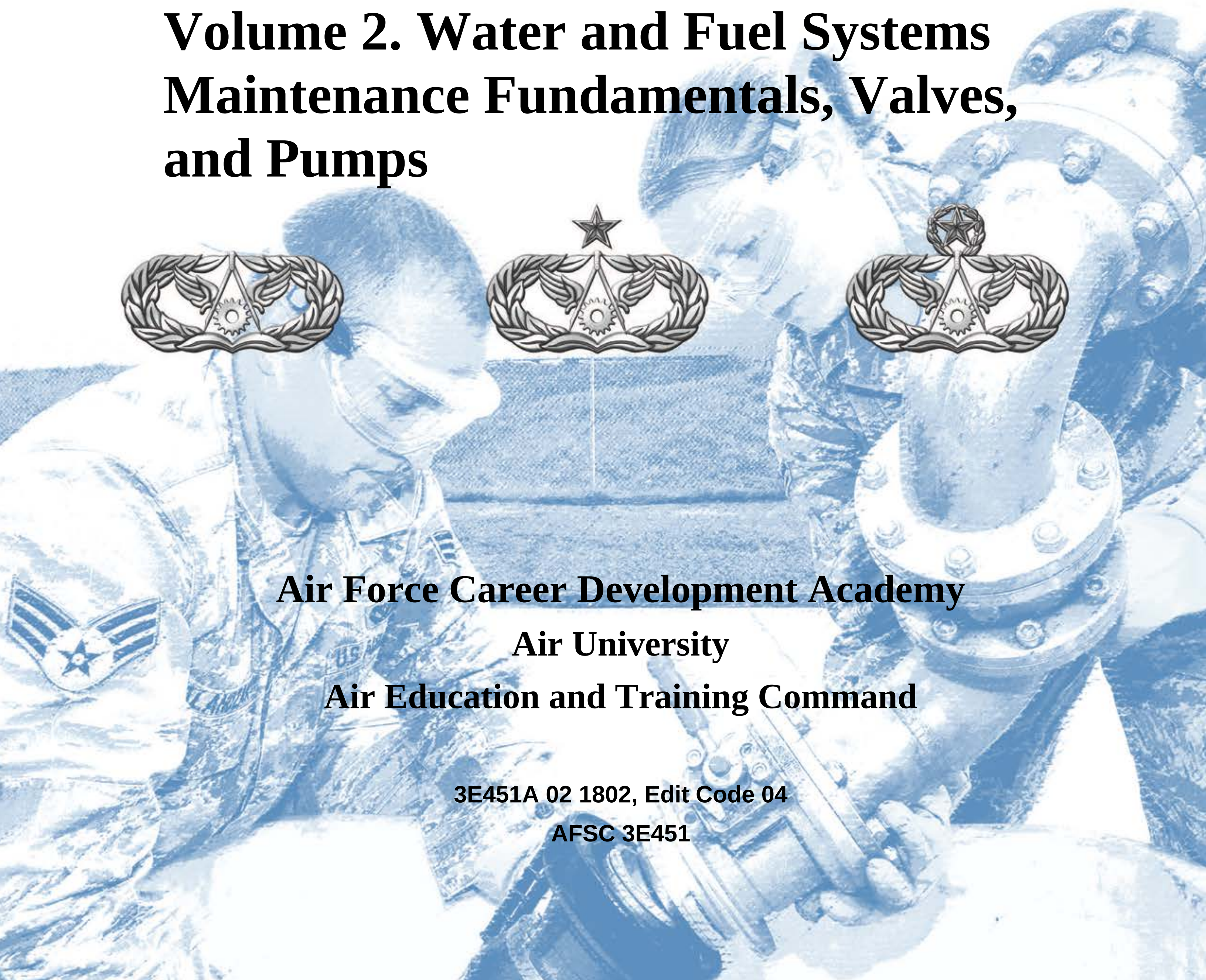
CDC 3E451A

Water and Fuel Systems Maintenance Journeyman

Volume 2. Water and Fuel Systems Maintenance Fundamentals, Valves, and Pumps



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THIS COURSE was designed with you, the student, in mind. We have taken the most recent information and expanded on the instructions taught at the Water and Fuel Systems Maintenance (WFSM) technical school. You will find that the information in this course is to the point and relies on supervisor involvement. Please do your part and answer the questions about the subjects covered.

This volume contains three units. In unit 1, we discuss water and fuel system fundamentals, including plans and sketches and plumbing fundamentals. In unit 2, we discuss construction and maintenance requirements of manual valves and specialized valves and replacement. In unit 3, we discuss positive and nonpositive displacement pumps and the operation and maintenance of the nonsurge check valve.

As you complete this course, you'll gain the knowledge that if applied with on the job training will give you the skills required to advance beyond the apprentice level. Read and study each lesson, do the self-test questions and complete the mentioned training qualification packages, and you will master the contents of this course.

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This volume is valued at 12 hours and 4 points.

Acknowledgment

PREPARATION of this volume was aided through the cooperation and courtesy of the following companies. Permission to use this information is gratefully acknowledged.

Company	Figure
Peerless Pump	3–12
John Crane Mechanical Seal	3–23
Dura Seal Mechanical Seal	3–24
General Twin Seal Valve Co	2–8, 2–10
CLA-VAL Company	3–25, 3–26, 3–27, 3–28, 3–29

NOTE:

In this volume, the subject matter is divided into self-contained units. A unit menu begins each unit, identifying the lesson headings and numbers. After reading the unit menu page and unit introduction, study the section, answer the self-test questions, and compare your answers with those given at the end of the unit. Then complete the unit review exercises.

Unit 1. Water and Fuel Systems Fundamentals

THE PURPOSE OF THIS UNIT is to refresh and build on some basic knowledge of the Water and Fuel Systems Maintenance (WFSM) career field. In this unit, you will learn about the basic maintenance of tools and equipment, planning jobs, and reading schematics. We will also discuss the essential math, biology, and chemistry to help you determine volume, flow, and specific quantities required for daily operations.

1–1. Plans and Sketches

Throughout your career, you will have to plan projects, interpret structural plans, and create drawings for plumbing projects. Knowing how to draw and interpret symbols is not only essential for your own planning, but key for workers who will have to interpret the plans you've drawn. Your ability to read plans is essential for proper installation of plumbing fixtures and piping and for determining appropriate valve locations.

201. Planning work requirements

It is essential to start any job planning with the full picture in mind. Utilize blueprints, sketches, and information from the end user to lay out a firm plan of attack to complete your project successfully. The below information is to help you start thinking how to best plan your project, but it is up to you to make your plan a success.

Planning work

The shop supervisor assigns a work request to a planner who researches the material requirements for the project. In this section, we will discuss how to plan your project.

A planner's responsibilities are:

- *Visit* the job site if necessary to determine the actual material requirements.
- *Write* a list of materials needed.
- *Draw* sketches and figure out work requirements.
- *Prepare* bill of materials (BOM).
- *Send* documents back to supervisor for approval.

Planners must fill material documents out properly to ensure that all the materials are on the correct documents. If the materials are identified properly and something else is received, civil engineering (CE) does not have to accept those materials. However, if a planner orders the wrong item by mistake, CE must accept the material and has to buy it, even if it can't be used for that job.

Let's look at the avenues that you may use to order the material. We'll cover construction plans and sketches later. Whenever a work requirement is identified, material will probably be needed to complete the work. The following short discussions and definitions will reinforce material support, requisition, and flow briefly covered in volume one.

Common definitions

Here we will cover some common definitions needed to understand the material ordering process within the CE organization. Knowing these terms will help you understand where to acquire materials that may already exist for your project. It is important that we use our excess material before ordering new materials for our projects; this allows you to be fiscally conservative with taxpayer's dollars.

Bench stock

This is a storage area in logistics where routinely used, high-use materials are stored. These are your everyday items such as polyvinyl chloride (PVC) pipe and fittings, glue, cleaner, nails, and so forth. Your Do-It-Now (DIN) truck will routinely stop here to restock the items on the truck; this allows them to complete urgent and routine calls with ease.

Shop stock

Shop stock is items partially used (broken issue) on work that can't be turned back into logistics. The shops will use up these materials on a day-to-day basis on various jobs. These items should be stored for easy visibility and access.

Holding area

This is an area *within CE* where ordered materials are held for a work order. As your BOM items arrive on base, you can check the status of your order. You may also need to verify that you're receiving the correct materials and equipment for the planned project. Once the order is received in full, you can complete the job you planned.

Residue holding area

Sometimes all the material ordered for a job is not used. When this happens, the supervisor ensures that the residue (excess) materials or equipment is cleaned, inventoried, and labeled with a condition tag and also ensures the item is then turned into logistics with the appropriate documentation for further processing. The area where these materials are stored is the residue holding area. The work authorization documents are not complete until the excess or residue materials or equipment is moved to the residue holding area. When planning your job, always check materials stored in residue and use those items before ordering new material for your project.

Civil engineer material acquisition system

Civil Engineer Material Acquisition System (CEMAS) is a computerized system used for identifying, acquiring, and controlling material requirements. Using CEMAS reduces paperwork required for ordering material because this part of the Work Information Management System (WIMS) can be used to order material via the computer.

Bill of materials

A BOM is a tabulated list of materials for a job showing the name, description, quantity, stock number, size, and sometimes the cost of the different items. Quantities are often taken from the plans or drawing by listing one item at a time.

When a special type valve or fitting is required for a certain job, locate the item in a commercial manual. Show the manufacturer's number and type to ensure positive identification. A BOM in which the cost must be listed requires that each item be researched in manufacturers' catalogs to obtain the unit cost. Include a list of so-called take-off items in the BOM. These are items known to be necessary to complete the job but are not included on the prints or drawings. They include such items as thread-cutting oil, joint compounds, and bolts or screws for attaching brackets.

To correctly order materials for your BOM:

- Properly label the name of the material or equipment ordered.
- Identify the item's manufacturer correctly; if you need a CLA-VAL part make sure you identify it by name.
- Correctly identify the amount needed. Do not order a box of ½" PVC fittings when you need two. Ordering 50 feet of tubing is significantly different from ordering 50 each. Be careful not to over order; this is wasteful and can be quite costly for your squadron.

202. Preventive maintenance

When planning your job, you need to be acutely aware of the maintenance requirements for the facility you will be repairing or constructing an addition to. We call this forethought into maintenance recurring work, and the Air Force (AF) has established a well-organized system to ensure that we extend our assets' useable life as much as possible. Next, we will discuss the preventive maintenance (PM) program and how it applies to your work center. You can find further information in the following instructions:

- Air Force Instruction (AFI) 32–1001, *Operations Management*.
- *Preventive Maintenance Playbook* on the United States Air Force (USAF) Civil Engineer Portal.

Preventive maintenance

PM (according to AFI 32–1001) applies to real property, real property installed equipment (RPIE) or systems, and other requirements maintained by the base civil engineer (BCE). PM will identify, forecast, and align maintenance actions to manage mission risks, ensure critical infrastructure components receive an appropriate level of PM, and maximize the life cycle of our existing and new equipment. Unlike other work orders, we know the scope and level of effort to perform recurring work. This eliminates the requirements to conduct an earlier visit to the job site each time the work is scheduled. PM includes work to prevent breakdown of critical facilities, equipment, or utilities. Except for utility operations and contracted services, the PM program encompasses all work of a normal preventive nature. Shop supervisors manage the program to ensure PM work is accomplished immediately after emergency and urgent work requirements. Shop supervisors do this by reserving hours for this work before other routine requirements are scheduled.

Element/shop responsibilities

All operations flight shops are responsible for the PM program. The operations flight must inventory and conditionally assess PM assets. PM tasks must be defined, standardized, balanced, scheduled, monitored, and measured addressing life-cycle management and return on investment (ROI) as part of the PM program. These activities must be executed by the civil engineering squadron (CES) operations engineering element (CES/CEOE) in concert with the heavy repair element (CES/CEOH), facility systems element (CES/CEOF), and infrastructure systems element (CES/CEOI). Material acquisition (logistics) maintains the appropriate stock levels of parts. They maintain this stock in either the CE supply store or forward stores/shop stocks. Operations engineering oversees the PM program's development and conducts assessments. This program review assesses the shop's PM requirements and makes recommendations to improve its effectiveness, efficiency, and manpower employment. First-line supervisors monitor daily completion of PM.

Work analysis

Some PM is service or operations related. Other work, such as flight-line sweeping or snow removal, is a service provided by the pavements and grounds work center of heavy repair and is typically listed as a work item in the PM. However, most is PM work, such as periodically testing and inspecting fire systems and backflow prevention devices on the installation. This type of PM often requires operations engineering analysis support and a close working relationship among all elements of the operations flight.

Operations engineering

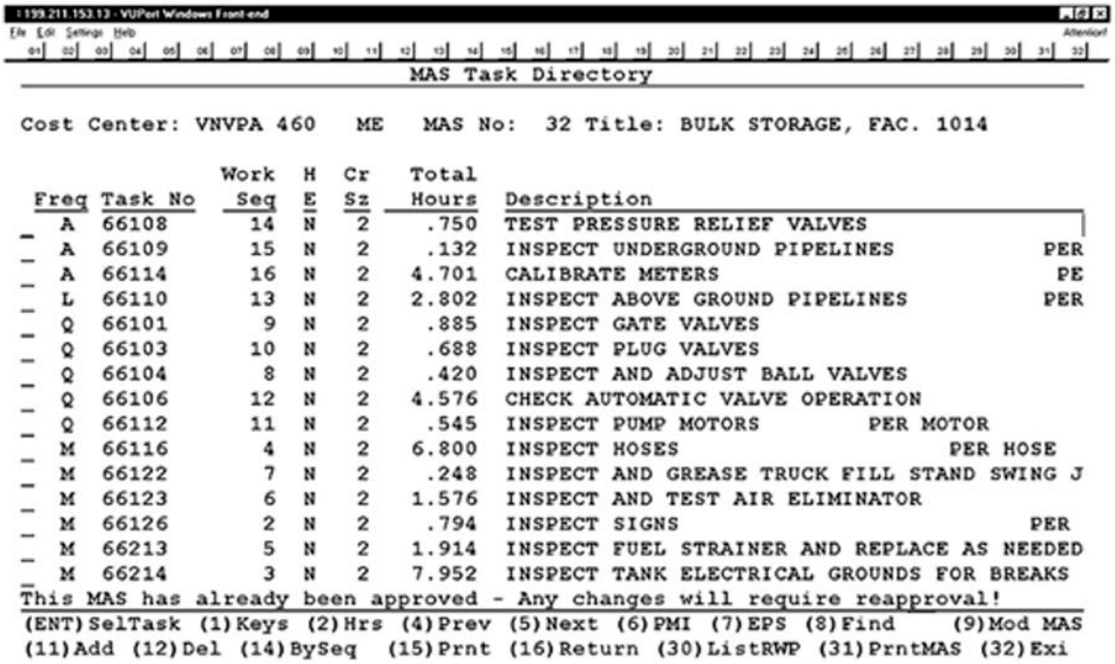
CEOE conducts an annual assessment for each shop’s PM program. Armed with this assessment, the work center improves its program and ensures manpower use in the most cost-effective manner. The challenge is to evaluate the long-term costs associated with PM schedules compared to the replacement costs of not performing maintenance and a resulting breakdown. Often, we can replace inexpensive, non-critical items, such as pumps, at a cheaper cost than the long-term PM costs to extend their life. However, downtime of some mission-critical WFSM equipment could cost the government not only the replacement cost of an expensive component, but also the downtime of the mission and, potentially, critical equipment in the facility. The task for CEOE is to strike a balance between appropriate PM and acceptable breakdown costs.

Maintenance action sheet

The first step to initiate the recurring work program process begins with the Interim Work Information Management System (IWIMS)-generated AF Information Management Tool (IMT) 1841, Maintenance Action Sheet (MAS). In the future, the preventive maintenance task list (PMTL) (fig. 1–1) will replace MAS sheets when IWIMS is replaced by the NexGen information technology (IT) solution using TRIRIGA software. When the AF brings a real property system or equipment on line, the shop or zone generates the MAS. The MAS (fig. 1–2) describes the system or equipment and outlines its maintenance requirement—including level of effort, frequency, materials, and labor-hours. We use the information from the MAS to generate the PM record—which is also an IWIMS-generated product. To generate the MAS and PM record, you must understand task intervals, hourly estimations, and multi-shop equipment support requirements.

Equipment Type:		**G3065 310 1950 52**	**Task Frequency**				
Component:		**Valve, Lubricated Plug, above 2”**					
PM Components (Task Description)			**Labor-hrs**	**W**	**M**	**Q**	**S**	**A**
1	Pressurize entire system, inspect flanged and threaded connections for leaks		0.170	X	X	X	X	X
2	Inspect for cleanliness		0.080	X	X	X	X	X
3	Open and close valve to check for ease of operation		0.080	X	X	X	X	X
4	Lubricate valve operator stems and all grease fittings		0.120			X	X	X
5	Inspect valve exterior for corrosion and tightness of bolts. Repaint/tighten as required		0.050				X	X
6	Ensure valve is properly labeled with numbering and normal position, verifying number with posted schematics		0.120				X	X
7	If additional maintenance actions are required, compile list of discrepancies and open corrective maintenance job order(s) to make the repairs		0.167	X	X	X	X	X
	Weekly		0.497					
	Total Weekly		18.886					
	Monthly		0.497					
	Total Monthly		3.976					
	Quarterly		0.617					
	Total Quarterly		1.234					
	Semiannually		0.787					
	Annually		0.787					
	Annualized		25.750					

Figure 1–1. Preventive maintenance task list.



