerage system is not available. Cesspools are usually dry-laid masonry or brick-lined wells without any masonry at the bottom. The sewage flows into them and leaches out into the soil. Floating solids collect at the top and settling solids collect at the bottom of the well. The leaching capacity of the well is exhausted when the solids accumulate and clog the soil. The use of chemicals is not recommended to increase the useful life of a cesspool.

When the first cesspool becomes filled, a second well may be built to take the overflow from the first. In such cases, the first cesspool should operate as a septic tank to collect the settling and floating solids and provide a trapped outlet on the connection leading to the next leaching cesspool. Septic tanks may be placed advantageously ahead of leaching cesspools in larger installations. Leaching cesspools should not be placed closer together than 20 feet by out-to-out measurement of walls.

Leaching cesspools should be used only where the subsoil is porous to a depth of at least 8 or 10 feet and where the ground water is normally below this elevation (*Figure 6-7*). When they are located in fine sand, the leaching area can be increased by surrounding the walls with graded gravel.

Figure 6-7 — Leaching cesspool.

The number and the size of cesspools required depend on the quantity of sewage and the leaching characteristics of the total exterior percolating area above the ground water table, including bottoms and sidewalls below the maximum-flow lines. The allowable rate of sewage application per square foot per day, based on the recommended leaching test, is given below in *Table 6-16*. Soils that require more than 30 minutes for a fall of 1 inch are unsatisfactory for leaching. Some other disposal method should be used.

Table 6-16 — Allowable Rate of Sewage Application per Square per Day.

Time for water to fall 1 inch (minutes)	Allowable rate of sewage application (gallons per sq ft of percolating area per day)
1	5.3
2	4.3
5	3.2
10	2.3
30	1.1

The test for leaching should be made by digging a pit about one half of the proposed depth of the cesspool, with a test hole 1 foot square and 18 inches deep at the bottom. The test hole is filled with 6 inches of water and allowed to drain off. Six inches of water is again added, and the downward rate of percolation is measured in minutes required for the water surface to lower 1 inch in the hole.

6.3.1 Leaching Fields

Leaching fields are an integral component of a septic tank individual sewage disposal system. Leaching field may be referred to as tile fields or absorption trenches. Whichever term is used, the function, testing, construction, and maintenance techniques of this component remain the same.

The lines in a leaching field are built of 4-inch PVC perforated pipe. Many types of perforated pipe are commercially available for use in leaching-field construction.

The following conditions are important for the proper functioning of a leaching field:

- Groundwater levels well below that of the leaching field
- Soil of satisfactory leaching characteristics within a few feet of the surface extending several feet below the leaching pipe
- Subsurface drainage away from the field
- Adequate area
- Freedom from polluting drinking water supplies, particularly from shallow wells in the vicinity

Before installing a leaching field in a specified area you must perform a percolation test. This test determines whether the area selected is suitable for subsurface sewage disposal; it also helps you to determine the overall size of the leaching field in relation to trench dimensions and pipe lengths.

The test consists of digging a test pit 2 feet square and at least 1 foot in depth. The optimum depth should be at the deepest point that the leaching pipe will be laid. Next dig a hole 1 foot square by 1 foot deep in the test pit. Fill this hole with 7 inches of water for wetting purposes. Allow the water to drop to 6 inches before recording the drop time. Then note the time required for the level to drop 1 inch (from 6 to 5 inches) in depth. You can then determine the length of pipe in the leaching field by using *Table 6-17*. Note that this table is based on the assumption that 4-inch pipe will be used as recommended by the *National Standard Plumbing Code.*

Table 6-17 — The Tile Length for Each 100 Gallons of Sewage per Day.

Time in minutes for 1 inch drop	Tile length for trench widths		
	1 ft	2 ft	3 ft
1	25	13	9
2	30	15	10
3	35	18	12
5	42	21	14
10	59	30	20
15	74	37	25
20	91	46	31
25	105	53	35
30	125	63	42

In the construction of a leaching field, the installer takes into consideration the results of the percolation test, type of soil, size of pipe, depth in reference to the ground water level and frost line, and standard requirements of materials placed in the absorption trench. *Figure 6-8* shows a typical layout of a leaching field.