MAS Task Directory

Cost Center: VNVPA 460 ME MAS No: 32 Title: BULK STORAGE, FAC. 1014

Freq	Task No	Work Seq	H E	Cr Sz	Total Hours	Description
A	66108	14	N	2	.750	TEST PRESSURE RELIEF VALVES
A	66109	15	N	2	.132	INSPECT UNDERGROUND PIPELINES PER
A	66114	16	N	2	4.701	CALIBRATE METERS PE
L	66110	13	N	2	2.802	INSPECT ABOVE GROUND PIPELINES PER
Q	66101	9	N	2	.885	INSPECT GATE VALVES
Q	66103	10	N	2	.688	INSPECT PLUG VALVES
Q	66104	8	N	2	.420	INSPECT AND ADJUST BALL VALVES
Q	66106	12	N	2	4.576	CHECK AUTOMATIC VALVE OPERATION
Q	66112	11	N	2	.545	INSPECT PUMP MOTORS PER MOTOR
M	66116	4	N	2	6.800	INSPECT HOSES PER HOSE
M	66122	7	N	2	.248	INSPECT AND GREASE TRUCK FILL STAND SWING J
M	66123	6	N	2	1.576	INSPECT AND TEST AIR ELIMINATOR
M	66126	2	N	2	.794	INSPECT SIGNS PER
M	66213	5	N	2	1.914	INSPECT FUEL STRAINER AND REPLACE AS NEEDED
M	66214	3	N	2	7.952	INSPECT TANK ELECTRICAL GROUNDS FOR BREAKS

This MAS has already been approved - Any changes will require reapproval!

(ENT) SelTask (1) Keys (2) Hrs (4) Prev (5) Next (6) PMI (7) EPS (8) Find (9) Mod MAS
(11) Add (12) Del (14) BySeq (15) Prnt (16) Return (30) ListRWP (31) PrntMAS (32) Exi

Figure 1–2. AF IMT 1841, Maintenance Action Sheet (Automated).

Task intervals

We refer to task intervals as frequencies. When there is more than one frequency, or multiple frequencies, we must distinguish between high and low frequencies. Higher and lower refers to how often a frequency occurs compared to another frequency. A lower frequency indicates a frequency that occurs less often than another frequency.

For example, a monthly frequency is lower than a weekly frequency because a monthly frequency occurs 12 times a year, whereas a weekly frequency occurs 52 times a year. A higher frequency example is monthly compared to quarterly, or quarterly compared to annual. A monthly frequency occurs 12 times each year, a quarterly frequency occurs four times each year, and an annual frequency occurs once each year. In other words, frequency is relative to what you are comparing it to. Task intervals are associated with a MAS sheet that details the actions to be taken at that interval. Lower task intervals include all higher task intervals and their associated MAS.

If you find this confusing, refer to the chart below then re-read this paragraph. Try to picture MAS as things you would do to your car and task intervals as how often you do them. Now consider that semi-annually you are scheduled to detail clean your car. However, as you know, you also do all the higher frequencies (in this example: wash, vacuum, and wax) besides the one that is “due.”

AUTO MAINTENANCE	
ANNUALLY	TOUCH UP PAINT
SEMI-ANNUALLY	DETAIL CLEAN
QUARTERLY	WAX
MONTHLY	VACUUM
WEEKLY	WASH

Estimated hours

On the MAS, estimated hours are based on identifying tasks and estimating task hours. We use facilities maintenance and repair cost data and local estimates to identify tasks. For tasks with multiple frequencies, the estimated hours are the hours for a specific frequency, plus the estimated hours for any higher frequencies. The estimated hours and tasks for a higher frequency are programmatically added to the estimated hours and tasks for a lower frequency. For example, an item has a monthly, quarterly, and annual frequency. In the MAS building process, the annual frequency contains all tasks and hours identified to be performed on the quarterly and monthly frequency plus additional tasks and hours to be performed once each year. The quarterly frequency includes all monthly tasks/hours plus additional tasks/hours to be performed four times each year.

Labor reporting

Use the operations and maintenance (O&M) labor program to report PM labor and frequency status. Report labor hours according to the individual equipment type and number. The labor program updates the daily labor record, the actual hours on the BCE Weekly Work Schedule, the PM record, and any corresponding financial management records.

The PM program accomplishes preventive maintenance before a system breaks; therefore, it is *proactive* instead of *reactive*. This lesson addressed the multi facets of the PM program including when it is cost effective to do PM and when it is not economical.

203. Use construction plans

The WFSM language is indicated on prints and drawings by the use of symbols. We use a series of symbols to indicate the type and location of materials, pipe runs, fittings, and fixtures on prints. Just think of these symbols as a form of shorthand.

In order to understand construction plans, it's critical that you learn the plumbing symbols and their meaning as shown in figure 1–3.

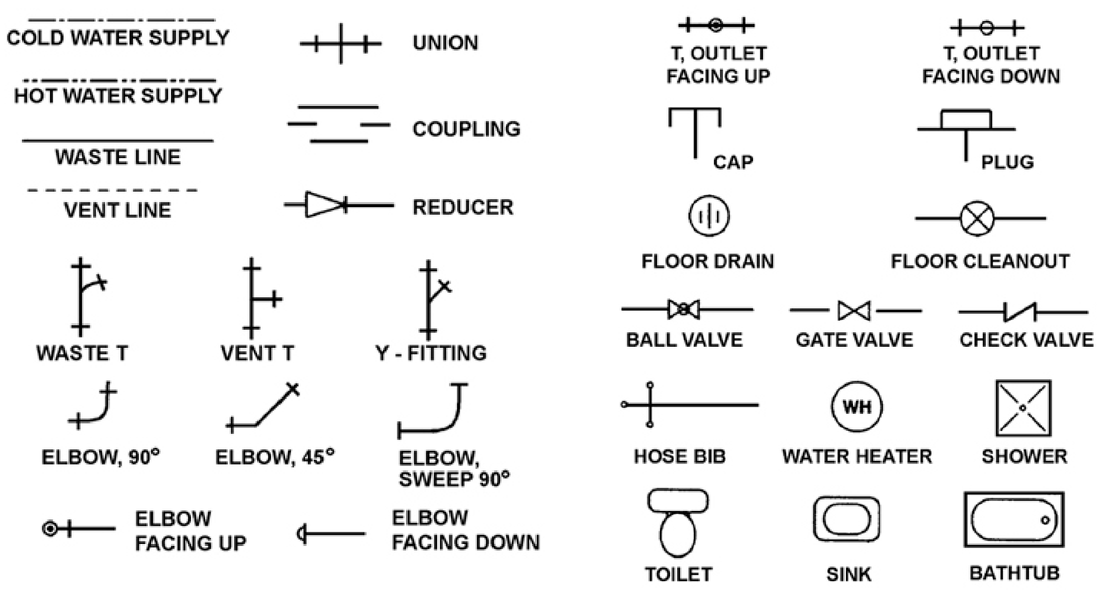


Figure 1–3. Plumbing symbols.

The blueprints for larger buildings are divided into three sets—structural, architectural, and mechanical.

Structural blueprints

These prints show the supporting structure of the building. This includes the necessary pilings, footings, foundation walls, columns, beams, floor slabs, and roof.

Architectural blueprints

Architectural blueprints are the complete building plan, except for structural and mechanical details. Architectural blueprints show framing, walls, partitions, wall-finish schedules, trim, cabinets, and all the measurements for walls and partitions.

Plot plan

A plot plan—also called site plan—shows boundaries of the construction site and the location of the building in relation to these boundaries. It shows the ground contour, roads, and walks and locates the utility lines such as sewer, water, gas, and so forth. Figure 1–4 shows a plot plan. This plan is drawn to scale (i.e., ¼ inch = 1 foot [ft.]). This means ¼ inch on the print equals 1 ft. The scale is usually found at the bottom of the print.

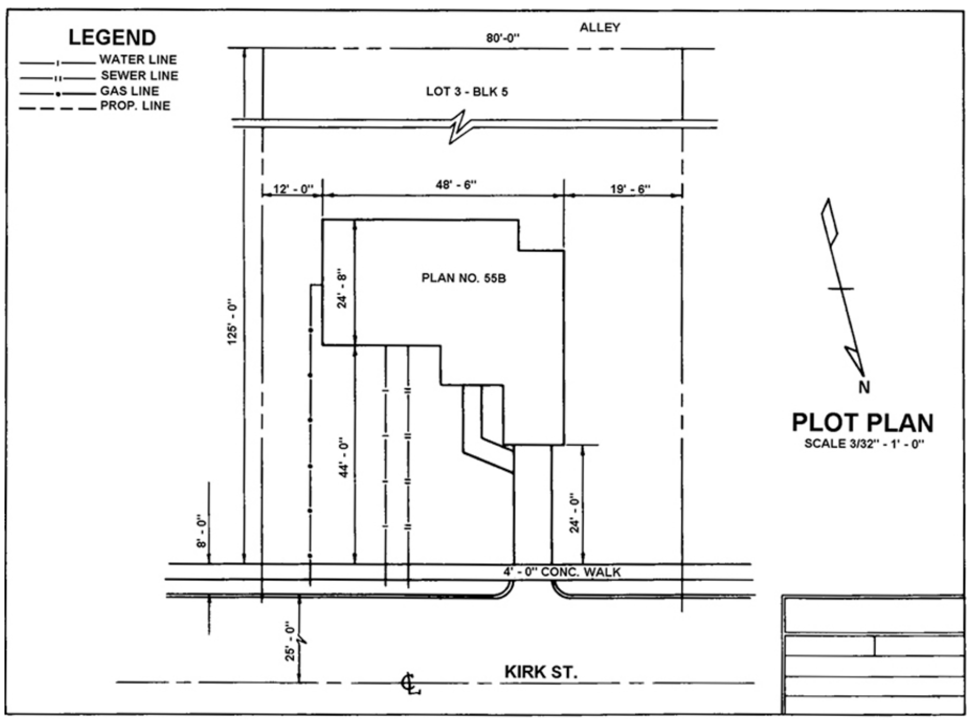


Figure 1–4. Plot plan.

Foundation plan

The foundation is the starting point of the actual construction. This plan shows a top view of the footings or foundation walls and their area and location by distances between centerlines and distances from reference lines or boundary lines. Foundation plans help us locate utility service entrances to the building.

Floor plan

A floor plan is a cross-sectional view of the building or structure, much as if you cut the top off a building, as shown in figure 1–5. If the structure has more than one floor, there will be a floor plan for each floor. The plan will show the outside shape of the building and the arrangement (type, size, and location) of doors and windows. In addition, the floor plan shows heating, lighting, and plumbing fixtures. Another item found on a print is the construction notes, which give information on how to do the work.

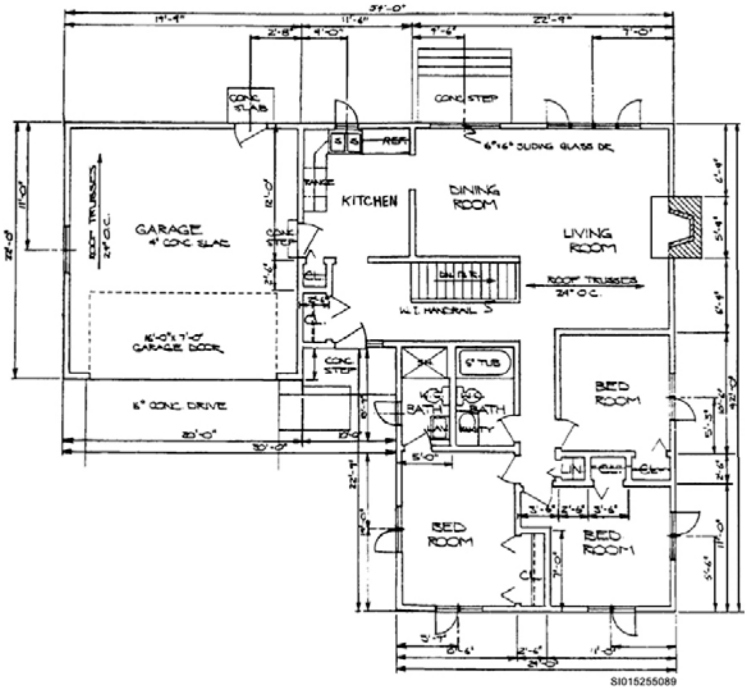


Figure 1–5. Floor plan.

Mechanical blueprints

Mechanical blueprints show the plumbing, heating/air conditioning, and electrical systems of the building. The mechanical blueprints are an outline of the architectural blueprints, but in the case of the plumbing systems, give a complete drawing of the plumbing fixture installation and piping. Figure 1–6 shows a plumbing plan. On smaller buildings, the structural and mechanical blueprints typically are incorporated in the architectural blueprints.

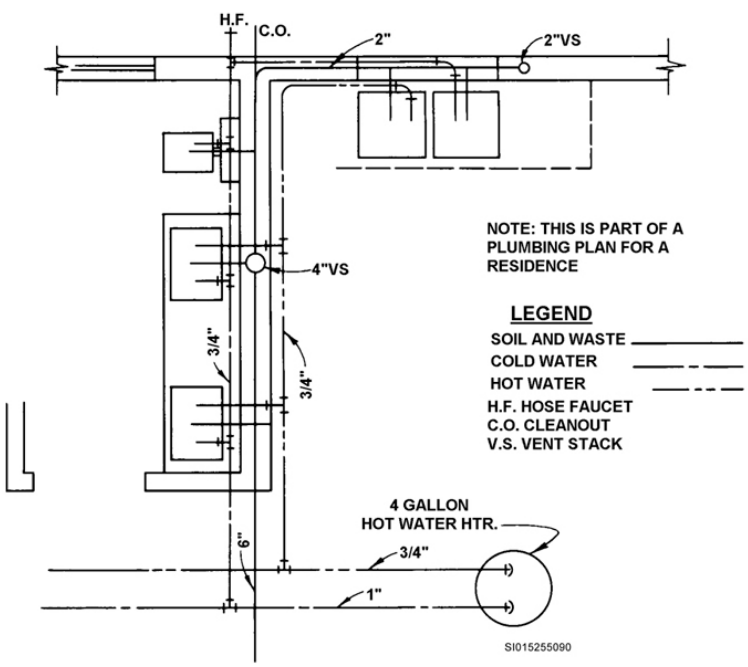


Figure 1–6. Plumbing plan.

Base utility maps

Base utility maps are also of interest to us. They are also drawn to scale. These maps show you where the water, sewer, gas systems, liquid fuel systems, and main electrical systems on base are located. Each of these systems will have their own “tab” or specific map showing only a particular system. An example of a water utility map is shown in figure 1–7. Most of these maps show the location of valves; fire hydrants; manholes; and water, sewer, and gas lines to and from buildings. They also indicate the size and type of pipe in some cases. Any time you make a change in a utility system (such as adding a new cutoff valve to a waterline), note the change on the utility map, and notify the engineering section. This also applies to the prints for buildings.

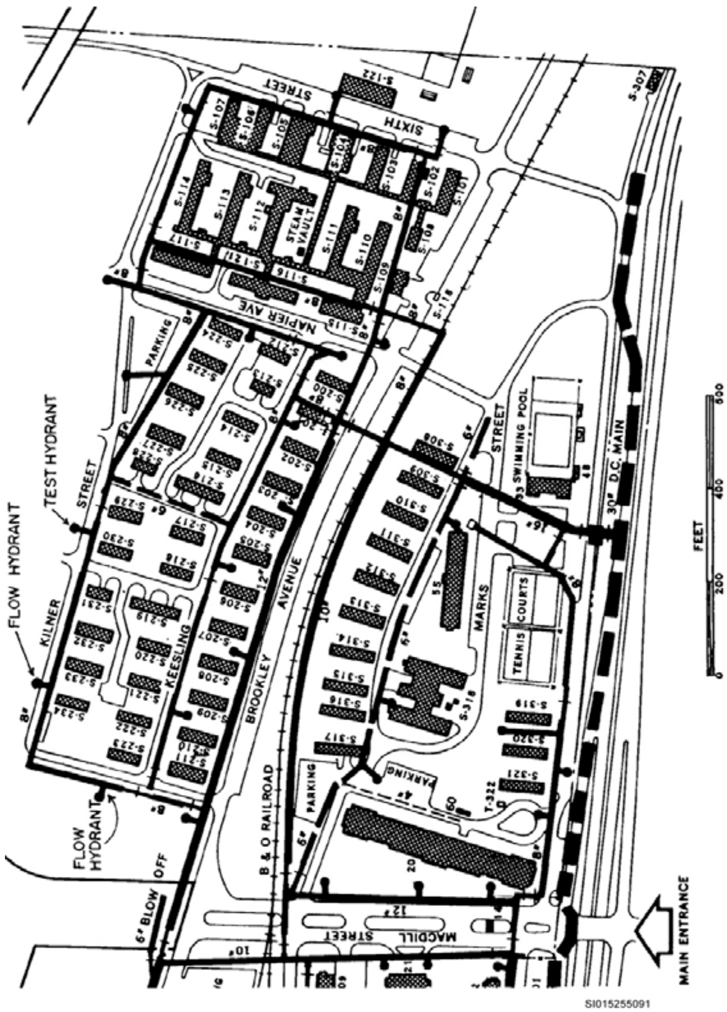


Figure 1–7. Base utilities map.

As a WFSM journeyman, one of your many tasks will be to mark or “locate” underground piping systems. Usually before underground work can begin, you will have to go out and mark the area where sewer, water, and gas system piping lies. The main method to accomplish this task is with utility maps.

204. Sketches

As a WFSM specialist, you make sketches of plumbing systems from which to work. Working sketches are simple line drawings using symbols to indicate plumbing lines and fixtures. A working sketch includes all piping, fittings, fixtures, and dimensions. Three types of sketches are used: the top, side, and isometric views. The top view (fig. 1–8) is the most common.

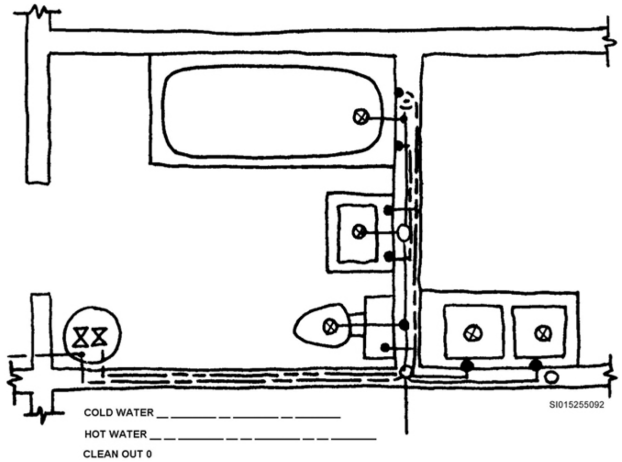


Figure 1–8. Top view of a working sketch.

Planning your work

Thorough planning is the key to successfully and efficiently completing any job. For repairing, modifying, replacing, or fabricating new systems, a review of existing plans, drawings, and schematics is your first step. This review can give you insight to the types of materials needed and some problems you may encounter before tearing into a wall or dismantling a system. If it is a simple job, a couple of pipe measurements and a short list of fittings and materials will be all that is written down on your notepad. However, if the job is more complex, then sketching your work will prove to be a valuable tool in getting the job done right.

There are many different types of materials used in the pipe fitting of water systems than there are for fuel. Fuel systems, almost exclusively, will use copper and stainless steel tubing as well as black iron and stainless steel pipe. Connections for fuel pipes over 2 inches will have welded and welded-flange joints for piping above ground and only welded joints for work that is buried. Any welded work on fuel piping requires a welder qualified by the major command (MAJCOM) fuels engineer or an American Petroleum Institute (API) certified welder. So for the most part, fuel systems pipe fitting work will be on lines smaller than 2 inches. Regardless of which water or fuel system being worked on, pipe-fitting is an art requiring some planning and measuring before doing the job.

Sketching your work

Your first task in sketching your work is to determine how the pipe is to be routed. Make a crude drawing of how you want the line to run (fig. 1–9). The drawing has to mean something to you, but it need not be fancy. Keep safety in mind! If possible, you do not want to route pipe that may cause a tripping or collision hazard. Also keep future maintenance in mind. You may need to add fittings such as a union to accomplish this. Now take measurements according to your planned routing.

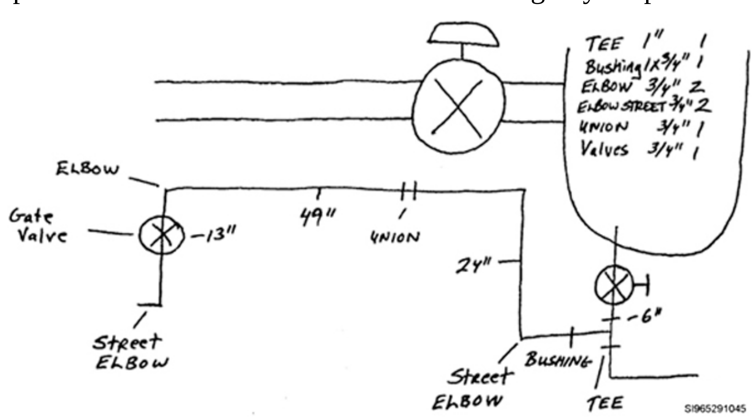


Figure 1–9. Sketch your work.

Selecting the fittings

Look at your drawing and determine what type of fittings and size pipe you are going to need. If you are connecting into existing piping, their composition (i.e., cast iron, black iron) and sizes must be noted to make your pipe and fitting determinations. Remember to annotate the 90-, 45-, and 22.5-degree turns you will need in your drawing. A good thought to keep in mind here is that the fewer fittings needed, the fewer places exist where leaks can occur. For fuel systems this is very important. Fuel leaks are always handled as emergencies because of their explosive or fire potentials.

Use the side view (fig. 1–10) and isometric sketch (fig. 1–11) when information cannot be given clearly in a top-view drawing.

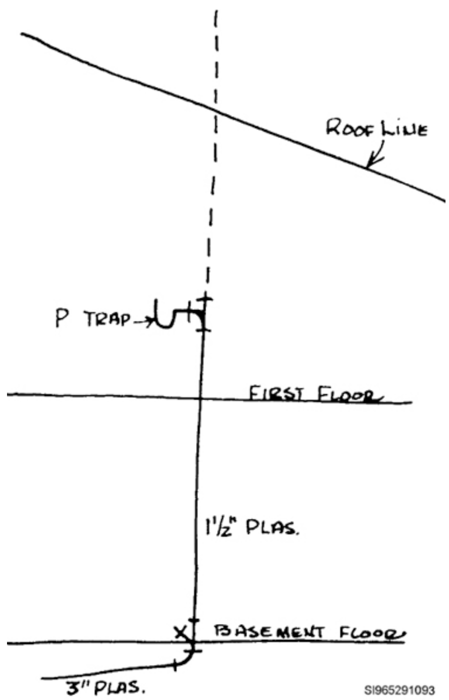


Figure 1–10. Side view of a working sketch.

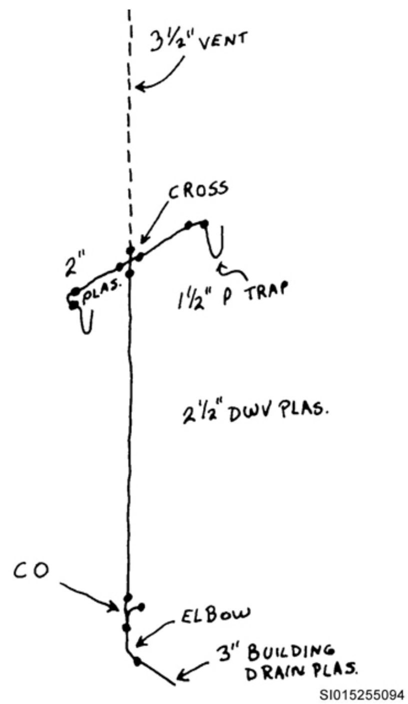


Figure 1–11. Isometric view of a working sketch.

Specifications

A specification (fig. 1–12) is a written document that supplements the building plans by explaining points that are not readily explained by the drawings. Specifications usually begin with a statement on the general conditions of the contract and then consider the various phases of construction. Each phase of construction is related to a particular operation or material. A separate specification sheet is written for each phase of construction, and these are compiled to parallel the job sequence.

The specifications cover type and quality of material, kind and quality of labor to be used, methods of construction, standards of workmanship, kinds of equipment delivery, and storage of materials. Inspection of work, protection of finished work, and many other points could not be covered if drawings alone were used. Specifications documents all of these items.

VITREOUS CHINA LAVATORY

NOM. SIZE	L	W	O	C	A	N
20 X 18"	20"	18"	7 1/4"	2 7/8"	6"	3 1/2"
24 X 20"	24"	20"	8"	3 1/8"	7"	4"

PLUMBERS NOTE - PROVIDE SUITABLE REINFORCEMENT FOR ALL WALL SUPPORTS. THESE ROUGH-IN MEASUREMENTS MAY VARY 1/4" (PLUS OR MINUS) AND ARE FOR THIS JOB ONLY.

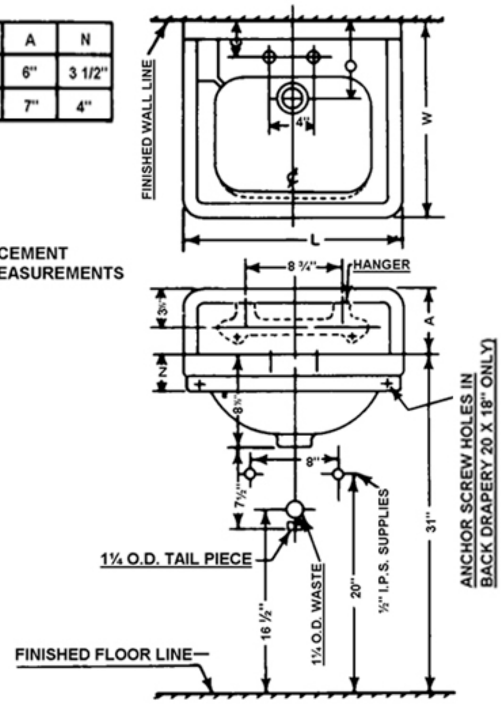


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Figure 1–12. Rough-in specifications.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

201. Planning work requirements

1. What are a planner's responsibilities?

2. Where are materials that are required on a routine basis kept?

3. Where is excess material returned?

4. What is a bill of materials?

202. Preventive maintenance program requirements

1. Match each PM description in column A with the corresponding answer in column B. Items in column B may be used once, more than once, or not at all.

Column A

____ (1) This is the goal of the PM program assessment.
____ (2) Manages the PM program.
____ (3) This work has a greater priority than PM.
____ (4) The first step to initiate the PM process.
____ (5) This program applies to real property, RPIE, or systems, and other requirements maintained by BCE.
____ (6) This section/element oversees PM's development and conducts assessments.
____ (7) If PM equipment has monthly, quarterly, and annual tasks; you would accomplish these tasks during an annual maintenance visit.
____ (8) What we generate from the MAS.
____ (9) This is how PM scope and levels of effort differ from other work orders.
____ (10) This makes up the maintenance requirement on the AF IMT 1841.
____ (11) This type of work makes up most of PM activities.
____ (12) PM includes this type of work.
____ (13) The appropriate PM stock levels are maintained by this shop/element.
____ (14) This is another word for task interval.
____ (15) Other than PM, this work has a lower priority.
____ (16) If PM equipment has monthly, quarterly, and annual tasks; accomplish these tasks during quarterly maintenance.
____ (17) This shop/element manages and executes the PM's day-to-day program.

Column B

a. Preventive maintenance.
b. We know the scope and level of effort.
c. Facility maintenance.
d. Equipment maintenance.
e. Utilities maintenance.
f. Utilities operations.
g. Contracted services.
h. Zone/shop supervisors.
i. Emergency work.
j. Urgent work.
k. Routine work.
l. Facility maintenance element.
m. Material acquisition (logistics).
n. Operations engineering.
o. PM work.
p. To balance PM against breakdown costs.
q. AF IMT 1841.
r. Level of effort.
s. Frequency.
t. Materials.
u. Labor-hours.
v. PM program record.
w. Frequencies.
x. Annual.
y. Quarterly.
z. Monthly.

203. Use construction plans

1. Match the terms in column B with the statements in column A. Column B items may be used only once.

Column A	*Column B*
_____(1) A plan that shows the boundaries of the construction site and the location of the building in relation to the boundaries, it also shows the ground contour, roads, walks, and utility lines, such as sewer, gas, and water.	a. Mechanical blueprints.
_____(2) A plan that shows a top view of the footings or foundation walls and their area and location by distances between centerlines and by distances from reference lines or boundary lines.	b. Plot plan.
_____ (3) A plan that shows the plumbing, heating/air conditioning, and electrical systems of the building.	c. Foundation plan.

2. What information is found on base utility maps?

204. Sketches

1. What are the three views in which working sketches are drawn?

2. What type of information is included in specifications?

1–2. Plumbing Fundamentals

In this section we are going to cover some of WFSM trade fundamentals and start introducing some of the systems that you will be responsible for at your duty assignment.

205. Mathematics

In the WFSM apprentice course, you learned how to make accurate measurements and calculations. This lesson expands on some of the calculations and formulas which will be useful in your career.

Area

Measuring area determines the size of the surface area of a shape. There are three basic shapes: rectangles (fig. 1–13), triangles (fig. 1–14), and circles (fig. 1–15). These figures show you how to calculate the area of the three basic shapes.

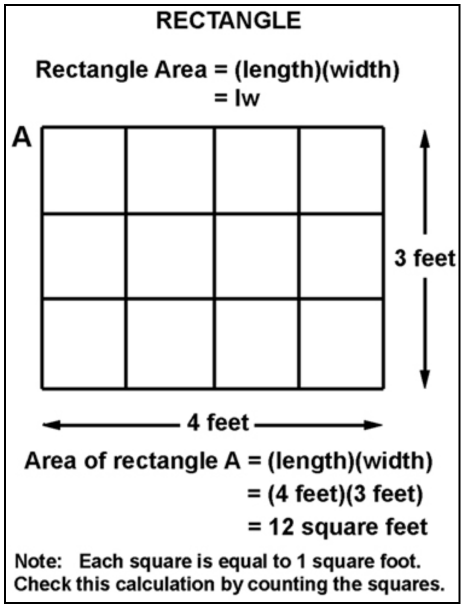


Figure 1–13. Calculating area of rectangles.

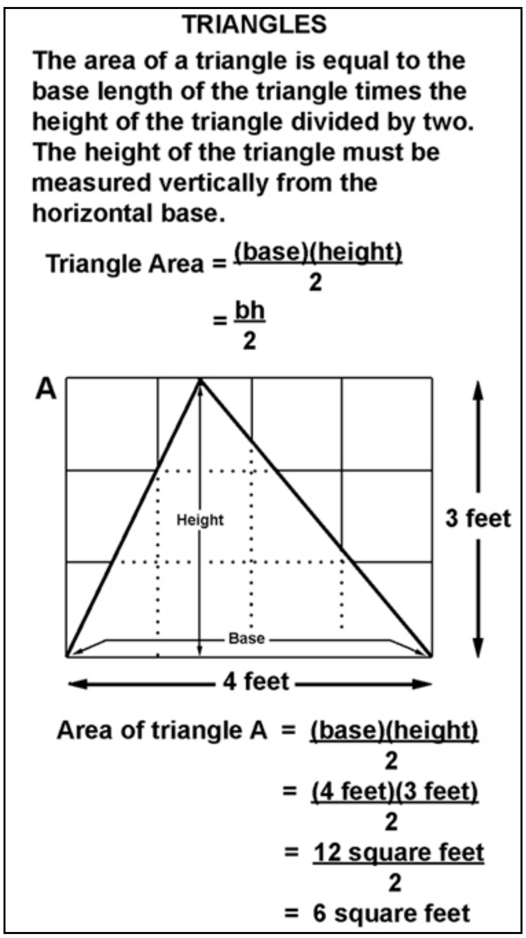


Figure 1–14. Calculating area of triangles.

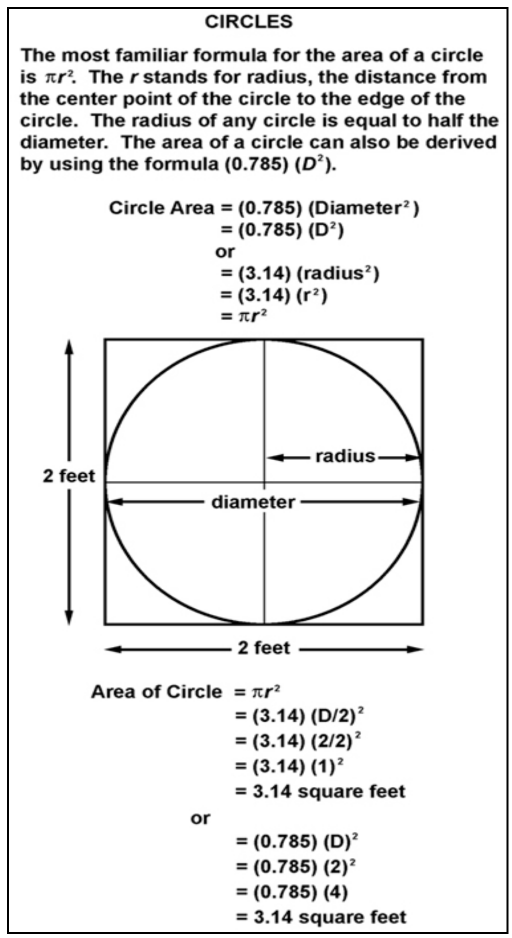


Figure 1–15. Calculating area of circles.

Volume

Volume measurements are the amount of space an object occupies. We commonly use volume to calculate how much water a tank can hold. Remember that there are 7.48 gallons (gal.) of water in a cubic foot (cu ft.). If you are looking for volume in gal., simply multiply cu ft. times 7.48 and that will equal to gal. of water in a particular basin (fig. 1–16) or cylinder (fig. 1–17).