Figure 6-8 — Typical layout of a subsurface tile system.

The type of soil at the location of the field will dictate the width of the trench. Sand and sandy loam requires a width of 1 foot, loam and sand and clay mixture 2 feet, clay with some gravel 3 feet. Note these are minimum trench widths based on the type of soil encountered at the jobsite.

Placing the leaching pipe below the frost line to prevent freezing is not necessary. Under no circumstances can you lay leach pipe below the ground water level. When digging the absorption trenches, you must consider the lengths of each lateral and their spacing in relation to each other. Do not make any lateral longer than 100 feet in length. *Table 6-18* shows the size and spacing requirements for disposal fields.

Table 6-18 — Size and Spacing for Disposal Fields.

Width of trench at bottom (in.)	Recommended depth of trench (in.)	Spacing tile lines * (ft)	Effective absorption area per lineal ft of trench (sq. ft)
18	18 to 30	6.0	1.5
24	18 to 30	6.0	2.0
30	18 to 36	7.6	2.5
36	24 to 36	9.0	3.0
• Greater spacing is desirable where available area permits			

After the trenches are laid out and dug, filler material must be placed along with the actual pipe. The filler material may be washed gravel, crushed stone, slag, or clean bank-run gravel ranging in size from 1/2 to 2 1/2 inches. Filler material in the trench should not be less than 6 inches deep below the bottom of the pipe. It should be at least 2 inches above the pipe. To prevent backfill soil from filling the voids in the filler material, it is recommended that a 3-inch layer of medium-screened gravel with another layer of fine-screened gravel, untreated paper, or straw of 2 to 3 inches in depth be placed in the trench.

Pipe should be laid with a minimum pitch of 2 inches to a maximum pitch of 4 inches per 100 feet. When open joints are used, they must not be spaced more than 1/2 inch apart. Asphalt-treated paper should be used to cover the joint. The open joint allows for free discharge of solids from the line to the trench. The asphalt-treated paper prevents gravel from entering the pipe.

The layout of the field requires attention to detail to prevent future maintenance and operation troubles. When the field is laid on sloping ground, the flow must be distributed so each lateral gets a fair portion of the flow. Individual lines should be laid nearly parallel to land contours, Leaching fields are commonly laid out either in a herringbone pattern or with the laterals at right angles to the main distribution pipe. Little or no maintenance is required for leaching fields. Preventive measures such as excluding all vehicle traffic and not planting trees or shrubs in the field area should ensure trouble-free operation for many years. When a leaching field becomes inoperable, you must replace it with a new system. Tree or shrub roots are a major factor in leaching-field failure. This requires the replacement of field components and complete root removal.

Test your Knowledge (Select the Correct Response)

4. What is the minimum acceptable size of a septic tank, in gallons?

   A. 2,000
   B. 1,250
   C. 1,000
   D. 500

Summary

The proper treatment and disposal of sewage are important for a healthy lifestyle and can affect morale. As a UT, you have the responsibility to treat and remove the waste. In this chapter, you learned some techniques on how to test, treat and dispose of this waste. Knowing the importance of your job and taking charge in doing it right, will make you a better UT and keep your shipmates safe.

Review Questions (Select the Correct Response)