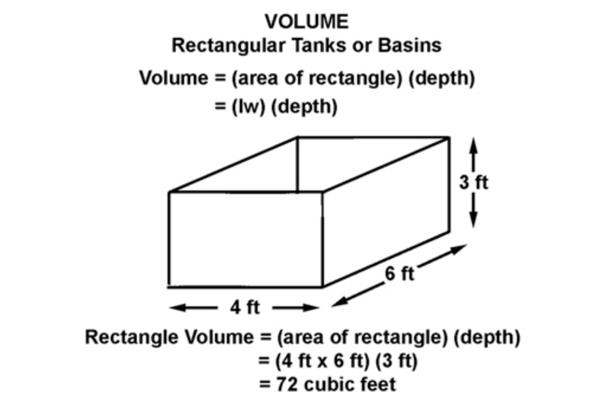


Figure 1–16. Calculating volume of rectangular basins.

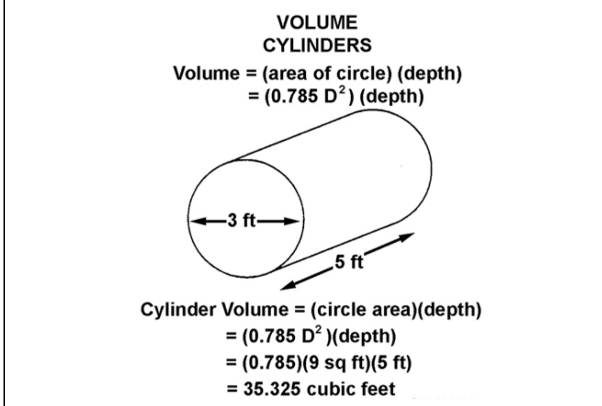


Figure 1–17. Calculating volume of cylinders.

Dosing

The dosing formula is useful in calculating chemical feed rate in pounds (lb.) per day. Figures 1–18 through 1–23 explain the concept.

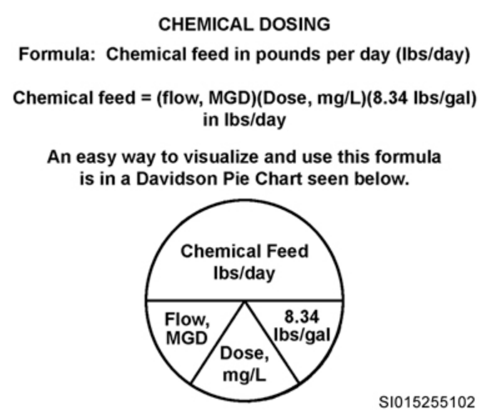


Figure 1–18. Calculating chemical dosage.

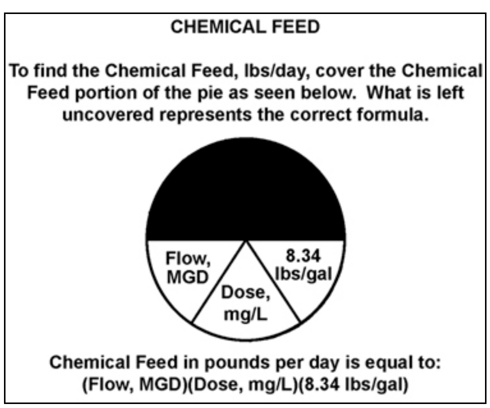
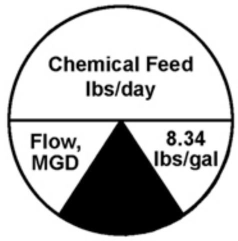


Figure 1–19. Calculating chemical feed rates.

CALCULATING DOSE

If you know what the chemical feed and flow are and want to calculate the dose, cover the dose section of the pie to set up the correct formula as seen below.



$$\text{Dose, mg/L} = \frac{\text{Chemical Feed, (lbs/day)}}{\text{(Flow, MGD)(8.34 lbs/gal)}}$$

Figure 1–20. Calculating dosage.

SAMPLE PROBLEM:

A .52 MGD system is feeding chlorine at a rate of 12 lbs/day. What will be the resulting chlorine dose?

$$\text{Dose, mg/L} = \frac{\text{Chemical Feed, (lbs/day)}}{\text{(Flow, MGD)(8.34 lbs/gal)}}$$

$$= \frac{\text{12 lbs/day}}{\text{(.52 MGD)(8.34 lbs/gal)}}$$

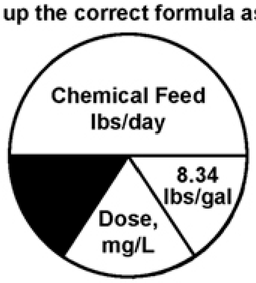
$$\text{Dose, mg/L} = \text{2.76 mg/L}$$

SI015255105

Figure 1–21. Sample dosage problem.

CALCULATING FLOW

If you know what the chemical feed and dose are and want to calculate the flow, cover the flow section of the pie to set up the correct formula as seen below.



$$\text{Flow, MGD} = \frac{\text{Chemical Feed, lbs/day}}{\text{(Dose, mg/L)(8.34 lbs/gal)}}$$

Figure 1–22. Calculating flow.

SAMPLE PROBLEM

Determine the chlorinator setting in pounds per day if you have a flow of 200 GPM and your target chlorine dose is 2.0 mg/L.

1. Convert flow from gallons per minute to million gallons per day (MGD).

   Multiply flow in gallons/minute by 1440 (the number of minutes in a day) to convert to gallons per day (GPD).

   200 gpm X 1440 min/day = 288,000.0 gal/day

   Move the decimal point six places to the left to convert to million gallons per day.

   .288 MGD

2. Use the formula for chemical feeds to determine the chlorinator setting in pounds per day.

   Chemical Feed = (Flow, MGD)(Dose, mg/L)(8.34 lbs/gal)

   Chemical Feed = (.288 MGD)(2.0 mg/L)(8.34 lbs/gal)

   Chemical Feed = (.288)(2.0)(8.34)

   Chemical Feed = 4.8 lbs/day

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Figure 1–23. Sample flow problem.

Hydraulics

The principles of hydraulics are inherent with the type of work carried on with water supply systems and sewage disposal systems. Naturally, you have water in pipes, tanks, pumps, valves, and many other items that make up a hydraulic system. Before we apply basic hydraulic laws, let us define some of the terms used.

Force

Force is the push exerted by water on a surface used to confine it. We express force in lb., tons, grams, and kilograms.

Force = pounds per square inch (psi) x area (in square feet).

Head

Head is the term used to define the vertical distance from the surface of water to a point of use (application) above or below it. We express head in feet or meters.

Head = psi x 2.31.

Pressure

Pressure is the term used to define the force per unit area. We express pressure in psi. There are two different types of hydraulic force in water and wastewater systems. These are the weight of the water and the pressure exerted by a pump.

psi = head ÷ 2.31.

The pressure of a foot of water is 1 psi ÷ 2.31 = 0.433 lb./ft.

Weight and volume

The weight (gravity) of water causes pressure. The weight of water is always a constant. One gal. of water weighs 8.34 lb., and at standard temperature and atmospheric pressure, a cu ft. of water weighs 62.4 lb.

You can use these values to calculate the static pressure of any system if you *also* know the highest and lowest elevations of the system.

For example, if each foot of height produces 0.433 psi, then a 100 ft. tower would produce 43.3 psi (100 × 0.433). Remember, also, that variations in elevation cause the water pressure to vary from one location to another (fig. 1–24).

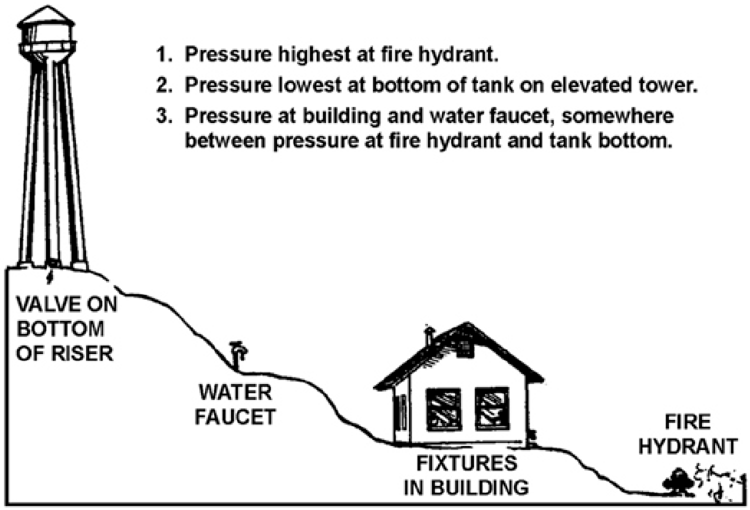


Figure 1–24. Relationship of pressure to elevation.

The ways in which we apply the laws of physics in our career field are countless. Let's take a look at the 62.4 lb./cu ft. constant in a different way. In our career field, we never empty a ground storage tank or a swimming pool when the ground water level is high. Why? Because the upward force exerted on the bottom of the tank or pool by the ground water can cause it to float or rupture the structure.

Determining needed pressure

Yet another application of the fundamentals we have been discussing is the amount of pressure needed to fill a water tower. Delivery rate does not fill a water tower—pressure does. You must remember that for every psi of water, there is 2.31 feet of head. So, to calculate head (in feet) multiply psi times 2.31.

206. Metric units of measurement

Length, volume, and weight are the three basic units of measurements. They each have equivalencies in the metric system. The unit of measurement for length is called a meter. The word meter was derived from the Greek word metron, which means measure. Volume is measured by liters. When you buy milk, soda, or any liquid today, somewhere on the carton it will be marked how many liters or parts of a liter it is. When we weigh something in the metric system, it is shown in grams. "Gram" is Latin for seed or grain, and the measurement was derived from the Romans weighing their grain when they sold it.

Metric system prefixes

Now that you know the three basic units of measurement (meter, liter, and gram), you'll need to know the prefixes used in the metric system. The prefix does for the metric system what the inch, foot, yard, ounce, quart, and gal. do for our measurement system. By adding a prefix to a metric unit of measurement, we know what the increments of the unit are. These prefixes are actually a decimal system based on multiples of ten. The following table shows many prefixes, but for our discussion we are going to talk about the four that are underlined. These are most commonly used.

Metric Prefixes		
Prefix	**Symbol**	**Multiple**
Milli	m	.001
Centi	c	.01
Deci	d	.1
Deka	da	10
Hecto	h	100
Kilo	K	1,000

Milli means that it takes 1,000 of them to make a meter, liter, or gram. One *milli*meter is one thousandth of a meter. One hundred *centi*grams make one gram, so it is one hundredth of a gram. Ten *deci*liters make one liter.

As you can see, they are just multiples of 10. For example, 10 milliliters makes 1 centiliter, 10 centiliters make 1 deciliter, and we've already said that 10 deciliters makes one liter.

If you think this is confusing, just think about our system. A meter is actually 39.37 inches, so it's basically the same as a yard. Now, if you break down a yard in our increments of measurement, you use inches and feet. If there are 12 inches in a foot, does that mean that there are 12 feet in a yard? No, of course not. For increments smaller than an inch, we use fractions. Remember the headaches fractions gave you in grade school? You can get even more confused with liquid measurements. Since there are 12 inches in a foot, does that mean that there are 12 ounces in a pint? No. See, to learn our system of measurement, we actually had to learn three different ways to understand length, volume, and weight. With the metric system, the prefix is always the same; it does not matter what you want to measure.

The last prefix we want to discuss is the kilo, which is a much larger increment. A 2-mile distance in our country would be about 3 kilometers in countries that use the metric system. Notice in the metric prefix table that the multiple for kilo is 10 to the 3rd power, meaning 10 × 10 × 10, which equals 1000. One thousand meters, then, equals one kilometer. How many yards equal a mile? If you can't answer that as fast as it takes to figure how many meters are in a kilometer, then don't say that our system is easier to understand.

Let's take some examples of how metrics can be used versus our way of measurement. When you buy $^{1}/_{10}$ of a lb. of candy, you are buying $1^{3}/_{5}$ of an ounce of candy. With metrics, when you buy $^{1}/_{10}$ of a kilogram of candy, you are buying 100 grams of candy. As you can see, with metrics there are no fractions. You can have very accurate measurements with whole numbers, which is much easier to understand. Where we have problems is converting our US Customary System into the metric system. The table below shows a conversion table. Sometime in the future this table will be part of a history lesson, because the metric system will be the measurement system of the US.

Metric Conversion Table		
LENGTH	**WEIGHT**	**CAPACITY**
1 millimeter = .039 inches	1 milligram = .000035 ounces	1 milliliter = .0338 ounces
1 centimeter = .39 inches	1 centigram = .00035 ounces	1 centiliter = .338 ounces
1 decimeter = 3.94 inches	1 decigram = .0035 ounces	1 deciliter = 3.38 ounces
1 meter = 39.37 inches	1 gram = .035 ounces	1 liter = 33.8 ounces
1 kilometer = .62 miles	1 kilogram = 2.2046 lb.	1 kiloliter = 33,800 ounces

Metrics and tools

In this day and age, you almost need two complete sets of tools: Society of Automotive Engineers (SAE) and metric. Tools are an important part of your job. Without the use of tools you can surmise problems in the system, but you would have no way of disassembling the equipment and repairing it.

You learned the different types of tools and how to use them in technical school. Right now, while you're in on-the-job training (OJT), you probably have used tools. Here we will look at the difference between metric and SAE tool sizes.

The types we are most concerned with are wrenches, nuts, and bolts. Hammers are sized in grams (centi and kilo), and you should have no trouble determining the size hammer you'll need. Wrenches are sized differently. SAE wrenches are sized by fractions. A normal set of SAE wrenches are sized into 16ths of an inch ($^1/_{16}$, $^1/_8$, $^3/_{16}$, $^1/_4$, $^3/_8$, $^5/_{16}$, etc.). You can also get some wrenches in 32ds and 64ths of an inch.

Metric wrenches are sized in millimeters and are whole numbers. At least, for some standardization, the socket drives are the same for both metric and SAE. Drives for sockets are $^1/_4$, $^3/_8$, $^1/_2$, and 1 inch.

Mixing SAE wrenches, nuts, and bolts with metric sizes will not work. You may find an SAE wrench that will almost fit a metric bolt; however, with any kind of torque you will probably strip the bolt head. Metric nuts and bolts cannot be interchanged with SAE nuts and bolts at all. Take a good look at the table below and you can see the difference between SAE sizes and the metric sizes. You'll notice some come very close to being the same size, but remember "close" can cause damage to equipment and tools and maybe even injury to yourself. *Always choose the right tool for the job.* A crescent wrench will fit either metric or SAE, but it is *not* the universal tool to use.

SAE and Metric Wrench Sizes			
SAE WRENCHES	**INCHES IN DECIMALS**	**METRIC MILLIMETER**	**INCHES IN DECIMALS**
$^1/_8$	.125	4 mm	.15748
$^1/_4$	.25	8 mm	.31496
$^3/_8$	.375	12 mm	.47244
$^1/_2$	.5	16 mm	.6299
$^5/_8$	.625	20 mm	.7874
$^3/_4$	.75	24 mm	.94488

207. Biology

Biology is the study of living things. The need to protect both the biological systems in the environment and the public health creates the need for treatment of both water and wastewater. Water treatment requirements have always been strict; the US has the purest drinking water in the world. Wastewater treatment, on the other hand, has not always been the best; consequently, the environment suffered. New requirements ensure that the effluents from wastewater treatment plants are safe for the environment.

The food chain

All organisms (living things) must have food and certain minerals to carry out their life processes. Food includes the organic compounds that furnish energy and the building blocks for growth. Nutrients are food and other substances required by the organisms.

Algae and other higher forms of plant life that contain chlorophyll (a green photosynthetic pigment) can take energy from sunlight, carbon dioxide (CO_2), water, and mineral nutrients to produce food. From these sources, they produce and store energy-rich organic compounds, such as sugar, starch, fats, and proteins. These compounds then become the food or source of energy building blocks for the growth of the organisms. With only a few exceptions, all forms of life depend on algae and other chlorophyll-rich plants for their food.

Pathogens

The study of biology is important because organisms (pathogens) cause disease not only in humans but in other organisms as well. Most of these pathogens are extremely small and cannot produce their own food or break down complex materials to get their energy. For the pathogens to obtain food, they must invade a host organism and rob it of some of the simpler nutrients. As the organism metabolizes the nutrients it robbed from the host, it also produces waste. This waste may be toxic to the host and cause the host to become infected with a disease; the disease contracted by the host depends on the type of pathogen that has invaded it. Some of the pathogens infect only a certain type of organism, while others may infect many different hosts. This accounts for the fact that humans cannot contract some types of animal diseases, while other diseases infect animals and humans alike. The animal kingdom is not the only kingdom affected by disease; plants also can become infected. Organisms that grow in the intestines of humans are discharged with the feces and are transmitted through contaminated water supplies to others. The most common diseases transmitted through drinking water are typhoid, dysentery, and cholera. Fortunately, modern methods of treating water have brought these diseases under control.

Environmental factors that affect life processes

Although the specific environmental and food requirements vary for the different types of organisms, some general environmental conditions affect the growth of all forms of life.

Temperature

An increase in temperature tends to increase chemical reaction. The chemistry of metabolism and the rate at which it takes place is very dependent upon temperature. For every form of life, there is an optimum, a minimum, and a maximum temperature for growth. The temperature range is the major factor that affects the growth rate of an organism. Most cells cannot multiply below freezing and die when boiled for 10 minutes, except for spores. The classifications of organisms according to their temperature range are:

Organism	Grows in the Range of
Psychrophilic	20 degrees Celsius (° C) to 30° C
Mesophilic	25° C to 40° C
Thermophilic	25° C to 85° C

Water

All forms of life require water as one of the most essential nutrients to keep them alive. Any organism can live without food for a much longer time than it can live without water. Water makes up approximately 75 percent of the mass of protoplasm, since it’s made up of solutions or colloidal systems. Some forms of life must live in water; these are called aquatic organisms. Other forms that live outside a body of water are called terrestrial, or land, organisms. Although an organism does not live in the water, it must have water to stay alive.