1. A heavy input of storm water into a sewage treatment plant results in what type of hydraulic problems?

   A. Underloading
   B. Bypassing
   C. Overloading
   D. Diverting

2. Within a 24-hour period, the lowest flow in a sewage treatment system is between what hours?

   A. 0000-0500 hours
   B. 0500-1000 hours
   C. 1000-1500 hours
   D. 1500-2000 hours

3. What is the normal color of wastewater containing dissolved oxygen?

   A. Black
   B. Brown
   C. Gray
   D. Green

4. Domestic sewage should have what noticeable odor?

   A. Moldy
   B. Sulphurous
   C. Grainy
   D. Musty

5. What term is used to describe suspended solids that neither settle of float in wastewater?

   A. Floatable solids
   B. Sludge
   C. Colloidal particles
   D. Sedimentation

6. Volatile solids either burn or evaporate within what temperature range?

   A. 1500°C to 1600°C
   B. 1200°C to 1300°C
   C. 700°C to 800°C
   D. 500°C to 600°C

7. The acid or base properties of a water solution is measured in _______.

   A. mg/1
   B. ml/l
   C. pH
   D. DO

8. What type of bacteria requires dissolved oxygen to remain alive?

   A. Facultative
   B. Anaerobic
   C. Aerobic
   D. Parasitic

9. A grab sample normally covers what time span, in minutes?

   A. 60
   B. 45
   C. 30
   D. 15

10. The flow proportional composite sample normally covers what time span, in hours?

   A. 48
   B. 36
   C. 24
   D. 12

11. Treatment plant influent water should be between what pH values?

   A. 8.5 to 10
   B. 6.5 to 8
   C. 4 to 6
   D. 2 to 4

12. An Imhoff cone should be used to perform which test?

   A. Dissolved oxygen
   B. Activated sludge
   C. Settleable solids
   D. Hydrogen ion concentration

13. When performing the BOD5 test, you should read one sample immediately and store the other at 20°C for exactly how many days?

   A. 7
   B. 5
   C. 3
   D. 2

14. In which test should the sample be allowed to sit for 30 minutes?

A. Dissolved oxygen
B. Activated sludge
C. Settleable solids
D. Hydrogen ion concentration

15. Which test should be used as a control test to help you decide whether to increase or decrease the rate of sludge return?

A. pH
B. MLSS
C. BOD5
D. COD

16. Which test should be performed within 30 minutes of taking a sample?

A. Total suspended solids
B. Mixed liquor suspended solids
C. Chlorine residual
D. Fecal coliform

17. After a sample is chilled to 4°C, a fecal coliform test should be performed within how many hours?

A. 12
B. 9
C. 6
D. 3

18. What is the cheapest operating effluent discharge method?

A. Intermittent
B. Continuous
C. Direct discharge
D. Indirect discharge

19. What type of effluent discharge requires a place to store the effluent?

A. Intermittent
B. Continuous
C. Direct discharge
D. Indirect discharge

20. Vegetation around evaporation and percolation basins should not be allowed to exceed what maximum height, in inches?

A. 24
B. 20
C. 15
D. 10

21. Trees should not be allowed to grow within how many feet of wastewater lagoons?

A. 500
B. 450
C. 200
D. 150

22. When a septic tank discharges into a leaching field greater than 500 feet in length, you should incorporate what component(s) into the system?

A. Dosing tank only
B. Siphon only
C. Dosing tank and siphon
D. Inlet and outlet filters

23. Regardless of size, a septic tank should be inspected at what standard intervals, in months?

A. 18
B. 12
C. 6
D. 2

24. What is the minimum distance in feet that a shallow well can be located from a septic tank?

A. 250
B. 200
C. 150
D. 100

25. What is the minimum distance in feet that leaching cesspools can be located from each other?

A. 40
B. 30
C. 20
D. 10

26. What inch diameter size of perforated pipe is used in leaching fields?

A. 10
B. 8
C. 6
D. 4

27. What is the maximum allowable length in feet of a leaching field lateral?

A. 125
B. 100
C. 75
D. 50

28. When a leaching field becomes inoperable, you must consider what option?

A. Chemical cleaning
B. System replacement
C. Adding additional piping
D. Pumping the septic tank

Trade Terms Introduced In This Chapter

influent	The passageway leading into the water treatment plant.
suspended solids	Deposits of waste that are floating within the wastewater.
floatable solids	Deposits of waste that float on the wastewater.
sludge	Deposits of waste that settle to the bottom of the wastewater.
colloidal particles	Deposits that are neither floating nor settle to the bottom.

Additional Resources and References

This chapter is intended to present thorough resources for task training. The following reference works are suggested for further study. This is optional material for continued education rather than for task training.

OSHA Regulations (Standards – 29 CFR)

Naval Construction Force Manual, *NAVFAC P-315*, Naval Facilities Engineering Command, Washington, D.C., 1985.