Light

Photosynthetic organisms must have sunlight to produce their food, although they can live for several hours on stored food. Sunlight may be fatal to other forms of life.

pH

The optimum pH (potential hydrogen) varies with the species. Only a few can survive in a solution with a pH above 9 or below 6.

Osmotic pressure

Water tends to pass through a permeable membrane from a solution with low-salt concentration to a more concentrated solution until the concentrations are the same. Since only pure water can pass through the membrane, the solution which loses the water becomes more concentrated; the solution which gains the water becomes diluted. A cell can control osmosis through its cell membrane to some degree, but if the difference in concentration is too great, the cell may dehydrate and die or it may swell and rupture.

Presence of toxic materials

Many materials may be toxic or produce conditions that are unfavorable to cell growth. Several metals, such as copper, may be required in very small amounts, but even in very low concentrations, they may become toxic to organisms in the water. Many organic, inorganic, and industrial wastes can kill or severely damage biological systems. The waste products of the metabolism of any organism (including humans), can change the growth environment and become toxic if allowed to accumulate.

Time

An organism does not live indefinitely, even under the most favorable conditions. The life span may vary from a few hours to several hundred years. A given organism attains life, grows, reproduces once or many times according to its genetic makeup, and dies. The increase in population of a species under the best conditions depends on the growth rate (reproductive time) of the organism, which may vary from 20 minutes (for some bacteria) to several years (for some plants).

208. Chemistry

Chemistry is a study of the composition of matter. Matter is anything that has mass and occupies space. All matter consists of one or more elements.

Element

Elements are fundamental substances that cannot be separated into its constituent parts and retain its chemical identity. Sodium (Na) is an element.

Atom

The smallest unit of an element is an atom. The parts of an atom are the *nucleus* and orbiting *electrons.* The nucleus has positively charged protons and neutral neutrons; the electrons are negatively charged. To keep an electrical balance, there are as many electrons as there are protons. The electrons are in orbit rings (shells) around the nucleus; the maximum number of shells is 7 (in the most complex elements); the maximum number of electrons per shell is 32; and the maximum number of electrons per atom is 103. Most of the weight of an atom is in the nucleus. The difference between elements is the number of electrons and protons in the atom.

Molecule

When chemically combining two or more elements, the substance is called a compound. The smallest unit of a compound, usually composed of two or more atoms, is known as a molecule. A molecule is the smallest unit of a substance that still has the properties of the substance in mass. The molecule may be a unit of an element or a compound.

Compound

Elements must be combined in definite proportions to form compounds. The makeup of a compound is shown by its formula, which is a combination of the symbols of the elements. Hydrogen and oxygen are both elements that when chemically combined in the correct proportion (two parts hydrogen to one part oxygen), they become water. Thus, water's formula is H_2O (the subscript represents the number of atoms in the element or molecule). Sulfuric acid contains two atoms of hydrogen, one atom of sulfur, and four atoms of oxygen; its formula is H_2SO_4.

The symbol of an element shows one atom and likewise the formula for a compound shows one molecule; thus, 2H means two atoms of hydrogen and $2H_2SO_4$ means two molecules of sulfuric acid.

Atomic number

The atomic number catalogs the elements and shows the amount of protons and the amount of electrons that are in a particular atom in its element state (when the atom has no charge). For example, helium's atomic number is 2, telling us that helium has a total of 2 protons in the nucleus and 2 electrons in its shells. Another example is neon. Its atomic number is 10, telling us that neon has 10 protons in its nucleus and a total of 10 electrons in its 2 shells.

Atomic weight

The atoms of an element have a definite weight called atomic weight. The atomic weights are based on the isotope carbon 12, which has a weight of 12.01115. If you need to know the molecular weight of a compound, you must figure it from the atomic weight of each atom in the compound.

Symbols

The elements are distinguished by abbreviations or symbols such as H for hydrogen, O for oxygen, C for carbon, and so forth. The periodic table found on many science books is used for this type of information.

Acids, bases, and salts

Acids, bases, and salts are other important aspects of chemistry.

Acids

What is an acid? You have acid in your car battery. An acid digests the food in your stomach. A weak acid makes a soft drink fizz when it is opened. An acid is a substance, usually a liquid that contains hydrogen that ionizes in water. Sulfur is an acid. Acids attack most metals. Some acids are very strong and ionize easily; some are quite weak and do not ionize well. Strong acids are dangerous and should be handled carefully. When you pour an acid into water, the hydrogen in the acid ionizes, or breaks away, and floats around in the water. It is so active that it mixes with almost anything with which it comes into contact. We use acids in some water tests; in water treatment for demineralizing water and lowering pH.

Bases

A base is the exact opposite of an acid. An acid releases the hydrogen cation when dissolved in water. A base also dissolves in water but releases a negative ion, or anion. We call this type of anion a hydroxyl ion, and its symbol is OH.

Sodium hydroxide (NaOH) is the strongest base there is. When NaOH is dissolved in water, the cation Na and the anion OH break apart and cause ionization. As with acids, there are strong bases and weak bases. The strength of a base depends on how much it ionizes in water. As with acids, there is an element of danger with bases. Lye, for instance, can cause bad skin burns. Bases are used in some laboratory tests to treat water, to rejuvenate demineralizers, and to raise the pH.

Mixing an acid and a base causes a reaction. This reaction, called neutralization, can be violent, depending on the strength of the two substances mixed. If we use the same amount of each, they neutralize each other (the same amount means the equivalent weights, which we cover later). Mixing equal parts of an acid and a base produces salt and water or salty water. Hydrochloric acid + sodium hydroxide yields sodium chloride (salt) + water.

Salts

There are many kinds of salt. All it takes to make salt is to mix a metal element (a base) with a nonmetal element (an acid). For example, combining iron with chlorine forms iron chloride. Other salts are calcium sulfate, sodium carbonate, magnesium nitrate, and so forth. Most salts either taste bad or harm you if you eat them. We use sodium chloride as table salt because it tastes good, dissolves easily, and has no toxic effects when used in moderation.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

205. Mathematics

1. What is the area of a 10’ x 20’ rectangle?

2. What is the volume of a 10’ square tank in gal.?

3. How much would a 3 gal. bucket of water weigh?

4. How much pressure is present at the base of a water tower when the full water level is 123 feet above the base of the tower?

206. Metrics

1. Match the unit of measurement in column B with its corresponding metric term in column A. Items in column B may be used once.

Column A	Column B
____(1) Meter.	a. Liquid volume.
____(2) Liter.	b. Weight.
____(3) Gram.	c. Length.

2. Match the multiplier in column B with its corresponding metric prefix in column A. Items in column B may be used once.

Column A	Column B
____ (1) Centi.	a. 0.1
____ (2) Deci.	b. 0.01
____ (3) Kilo.	c. 0.001
____ (4) Milli.	d. 1,000

3. What metric unit of measurement is used to order or describe hammers?

4. What is the visible difference between SAE and metric wrenches?

5. Why should you not use metric wrenches on SAE nuts and bolts?

207. Biology

1. What must an organism have in order to take energy from sunlight, CO_2, water, and other nutrients?

2. Why must most pathogenic organisms invade a host in order to survive?

3. What are the three most common diseases that are transmitted through drinking water?

4. Match the terms in column B with appropriate statements in column A. Column B items may be used once.

Column A	Column B
_____(1) Few organisms can survive when it is above 9 or below 6.	a. Temperature.
_____(2) Photosynthetic organisms require this to produce food.	b. Psychrophilic.
_____(3) An organism which grows in the range of 25° C to 85° C.	c. Mesophilic.
_____(4) An increase tends to increase the rate of a reaction.	d. Thermophilic.
_____(5) Required by all forms of life.	e. Water.
_____(6) An organization which grows in the range of 20° C to 30° C.	f. Light.
_____(7) Water tends to pass through a permeable membrane from a solution with low salt concentration to a more concentrated solution until the concentrations are the same.	g. pH.
_____(8) An organism which grows in a range of 25° C to 40° C.	h. Osmotic pressure.
_____(9) Many organisms may produce conditions which are unfavorable to cell growth.	i. Pressure of toxic materials.
____ (10) The life span of an organism may range from a few hours to several hundred years.	j. Time.

208. Chemistry

1. Match the terms in column B with appropriate statements in column A. Column B items may be used once.

Column A	Column B
_____(1) Value based on the isotope carbon 12.	a. Element.
_____(2) Smallest unit of a substance that still retains the properties of the substance in mass.	b. Atom.
_____(3) Fundamental substances that cannot be divided into simpler substances.	c. Molecule.
_____(4) Abbreviations to identify elements and compounds.	d. Compound.
_____(5) The smallest quantity of an element.	e. Atomic weight.
_____(6) Molecules of two or more elements combined.	f. Symbols.

2. What two elements make water? How much of each element is involved?

3. Match the chemical terms in column B with appropriate statements in column A. Column B items may be used more than once.

Column A	Column B
____(1) Releases the hydrogen cation in water.	a. Acid.
____(2) Neutral substance that results from combining acid and base.	b. Base.
____(3) Opposite of an acid.	c. Salt.
____(4) Opposite of a base.	

4. What happens when an acid and a base are mixed?

5. What is used to control the pH of water?

6. How is salt formed?

Answers to Self-Test Questions

201

1. Visit the job site if necessary to determine the actual material requirements; write a list of materials needed; draw sketches and figure out work requirements; prepare bill of materials; and send documents back to supervisor for approval.
2. Bench stock.
3. Residue holding area.
4. A tabulated list of materials for a job showing the name, description, quantity, stock number, size, and cost of the different items.

202

1. (1) p.
   (2) h.
   (3) i, j.
   (4) q.
   (5) a.
   (6) n.
   (7) w, y, z.
   (8) v.
   (9) b.
   (10) r, s, t, u.
   (11) o.
   (12) c, d, e.
   (13) m.
   (14) w.
   (15) k.
   (16) y, z.

(17) l.

203

1. (1) b.
   (2) c.
   (3) a.
2. Shows where the water, sewer, gas systems, liquid fuel system, and main electrical systems are located on base.

204

1. Top, side, and isometric views.
2. Explains points that are not readily explained by other drawings.

205

1. Area=(Length) (width)
   Area= (10’) (20’) = 200 sq ft
2. Volume in gal.=(area) (depth) (7.48 gal. per cu ft.)
   Volume in gal.= (10 length) (10 width) (10 depth/height) (7.48)
   Volume of a 10’ square tank is 7,480 gal.
3. 1 gal. of water weighs 8.34 lb.
   (3 gal.) (8.34) = 25.02 lb.
4. 1 foot of water = .433 psi
   (123 feet of water) (.433) = 53.3 psi

206

1. (1) c.
   (2) a.
   (3) b.
2. (1) b.
   (2) a.
   (3) d.
   (4) c.
3. Grams.
4. SAE wrenches are sized by fractions; metric wrenches are sized by whole numbers.
5. With any kind of torque, you will probably strip the bolt head.

207

1. Chlorophyll.
2. They are extremely small and cannot produce their own food.
3. Typhoid, dysentery, and cholera.
4. (1) g.
   (2) f.
   (3) d.
   (4) a.
   (5) e.
   (6) b.
   (7) h.
   (8) c.
   (9) i.
   (10) j.

208

1. (1) e.
   (2) c.
   (3) a.
   (4) f.
   (5) b.
   (6) d.
2. Hydrogen and oxygen. Two parts hydrogen to one part oxygen.
3. (1) a.
   (2) c.
   (3) b.
   (4) a.
4. When mixed in the proper proportions, they form salts.
5. Acids and bases are used for pH control of water, depending on whether you wish to raise or lower the pH.
6. Mixing equal amounts of bases and acids forms salt and water.

Complete the UREs before moving to the next unit.

Unit Review Exercises

Note to Student: Consider all choices carefully, select the *best* answer to each question, and *circle* the corresponding letter. When you have completed all unit review exercises, transfer your answers to the Field-Scoring Answer Sheet.

Do not return your answer sheet to the Air Force Career Development Academy (AFCDA).

1. (201) In which storage area would you find routinely used, high-use materials, such as polyvinyl chloride (PVC) pipe, glue, cleaner, and nails?
   a. Residue holding area.
   b. Holding area.
   c. Shop stock.
   d. Bench stock.

2. (201) What happens when an individual planning a job orders the incorrect material by mistake?
   a. Civil engineering (CE) must accept the material, even if it cannot be used for that job.
   b. Incorrect materials that are actually delivered are returned at the sender’s expense.
   c. The individual who ordered the incorrect materials is entered into training.
   d. The individual who planned the job pays for the incorrect material.

3. (202) What type of work is *not* part of preventive maintenance (PM)?
   a. Utilities operations.
   b. Utilities maintenance.
   c. Facility maintenance.
   d. Equipment maintenance.

4. (203) Which plan shows a top view of the building as if the top was cut off (cross-sectional)?
   a. Mechanical plan.
   b. Foundation plan.
   c. Elevation plan.
   d. Floor plan.

5. (203) What do you do to a base utility map any time you make a change in a utility system?
   a. Discard the old prints.
   b. Never modify original prints.
   c. Have all original prints cleared through engineering.
   d. Note changes on prints and notify engineering for updates.

6. (204) What three views are used in working sketches?
   a. Isometric, back, and side.
   b. Top, side, and isometric.
   c. Front, back, and side.
   d. Back, top, and front.

7. (204) What written documents explain points that are not readily explained by drawings?
   a. Base utilities maps.
   b. Working sketches.
   c. Bill of materials (BOM).
   d. Specifications.

8. (205) What formula is used to calculate chemical feed rate in pounds per day?
   a. Perimeter.
   b. Volume.
   c. Dosing.
   d. Area.

9. (205) What is defined as the vertical distance from the surface of water to the point of use?
   a. Head.
   b. Weight.
   c. Volume.
   d. Velocity.

10. (205) What is the weight of one gallon (gal.) of water?
   a. 6.34 lb.
   b. 7.34 lb.
   c. 8.34 lb.
   d. 9.34 lb.

11. (205) How many feet of head does 1 pound per square inch (psi) of water produce?
   a. 1.31.
   b. 2.31.
   c. 3.31.
   d. 4.31.

12. (206) Which metric prefix equals 1,000?
   a. Milli.
   b. Centi.
   c. Deci.
   d. Kilo.

13. (206) Metric wrenches are sized in
   a. kilometers.
   b. decimeters.
   c. centimeters.
   d. millimeters.

14. (207) What is the study of living things?
   a. Biology.
   b. Geometry.
   c. Chemistry.
   d. Anatomy.

15. (207) Which disease is commonly transmitted through drinking water?
   a. Typhoid.
   b. Measles.
   c. Mumps.
   d. Cancer.

16. (207) What is osmotic pressure?
   a. The passing of air from an area of low-salt concentration to an area of high concentration.
   b. The passing of water from an area of low-salt concentration to an area of high concentration.
   c. It is like atmospheric pressure, but it does not include ozones.
   d. It is like atmospheric pressure, but it includes ozones.

17. (208) What is the study of the composition of matter?
   a. Biology.
   b. Chemistry.
   c. Ecology.
   d. Geology.

18. (208) What is the smallest unit of an element?
    a. Molecule.
    b. Atom.
    c. Nucleus.
    d. Electron.

19. (208) What happens when a base and an acid are mixed?
    a. Coagulation.
    b. Disinfection.
    c. Neutralization.
    d. Sedimentation.

Please read the unit menu for unit 2 and continue ➔

Unit 2. Manual Valves

WHEN YOU START YOUR INSPECTION of water, wastewater, and fuel systems, the components you will frequently come into contact with are the manual and automatic valves. Manual valves can be of different sizes and shapes, but their main function will be the same. They are used to direct the flow of liquids to the parts of the system you are using and to block the flow from unused lines. They also isolate equipment on which you are doing maintenance. They are operated by turning a hand wheel, handle, or turn-key. Automatic valves also vary in size and shape and their main functions are to automatically regulate flow rates and pressure. In this unit you will learn about the different types of manual valves and a couple of common automatic valves. The majority of the automatic valves will be discussed in greater detail when we learn about the systems they apply to in later volumes.

2–1. Construction and Maintenance Requirements

In this section, we will discuss the construction and maintenance requirements for the following valves: gate, globe, plug, ball, and specialized valves we use in WFSM systems.

209. Gate valves

Gate valves are the most widely used valve in water systems. They are also used in main fuel system lines and cross-country pipelines. They are typically used as block valves where larger supply lines require periodic cleaning or where products are batched through the pipelines. Gate valves are one of the oldest valves still used today because of their simple design and functional use. They are not used to limit liquid flow, so they are either fully open or closed.

Construction of gate valves

Gate valves, when used in fuel systems, shall conform to the requirements of the API Specification (Spec) 6D, *Specification for Pipeline Valves*, and shall be fire tested and qualified in accordance with (IAW) API Spec 6FA, *Specifications for Fire Test for Valves*. Water system requirements are not as stringent as fuel systems. You may use a standard local purchase gate valve for water systems. They will have either a flexible wedge disc, split wedge, solid wedge, parallel slide gate, conduit disc, or a double disc. Gate valves used in cross-country pipelines are designed so the valve gate moves completely out of the way when the valve is fully open. This *primary* feature makes it possible to send line scrapers through long runs of pipeline without interference. You will also find gate valves throughout your water systems of various sizes on your home station base as well as part of some contingency equipment. Gate valves are found in two basic designs—rising stem and non-rising stem.