Facilities Planning Guide, NAVFAC P-437, Volumes 1 and 2, Naval Facilities Engineering Command, Alexandria, VA, 1982.

Maintenance and Operation of Water Supply , Treatment and Distribution Systems, NAVFACMO - 210 , Naval Facilities Engineering Command, Alexandria, VA, 1984.

Fluid Power, NAVEDTRA 12964, Naval Education and Training Professional Development and Technology Center, Pensacola, FL, 1994.

Water Purification Unit , Reverse Osmosis 600 – GPH Trailer Mounted, TM-5-4610-215-24, Department of the Army, Washington, DC, 1983.

Water Supply Point Equipment and Operation, FM-10-52-1, Headquarters Department of the Army, Washington, DC, 1991.

Plumbing Manual, Volume II, NTTC Course 140-B, NAVFAC P-376, NAVFAC Technical Training Center, Navy Public Works Center, Norfolk, VA, 1965.

Safety and Health Requirements Manual, EM-385-1-1, Department of the Army, U.S. Army Corps of Engineers, Washington, DC, 1992.

Chapter 10,National Standard Plumbing Code, Illustrated, National Association of Plumbing-Heating-Cooling Contractors, Falls Church, VA, 1990.

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Chapter 7

Compressed Air Systems

Topics

To hear audio, click on the box.

Overview

The Utilitiesman is involved in the installation of compressed air systems. The senior UT must be capable of identifying and directing the proper construction techniques for installation of fittings and components. You will also be involved in the maintenance of systems installed previously. In this chapter, compressed air systems and air quality requirements are also discussed.

Objectives

When you have completed this chapter, you will be able to do the following:

1. Identify the classifications of compressed air systems.
2. Identify the air quality requirements.
3. Describe the components of air compressors and auxiliary equipment.
4. Describe the different types of distribution systems.
5. Describe the maintenance requirements associated with air compressor systems.

Prerequisites

None.

This course map shows all of the chapters in Utilitiesman Advanced. The suggested training order begins at the bottom and proceeds up. Skill levels increase as you advance on the course map.

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Features of this Manual

This manual has several features which make it easier to use online.

- Figure and table numbers in the text are italicized. The figure or table is either next to or below the text that refers to it.
- The first time a glossary term appears in the text, it is bold and italicized. When your cursor crosses over that word or phrase, a popup box displays with the appropriate definition.
- Audio and video clips are included in the text, with an italicized instruction telling you where to click to activate it.
- Review questions that apply to a section are listed under the Test Your Knowledge banner at the end of the section. Select the answer you choose. If the answer is correct, you will be taken to the next section heading. If the answer is incorrect, you will be taken to the area in the chapter where the information is for review. When you have completed your review, select anywhere in that area to return to the review question. Try to answer the question again.
- Review questions are included at the end of this chapter. Select the answer you choose. If the answer is correct, you will be taken to the next question. If the answer is incorrect, you will be taken to the area in the chapter where the information is for review. When you have completed your review, select anywhere in that area to return to the review question. Try to answer the question again.

1.0.0 SYSTEM CLASSIFICATIONS

Compressed air is a form of power that has many important uses in industrial activities. An air compressor plant (*Figure 7-1*) is required to supply air of adequate volume, quality, and pressure at the various points of application. Compressed air is stated as pounds per square inch gauge (psig). These plants or systems are classified as low-pressure (0 to 125 psig), medium-pressure (126 to 399 psig), or high-pressure (400 to 6,000 psig) systems.

Figure 7-1 — Air compressor plant.

1.1.1 Low-Pressure Systems

Low-pressure systems provide compressed air up to 125 psig pressure. When you are installing a low-pressure system, pressure is usually reduced at reducing stations for branches requiring lower pressures. Several air pressure requirements for low-pressure air consumers are listed below:

- Laboratories - 5 to 50 psig
- Shops - 60 to 125 psig
- Laundries and dry cleaning plants - 70 to 100 psig
- Hospitals - 20 to 50 psig