Rising stem valve design

The first and most widely used type design is known as a *rising* stem gate valve. Figure 2–1 illustrates one type of rising stem valve in both the open and closed position. In the figure, you see that when the valve is closed, the wheel, or handle, is down or close to the valve body. When it is open, the wheel, or handle, and stem are away from the valve body.

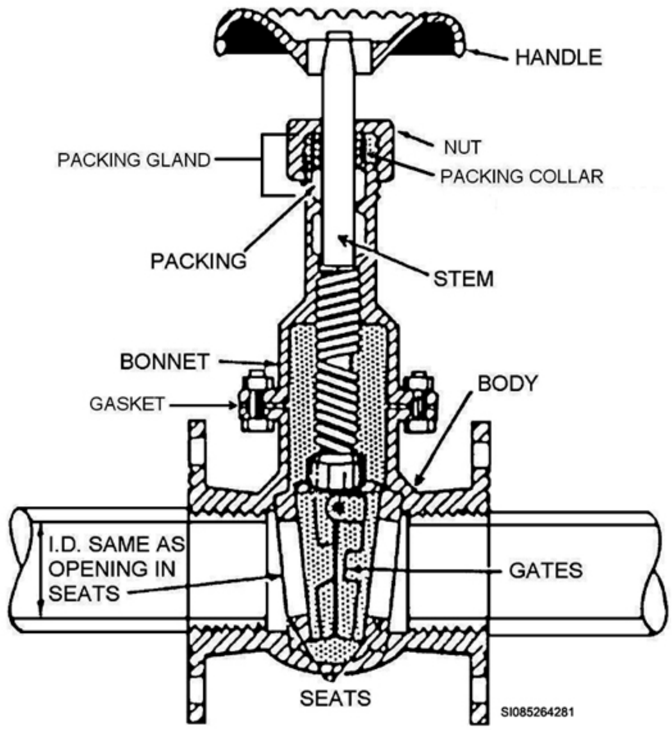


Figure 2–1. Rising stem gate valve (Type 1).

Figure 2–2 illustrates the *second type* of *rising* stem gate valve. The wheel, or handle, remains at a fixed distance above the body of the valve, but the stem moves up and down through the center of the wheel, or handle. With either of these valves, looking from distances of up to several yards, you can readily observe the position of the valve by the position of the wheel, or handle, and/or stem.

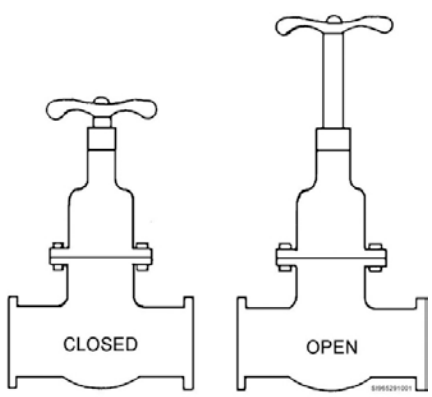


Figure 2–2. Rising stem gate valve (Type 2).

Non-rising stem valve design

The *second* design of the gate valve is known as the *non-rising* stem gate valve. In this valve design, the wheel, or handle, and the stem remain at a fixed height from the valve body. The wheel, or handle, must be turned to determine the valve position. This type of valve is used in confined areas, such as pits and outdoor locations, where the valve is *not* operated frequently, or in places where the stem would come into contact with other components. The internal construction of a typical gate valve is shown in figure 2–3. The particular one shown here is a rising stem-type valve. Gate valves used on fuel tank dike drain lines must be capable of being locked in the closed position to prevent the unauthorized draining of the tank dike area.

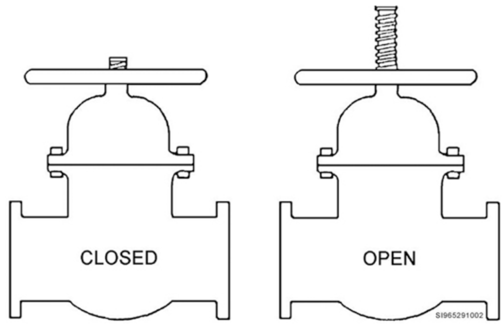


Figure 2–3. Gate valve construction.

Operation of gate valves

Normally, gate valves operate slowly, especially those in the larger sizes. For this reason, there is less chance of closing the valve too rapidly, reducing the chance of hydraulic shock. High pressure on a line can make a gate valve difficult to open.

Mechanical advantage is defined as the ratio of resistance to the effort. When the resistance of a closed valve under pressure is 200 pounds, and the effort to open it is 40 pounds, then the mechanical advantage we get from the wheel, axle, and screw is 5 to 1. Look again at figure 2–3. You will notice that the wheel and axle (the handle) and the screw (threads on the stem) work together to make opening the valve easier. Two seats are set into the body of the valve at an angle. This gives the cross-section a wedge shape. The wedge-shaped disc (valve gate), at the bottom of the stem, moves downward into the opening between the seats until firm contact is made. Notice that the gate has two halves pivoted at the top. This permits the gate to adjust to the seat surfaces to provide a positive seal. The stem is free to rotate in the head of the valve gate. As the handle is rotated, the stem screws upward or downward in the bonnet. Thus, when the valve is open, the stem will extend upward from the valve collar.

NOTE: In the case of a non-rising stem valve, the valve gate will move upward or downward on the stem. The non-rising stem will remain in the same position.

The packing gland nut is found at the top of the bonnet, which covers the packing collar and spiral graphite or ring-packing wrapped around the upper valve stem. This chamber around the upper stem is called the packing gland. The packing in the packing gland is compressed to form a seal around the stem to contain the liquid in the lower portion of the bonnet. As the packing gland nut is tightened, the packing collar compresses the packing material tightly around the stem. Tighten the packing gland nut just enough to prevent stem leakage because friction is created during the packing compression which results in a loss of mechanical advantage making the valve harder to open or close.

Inspection and maintenance of gate valves

The inspection requirements for gate valves are quite limited. Since fuel system operators (petroleum, oil, and lubricants [POL] personnel) are required to operate and inspect gate valves in fuel systems on a weekly basis, *you* have to inspect those gate valves on a quarterly basis. In water systems, these valves are operated and inspected semiannually. To satisfy inspection requirements, you need to operate the valves (for proper opening and closing), check for leaks, adjust the packing gland nut if needed, lubricate the gear housing, inspect for visible external damage, and ensure corrosion control.

Problems encountered with gate valves are usually limited to failure to seat, sticking, and stem leakage. Foreign matter has a tendency to collect in the gate area of the valve and prevent the valve from seating properly. Sometimes operating the system with the valve only slightly open will flush the debris from under the gate. If this does not cure the problem, you must remove and clean the valve seat. Should the seat show evidence of grooves, warps, pits, or scratches, you will need to grind or lap the seat with a lapping compound until all surfaces are smooth and flat. If internal wear or damage is too great, replace the valve.

When operating a gate valve, always open or close it to its maximum travel, then back off a little to relieve the strain on the valve stem. If you do *not* back off a little, you may jam the gate, either by metal-to-metal contact or by foreign matter caught between the surfaces. Infrequently operated gate valves are subject to sticking. If the valve stem is leaking, tighten the packing gland nut until you have stopped the leak. If tightening does *not* stop the leak, replace the packing. To do so, turn the wheel to the *CLOSED* position, then remove the handle, packing gland nut, and old packing. You should replace the packing with new graphite or Teflon cord or Teflon ring packing. Now replace the packing gland nut and tighten it until you have made firm contact with the packing. Next, replace the handle and open the valve. Be sure to tighten the gland nut only as tight as required to stop leakage. Do *not* over tighten the gland nut when new packing is installed. Because of its ability to form tight seals when compressed and to resist break down in fuel, Teflon packing seems to be the *best* packing to use on most valves including gate valves. Always read the manufacturer's manual for repair and replacement guidance.

If the handle is frozen or the gate refuses to move, you may access the insides of the valve by unbolting the bonnet from the valve body. Then you can remove the entire valve mechanism for repair.

When solar heating (sunlight) affects gate valves on a pipeline, they should have a bypass relief valve and line installed around the valve to relieve the solar heating pressure (expansion).

WARNING: Do *NOT* use gate valves as tank valves on aboveground storage tanks because heat will expand the product trapped in the bonnet (upper portion of the valve) and may blow the bonnet gasket or packing.

210. Globe valves

You will find manual globe valves in smaller pipelines such as gauge lines, drain lines, hose bibs, and stripper and bleeder connections. Their function is to limit flow and isolate smaller lines and components.

CAUTION: Do *NOT* use globe valves in primary fuel pipelines because the valves have a high flow resistance. Globe valves are available in a wide variety of sizes and models to handle different working pressures and types of liquids. A common use of a globe valve is to isolate pressure gages for removal and tested or replacement.

Construction of globe valves

Globe valves, when used in fuel systems, shall conform to the requirements of API Spec 6D and API Spec 6FA. Figure 2–4 illustrates a typical globe valve. Its components include the body, wheel, valve stem, packing, packing nut, cover, disc, and seat. Note that a metal wall that is a part of the valve body divides the valve. An opening in the wall has a faced seat. A cone-shaped disc mounted on the end of the stem closes against this seat and stops the flow of product. You can readily see that a partially closed valve controls or limits the rate of flow. The material of which the disc is constructed varies with the use of the valve. Valves that control the flow of water, steam, oil, or gas commonly have composition or brass discs. For frequently operated valves, nickel-steel discs are also used.

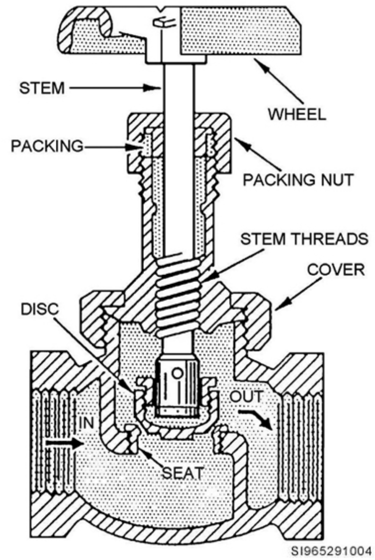


Figure 2–4. Globe valve construction.

Operation of globe valves

As stated before, globe valves installed throughout WFSM systems control flow rates, just as in drain lines. This type of valve allows the flow rate to increase gradually as you are opening the valve. Refer again to figure 2–4 and notice that the flow will come under the valve seat and disc and on through the valve. As the opening between the disc and seat is increased, the flow of product will increase. When the valve is closed, the line pressure will *not* be within the bonnet, thus making it possible to replace the packing while the *upstream* line is pressurized.

CAUTION: Always make sure that the piping *downstream* is *not* pressurized before replacing the packing.

Inspection and maintenance of globe valves

Like gate valves, the inspection of globe valves is limited to valve operation and checking for leaks, damage, and corrosion on a quarterly basis for fuel systems and a semiannual basis for water systems. Teflon string is the most common packing for globe valves, providing a leak-proof seal around the valve stem. If this valve leaks around the stem, tighten the packing nut or replace the packing. Remember to close the valve when doing this task. Over time, frequently used globe valve discs and seats can become worn and cause internal leakage. Since the cost of smaller globe valves is relatively minimal, replacement instead of repair can be cost effective. Larger globe valves are more expensive, so the repair of their discs and seats will save the cost of replacing the entire valve.

Internal leakage is very common for this type valve. To remedy this problem, the removal and replacement of some manufacturers' discs and seats is possible. Others cannot, so a lapping compound is used to lap the disc to the seat to make an effective seal and stop the internal leak. With the valve removed, just back off the cover from the valve body to remove the stem and disc. Apply a little fine-grade lapping compound to the disc face and fit it to the valve seat. Tighten the cover on the body a few turns to make sure of proper alignment of disc and seat. Then, with the stem steady and straight out from the valve seat, use light pressure as you rotate the disc back and forth several times on the seat. Lapping the disk on the seat ensures that that the sealing surfaces mate. When you get a good fit of the disc and seat, clean out the valve and put it back together. If lapping does not work and the disc and seat are not removable, replace the valve. When installing the valve, make sure that the flow is under the disk and seat.

211. Non-lubricated plug valves

Because there are some differences among non-lubricated valves, we will cover the main types found in fuel systems. Even though we will not cover every model of non-lubricated plug valves, you will get a good idea of their construction, operation, and maintenance.

All plug valves *downstream* of the fuel system's filter/separator (F/S) or in potable water systems will be non-lubricated. Using non-lubricated plug valves eliminates the possibility that grease will contaminate the water system or enter the fuel system on the downstream side of the F/S.

Construction of non-lubricated plug valves

These valves vary in design, but generally, they fall into four classifications: lift-plug, movable-seat, resilient-liner, and double block and bleed (DBB) plug. In the figures that follow, you will notice that the plugs of all these type are quite similar. When used for petroleum service, these valves shall conform to the requirements of API Spec 6D and API Spec 6FA.

Lift-plug valve

The lift-plug valve contains a mechanical screw jack lever (fig. 2–5). This lifts the plug up and away from its seat when the valve is opened or closed. This action is automatic when the valve handle is rotated. Gearing and locking devices built into the valve prevent the plug from being turned in its seat and to make sure the plug is reseated after it has been rotated.

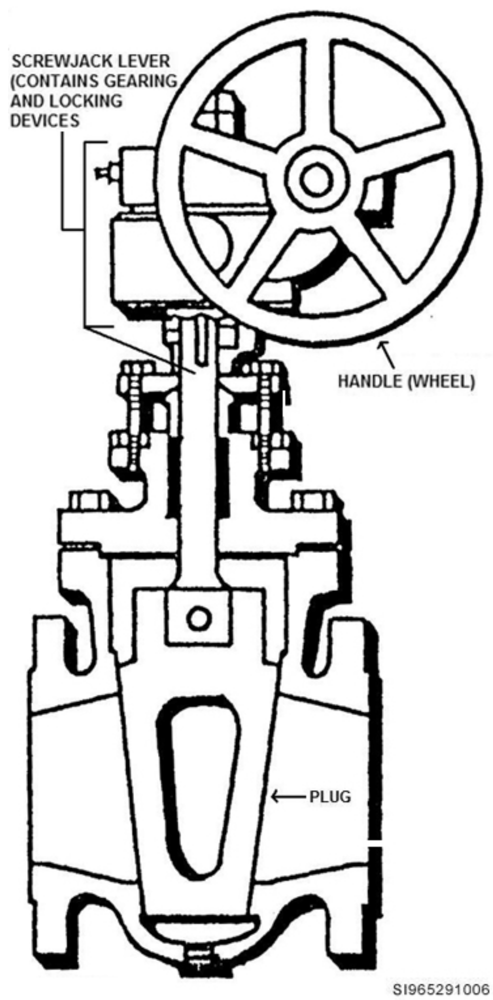


Figure 2–5. Lift-plug valve.

Movable-seat plug valve

The movable-seat plug valve contains seating segments instead of a solid seat (fig. 2–6). When you rotate the valve, the seat segments expand or move away from the plug, releasing it so that it turns. When you rotate the valve plug to its new position, the segments close around the plug to form the seal. Expansion and contraction of the seat segments integrate mechanically with the turning of the valve, so the seats expand before the plug moves, and they contract after the plug stops turning. It is *not* necessary to lubricate the plug or seat segments because they do *not* rub against each other during the opening or closing cycles, but the gear working inside the operator on top of the valve body may require lubrication according to manufacturer's specifications.

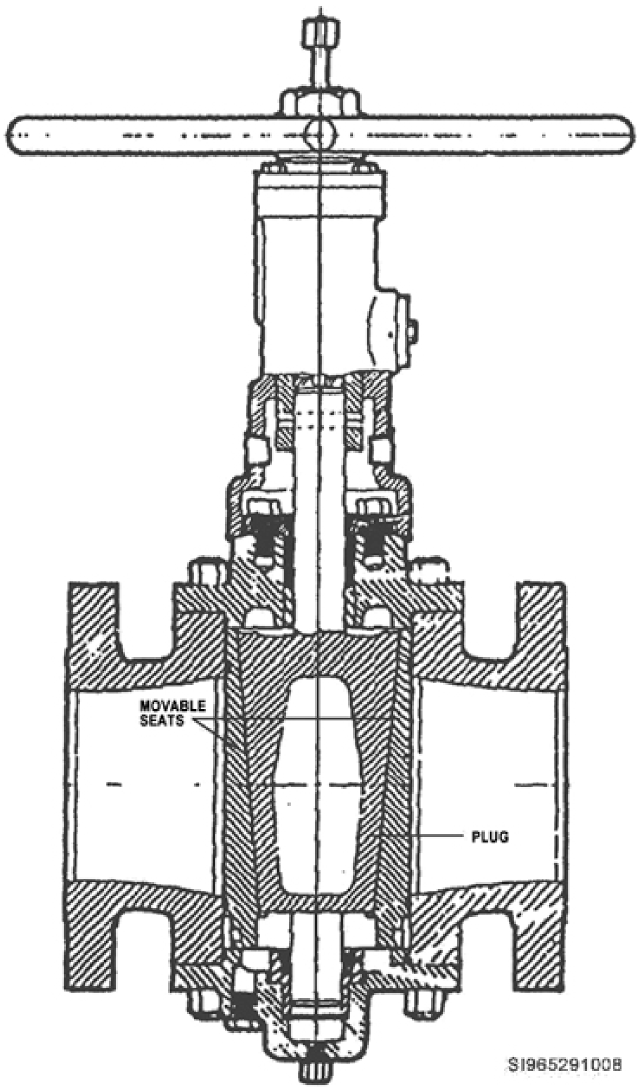


Figure 2–6. Movable-seat plug valve.

Some plug valves have manual bleed systems, thermal relief systems, or both. Moveable-seat plug valves develop high thermal pressure inside the body. This thermal pressure can hinder the opening of the valve. With the manual bleed system, you open a small valve to relieve pressure. The thermal relief valve releases any thermal expansion of the body liquid back safely and automatically to the pipeline. It relieves at 25 psi.

Resilient-liner plug valve

The resilient-liner plug valve incorporates a resilient (elastic or springy) liner that surrounds the plug in the same manner as a solid metal seat does. Because of the elasticity of the seat, it maintains leak-proof pressure contact with the plug but will give enough to permit the plug to rotate by slipping against the surface of the liner. Figure 2–7 shows a resilient liner plug valve. Notice that the sleeves are around the top and bottom of the plug only. A diaphragm seal prevents leakage past the hub.

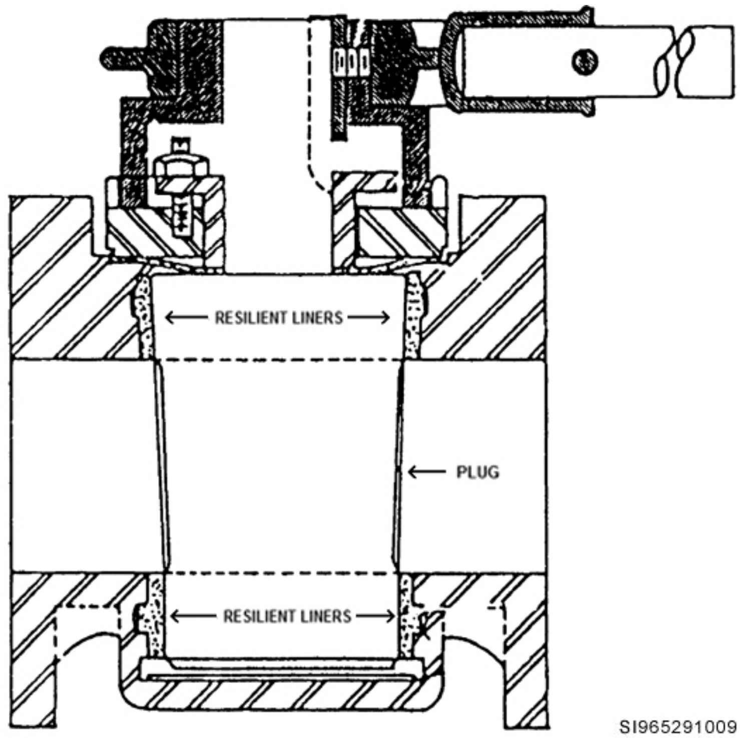


Figure 2–7. Resilient-liner plug valve.

DBB plug valve

DBB plug valves are fast becoming the most widely used manual valve in the AF fuel systems. Its big advantage is that this valve can be left in the pipeline during pipeline pressure testing. In the case of other valve types, skillet flanges would have to be installed or the valve laboriously removed and blind flanges installed; therefore, because of its positive shutoff and the ability to test the valve for "leak by," you do *not* need to remove the DBB plug valve from the pipeline during pipeline hydrostatic testing.

A DBB plug valve is a non-lubricated, resilient, double-seated, trunnion-mounted, tapered lift plug. The plug has two sealing slips capable of sealing both sides of the valve ensuring its "double block" feature (fig. 2–8). Its "bleed" feature enables you to vent the internal plug chamber between the sealing slips (when the valve is closed) to determine if the sealing slips are holding pressure. The valve body is constructed of stainless steel or carbon steel with chrome-plated interior, and the tapered plug is constructed of steel or ductile iron with chrome or nickel plating. The sealing slips are made of steel or ductile iron with Viton seals and held in place by dovetail connections. The sealing slips are replaceable from the bottom of the valve without removing the valve from the piping.

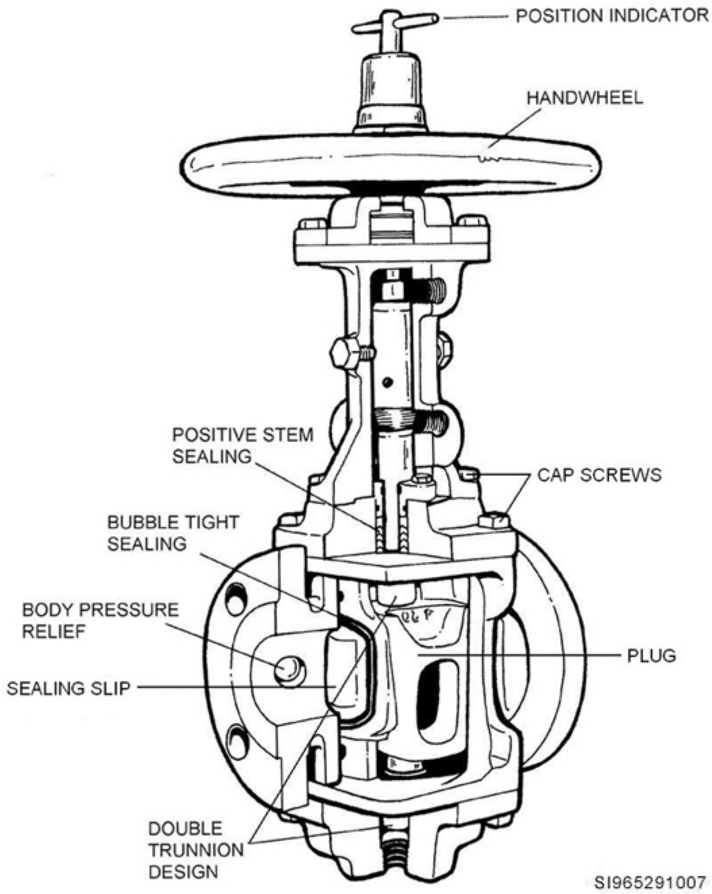


Figure 2–8. Double block and bleed plug valve.
(Reproduced by permission of General Twin Seal Valve Co.)

Manual bleed and thermal relief

Most DBB valves are equipped with a thermal relief system that allows pressure trapped inside the closed valve body to relieve to the piping. Excess pressure could damage the valve or even rupture the valve body causing a fuel spill.

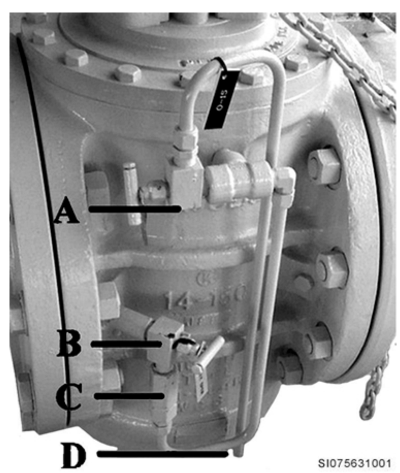


Figure 2–9. Manual bleed and thermal relief system.

As shown in figure 2–9, during normal operation of a closed valve, manual valve “A” should be closed while manual valve “B” should be open to allow pressure to relieve back to the system piping. The relief valve “C” relieves at 25 psi above system pressure.

Verify the positive closing and sealing of the main valve by closing valve “B” and opening valve “A”. This will vent the internal body cavity to atmosphere at “D”. Have a grounded drip pan ready to catch any fuel discharged. Expect some fuel initially, but a constant drip indicates one side of the valve is not sealing. Sealing verification is normally reserved for troubleshooting and system pressure tests. Return valves “A and B” to normal configuration when complete.

Inspection and maintenance of non-lubricated plug valves

Inspect non-lubricated plug valves quarterly for ease of operation, leaks, and corrosion. Very little maintenance is required other than functional repair resulting from periodic inspections. To prevent binding over time, POL personnel operate these valves in fuel systems on a weekly basis. Valves, like many other mechanical devices, will last longer and function better if they are operated regularly. Ordinarily, valves will *not* stick unless they are jammed into the seats or neglected for a long time.

When a valve stem develops a leak, you can generally stop it by tightening the packing glands. Of course, there are times when tightening does *not* stop the leak. Then you need to remove the old packing and replace it with new.

Normally you can stop internal leaks developing in resilient-liner valves by tightening the adjusting nut at the top of the valve. This action forces the plug farther down into the valve body, where it fits tighter against the resilient material of the liner.

Several different companies manufacture the types of valves we have just discussed. They have minor, but sometimes important, design differences. Each manufacturer issues instructions for lubrication, repair, and maintenance. You should always follow the instructions for the particular valve concerned.

Inspection and maintenance of DBB valve

As with other valves, there are now many manufacturers of DBB valves with just as many different operator designs. DBB valve inspection and PM includes proper opening and closing of the valve, lubricating the operator through the grease fitting, and checking for leaks and corrosion control on a quarterly basis when located in fuel systems and semiannually in water systems.

During an annual or 5-year fuel pipeline pressure check, perform the bleed test to determine if seating slips are sealing properly. If you have determined that the seating slips need to be inspected or replaced, place the valve in the full open position, remove the bottom plate, and slide out the slips and replace with new ones if necessary. Save the old slips to send back to the manufacturer to be refurbished.

The most frequent cause of trouble with these valves is failure to keep the operator properly lubricated. Improper lubrication can cause various problems to include operator sticking, wearing of metal components, and rust in the operator gears. Lubricate the valve operator with the manufacturer’s recommended lubricant type. Regardless of the manufacturer, consult their valve maintenance manual to develop a proactive approach to preventing valve malfunctions.

Plug valve operators

There are several types of plug valve operators. Plug valves that are larger than 6 inches have a worm gear operator. Valves from 2 to 6 inches will have a wrench operator. Valves that are smaller than 2 inches will have lever-type handles. The 6-inch and larger DBB plug valves are common in new fuel systems and their operators are more complicated that the other non-lubricated plug valves.

Construction and operation of the DBB plug valve operator

The DBB valve operator is essentially a screw-jack device that provides the mechanical advantage to “lift and turn” the plug, reseat the plug, and apply pressure to the seals when closing the valve. This operator has a list of parts that work together to open and close the valve.

Closing the valve

To close the valve, turn the hand wheel clockwise. As the hand wheel is turned clockwise, the valve plug with the sealing slips is rotated 90 degrees to the closed position but is still raised. By continuing to turn the hand wheel, the plug is lowered to align with the valve body seats, and the slips are forced away from the plug toward the seats until a snug slip-to-seat fit is achieved. The valve is now fully closed.

Opening the valve

To open the valve, turn the hand wheel counterclockwise. As the hand wheel is turned counterclockwise, the slips are unseated and the plug is raised. By continuing to turn the hand wheel, the plug is rotated 90 degrees and the valve is now open.

Removing the operator from the valve

The only reason to remove the operator is because it is not doing its job of opening or closing the valve. Even though this is rare, an operator's parts can become worn or break causing an inoperable condition. To remove the valve operator (fig. 2–10), you must *first* fully close the main valve. Then, remove the two plastic plugs (item 22) at the bottom of the operator housing. Knock out only the lower coupling pin (item 32); do not remove the upper coupling pin. Remove the cap screws attaching the operator to the valve bonnet. Once this is done, just lift the operator off the valve by pulling up vertically until it clears the upper plug trunnion.

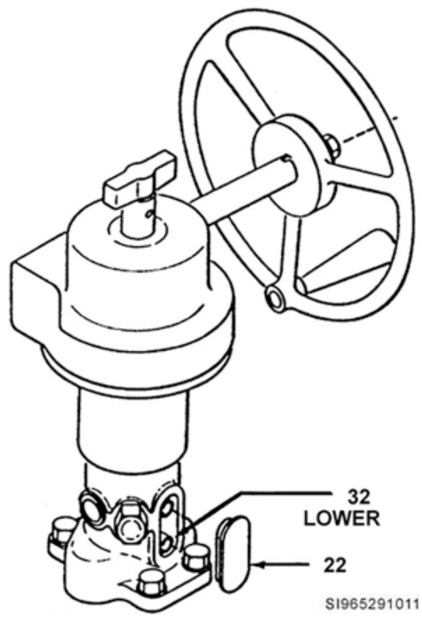


Figure 2–10. General Twin Seal Valve operator.
(Reproduced by permission of General Twin Seal Valve Co.)

Operator disassembly

After removal of the operator from the valve, you can disassemble it to find the cause of any problems. You *must* refer to the manufacturer's repair manual to successfully disassemble the operator. When disassembling anything that has more than a handful of parts like these valve operators, you should lay out a parts cloth and place the parts on the cloth in the order of disassembly. That way, the sequence order of reassembly is already done. Also, have a pad and pencil to note any specific orientation or position the part was in during disassembly to aid in reassembly.

212. Ball valves

Ball valves, also known as quick opening valves, are quite popular in all WFSM systems and are made of various materials for different uses. Ball valves come in two main designs. The *first* and most popular is the ball valve that requires only a quarter turn of the valve stem to rotate the ball 90 degrees to fully open or close the valve. The *second* ball valve design requires the turning of a hand wheel to slowly rotate the ball 90 degrees to open or close the valve. These types of ball valves will normally be found in fuel systems where the valve size is over 6 inches.

Construction of ball valves

Ball valves will vary in sizes from ¼” to 24” and will have threaded ends for smaller diameter pipes up to 2 inches while the larger ones have flanged ends. Ball valves for petroleum service shall conform to API Spec. 6D, and shall be fire tested and qualified IAW API Spec. 6FA. Ball valves are non-lubricated valves that operate from the fully open position to the fully closed position with 90 degrees rotation of the ball. The balls in 10-inch or larger ball valves will have trunnion-type support bearings at the bottom of the ball to provide a centered pivot point for the heavier balls. The constructional features of the first design (quarter-turn type) (fig. 2–11) include the valve body, seats, ball stem, stem seals, and handle. The smooth surfaces of ball and seat create a tight fit within the valve, and the stem seals prevent stem leakage. Valve “stops” on top of the valve prevent the handle from turning the ball more than the 90 degrees to either open or close the valve.

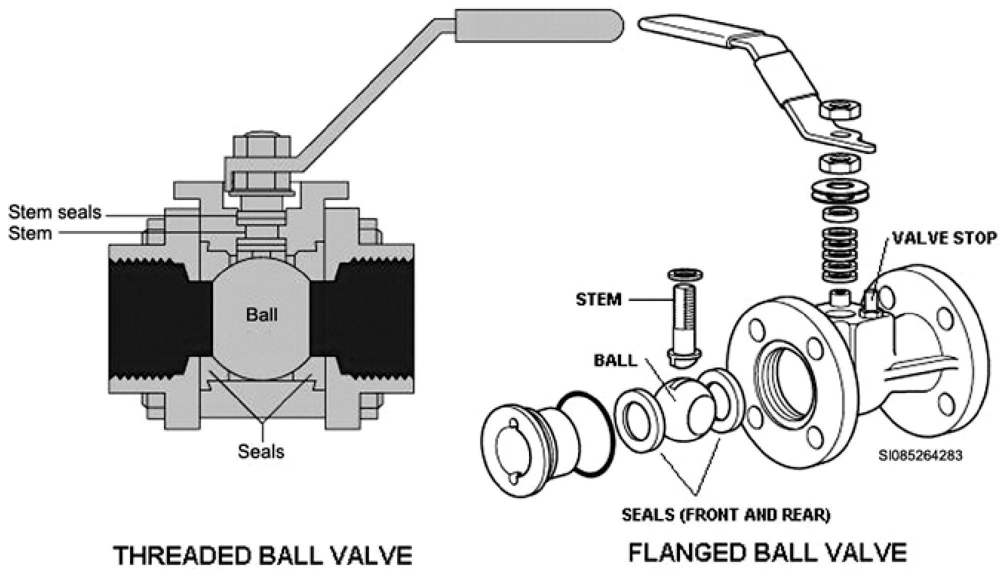


Figure 2–11. Ball valves.

The constructional features of the second design (fig. 2–12) include the valve body, ball, seat, bonnet, packing, packing rings, packing adjustment screw, stem (with grooved stem guide channel), stem guide, and hand wheel. This design is found on larger valves therefore requiring trunnion-type support bearing. The packing adjustment screw fitting provides the port to inject packing around the stem and against the upper and lower packing rings. The packing adjustment screw is then tightened to apply enough pressure throughout the packing cavity preventing stem leakage. The stem guide fits into the stem guide channel and acts as internal “stops” when the hand wheel is turned to position the ball for proper seating when the valve is fully opened or closed.

When you look at a ball valve from the side, you see a circular opening about the same size as the pipeline. But even with this circular opening through the valve, the ball valve *cannot* be substituted for a gate valve in the main fuel supply pipelines because if the ball port is slightly out of line with the pipe, a batching or cleaning pig could become stuck. This type of valve is a suitable substitute for the non-lubricated plug valve because it is also a non-lubricated valve and its standard port opening in the ball will not restrict flow. Full-port ball valves are used when installed within 10 pipe diameters of a flow valve, pressure control valve, or flow-sensing device such as a venturi. The full-port design prevents any restriction of flow through the ball valve, which could otherwise affect the control valve or venturi.

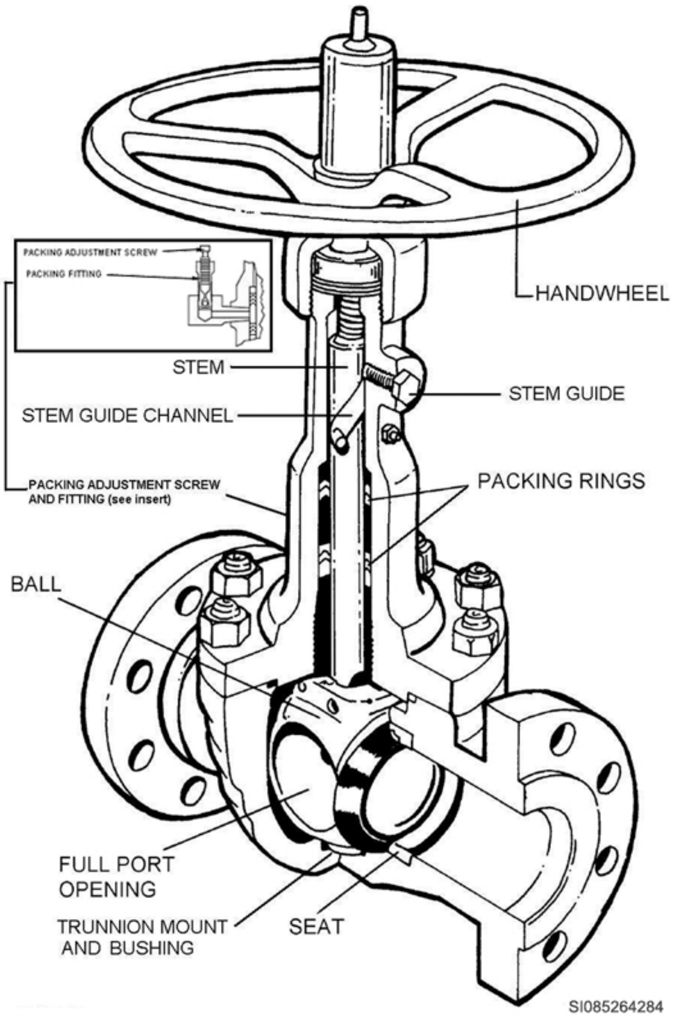


Figure 2–12. Hand wheel ball valve.

Inspection and maintenance of ball valves

Inspect ball valves in fuel systems quarterly and in water systems semiannually for ease of operation, leaks, and corrosion.

Maintenance of the ball valve commonly includes replacement of packing, packing rings, gaskets, seals, and ball. However, the normal day-to-day operation of the valve will keep the valve working properly and needed repairs down. Some bonnets of the second design may have grease ports to lubricate the upper portion of the stem. When ball valves do require maintenance, refer to the applicable manufacturer’s manual to familiarize yourself with its construction and replacement parts. As with all pieces of equipment, do not use parts from different manufacturers or utilize parts from different valve models of the same manufacturer unless the part numbers match.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

209. Gate valves

1. Why is the gate valve designed so that when it is fully open, the gate moves completely out of the pipeline?

2. What are the two basic designs of a gate valve?

3. Which type of gate valve can you readily observe, from a distance, to be open or closed?

4. Which type of gate valve should you use in confined areas, such as pits?

5. Normally, how should you close a gate valve? Why?

6. How many seats are set into the body of a gate valve?

7. What component of a gate valve is tightened to compress the packing around the stem?

8. Explain the inspection frequencies and requirements for gate valves.

9. Explain the problems encountered with gate valves and how to fix them.

10. Explain the proper method of opening and closing a gate valve.

210. Globe valves

1. Why are manual globe valves used only in small pipelines rather than primary pipelines?

2. List the components of a globe valve.

3. Briefly explain what will happen to the flow of a product through a partially closed valve.

4. In which direction should flow be directed through a globe valve? Why?

5. A globe valve should be in what position when you replace the packing?

6. How do you stop internal leakage of a globe valve?

211. Non-lubricated plug valves

1. What type of plug valve will be used downstream from an F/S?

2. What are the four classifications of non-lubricated plug valves?

3. What prevents the plug form being turned in its seat in a lift-plug valve?

4. Which type of non-lubricated plug valve uses seating segments instead of a solid seat?

5. On a resilient-liner plug valve, what does the diaphragm seal prevent?

6. What are the DBB valve inspection and maintenance requirements?

7. What would be the next course of action if tightening the packing gland of a non-lubricated plug valve will *not* stop a valve stem leak?

8. The DBB operator is essentially what kind of device designed to do what?

212. Ball valves

1. What are the two main ball valve designs?

2. Ball valves that are 10 inches or larger must have what type bearings? Why?

3. Ball valves are a suitable substitute for which type of manual valve?

4. What inspections are made on ball valves?

5. What maintenance may be required on ball valves?

2–2. Specialized Valves and Replacement

In this section, we will discuss specialized valves and the process of manual valve replacement.

213. Specialized valves

The valves that are designed for specialized functions or conditions include two manual valves: the check and butterfly valves, and three automatic valves: the pressure reducing, pressure relief, and altitude valves. These specialized valves are described in this lesson.

Check valves

Check valves are probably the simplest of all valves, both in construction and in operation. Check valves are used to control the direction of product flow in a system. They do *not*, however, meter or affect the rate of flow.

Construction and operation of check valves

As a WFSM maintenance technician, there are two general designs of check valve you will find in both large and small piping: the flapper (swing) check and the lift check valves (fig. 2–13). Check valves can have either threaded (for smaller pipes) or flanged ends for larger pipes. For petroleum, service shall be swing type conforming to API Spec 6D and shall be fire tested and qualified in accordance to API Spec 6FD, *Specification for Fire Test for Check Valve*. To conform to API Spec 6D, the seat and disc of both types must be removable without removing the entire valve from the pipeline.

The primary purpose of a check valve is to control the direction of product by trapping it in a line or in parts of a system, thus preventing reverse flow. For example, a check valve would be used in a line that could empty by gravity flow. By using a check valve, the line remains full, and flow through the line is immediate when pumps are started. If the line were permitted to drain, there would be a time delay before the pipe and any affected components refilled. There would also be the problem of air trapped in the lines or pump vapor locks. The air would have to be bled off somewhere along the way.

Figure 2–13, left, shows the flapper-check valve. It has a plate with a flat seating surface that is hinged at the top. It hangs in the CLOSED position when the system is static. Product entering from the left simply pushes the flapper up out of the way. If the flow reverses, the weight of the flapper causes it to swing shut; and the pressure of the product forces it tight against its seat. *No* product should flow through the valve in the reverse direction.

Figure 2–13, right, shows the construction of a typical lift-check valve. The weight of the valve disc is enough to provide positive seating with no flow.

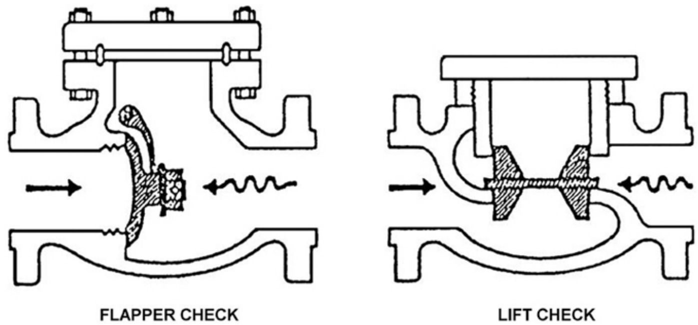


Figure 2–13. Check valves.

You need to know two other check valves you will come across in WFSM systems. The ball (or "in-line") check valves are usually found on automatic valve control tubing. The ball check has an internal ball that will be pushed away from its seat when the liquid flows one way and reseats itself when the flow reverses. Spring-loaded checks valves are found in some gas station dispenser pumps or used as foot valves on vertical piping in underground tanks. The spring-loaded check has a low-tension spring that holds the disc on a seat until enough pressure or vacuum overcomes the spring tension and pushes or pulls the disc up off the seat. Both perform the same function of preventing reverse flow.

Inspection and maintenance of check valves

Inspection and maintenance are at a minimum on check valves. Visually inspect for leaks, damage, or corrosion unless there is evidence of valve failure.

If an internal malfunction is suspected, check valves are opened for internal inspection and repair. The important thing to remember is that the flapper or valve disc must fit its seat as perfectly as possible. Any uneven seating permits leakage, which defeats the purpose of the valve.

NOTE: The orientation of a check valve in a pipeline is important. In addition to being installed with the proper flow direction, some check valves (flapper checks) require that the top of the valve be installed only at the "12 o'clock" position so that the flapper disc properly seats.

Damaged check valves in smaller lines up to 2 inches can be replaced due to their low costs. Larger check valves that are internally damaged may be repaired by using a lapping compound to restore the disc-to-seat seal or simply replace any removable damaged parts.

Butterfly valves

The butterfly valve is a manual valve used when the space between two flanges is small but at a location where the line periodically still needs to be closed off (fig. 2–14). This valve requires the least amount of space in a pipeline compared to other manual valves for the same size pipeline.

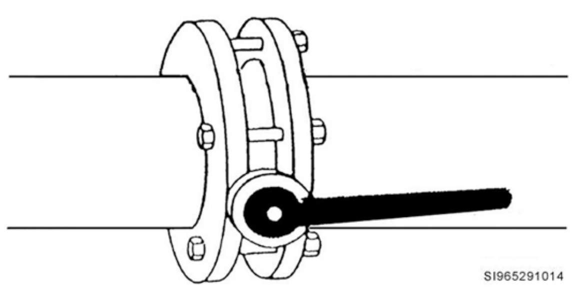


Figure 2–14. Butterfly valve.

Construction and operation of butterfly valves

Notice in figure 2–15 that the valve is of a simple design. It consists of body, disc, stem, seal, bushing, bolt, O-ring, and packing. The second bolt above the center of the disc is installed to prevent any turning of the disc. Butterfly valves for petroleum service shall be in accordance with API Standard (Std) 609, *Butterfly Valves: Double Flanged, Lug and Water-Type,* and shall be fire tested and qualified in accordance with API Spec. 6FA. As we have said before, this valve will take up a very small space in a pipeline. For example, a 4-inch butterfly can be only 4 inches across while a different type of manual valve for the same 4-inch pipeline could be 8 to 12 inches across. The type handle used to open and close the valve will depend on the function it is to provide. It can have a handle that can be locked in any position from OPEN to CLOSED, or it can be spring-loaded closed and held open by a fusible link to close automatically in case of fire. Fusible-link butterfly valves are normally located on aboveground fuel tank piping.

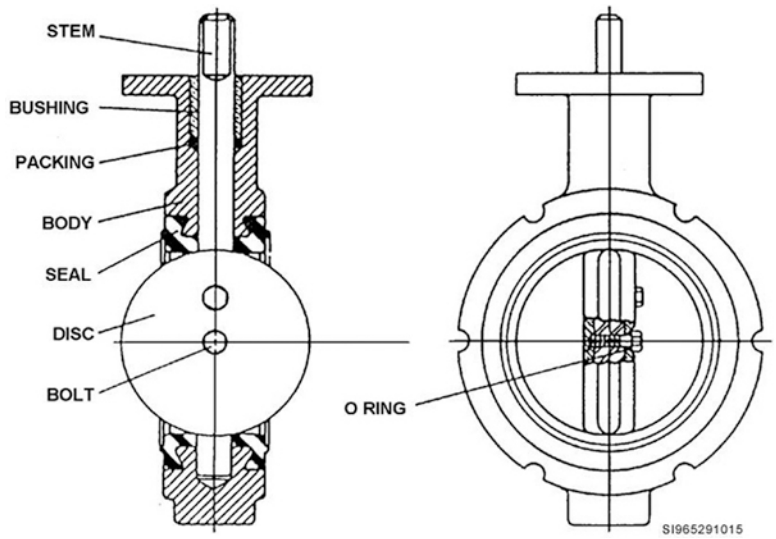


Figure 2–15. Butterfly valve construction.

Inspection and maintenance of butterfly valves

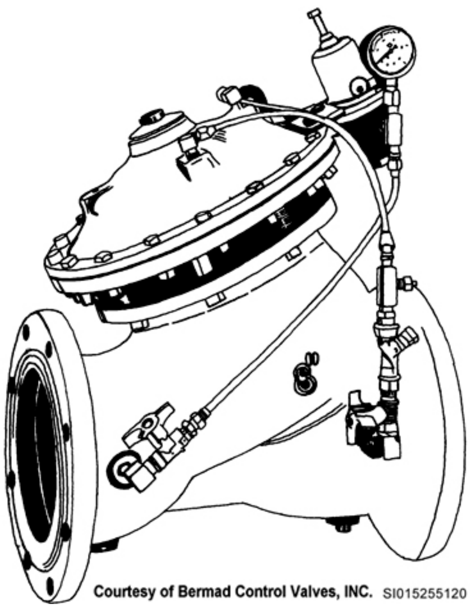
This type of valve requires only inspection for leaks and corrosion. Any maintenance required on the valve, except replacing the packing, will require removal from the line. Before relieving line pressure, open the butterfly valve slightly to *equalize* the pressure on both sides of the valve. Then relieve the line pressure, drain all fuel from the line, and close the valve before removing the flange stud bolts. The valve *must* be completely closed before you can remove it from the line. Repair or replace any parts as needed according to the manufacturer's manual.

Pressure-reducing (regulating) valves

Pressure-reducing valves (PRV) literally reduces the pressure in the line downstream of the valve. In water systems, pressure reducing valves are designed specifically to prevent water line breaks due to high water pressures. These high pressures can come from an elevated storage tank or any other high-pressure water distribution system. In fuel systems, these valves perform the same pressure-reducing function and are located at the junction of the cross-country pipeline and base's fuel system before the first line of filtration (the F/S) or bulk storage tanks to prevent damage to those systems. The PRVs in the water and fuel systems operate similarly, yet we will discuss only the PRV in water systems because the fuel system PRV will have components similar to the automatic valves discussed in a later volume.

Construction and operation of pressure reducing valves

The construction of this valve consists of a main valve, diaphragm, spring, disc, seat, and pilot control. The two-way pilot control governs the PRV by way of copper control lines connected to both the inlet and outlet of the main valve as well as the top of the diaphragm inside the main valve cover chamber (fig. 2–16). The spring tension on top of the diaphragm keeps the main valve normally closed when there is no flow through the valve. The pilot control governs the main valve by sensing the downstream pressure and applying more or less back pressure onto the top of the main valve cover chamber. Once flow starts, the pilot control will sense low pressure on the downstream side of the valve. The pilot control then allows most of the pressure to come off the main valve cover chamber, allowing the main valve to open. If the downstream pressure gets too high, the pilot control senses this increase in pressure and allows less pressure to come off the main valve cover chamber through the copper control line. With less pressure coming off the cover chamber, more pressure remains on top of the diaphragm, thus forcing the disc closer to the seat and allowing less liquid and pressure through the main valve. During flow, this valve should never close, but instead throttle to maintain the required downstream pressure.



Courtesy of Bermad Control Valves, INC. SI015255120

Figure 2–16. Pressure reducing valve.

Inspection and maintenance of pressure reducing valves

Pressure reducing valves require an annual inspection for leaks and corrosion as well as testing the pilot control setting. To test the setting of the pilot control, first ensure a pressure gauge is installed downstream of the valve. Next, start flow through the line and note the downstream pressure. Slowly close a manual valve downstream to increase the pressure sensed by the pilot valve. As the pressure increases, the main valve should throttle down. Then re-open the manual valve to resume normal flow. Note the downstream pressure again. Finally, if the pressure is within the acceptable range for that system, you are done. If the pressure is not within the acceptable range for that system, adjust the pilot control setting and re-test.

Pressure-relief valves

Pressure-relief valves are devices that prevent excessive pressure in a system, most commonly used on water heaters in water systems and throughout fuel systems. These valves are normally located on smaller lines or around manual valves and can be ordered from the manufacturer with preset pressure relief settings.

Construction and operation of pressure relief valves

Most pressure relief valves are constructed the same (fig. 2–17). The body is made of cast brass, bronze, iron, or stainless steel with an upper chamber containing an adjustment screw and spring and a lower chamber containing the disc and seat with a diaphragm in between. High pressure enters the valve at its side port and pushes up against the diaphragm and spring. The valve will open when enough pressure is exerted to overcome the spring tension setting the disc will lift up off the seat relieving the pressure through the bottom port and reseat itself again. The valve remains open only long enough to relieve the excess pressure.

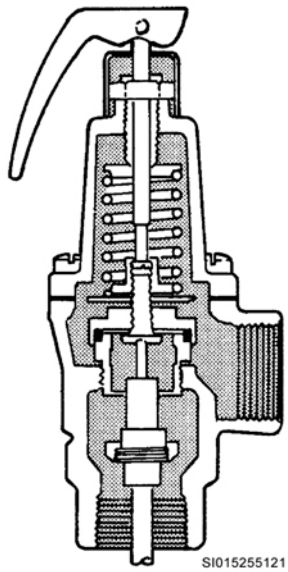


Figure 2–17. Pressure relief valve.

Inspection and maintenance of pressure relief valves

Pressure relief valves require minimal inspection and maintenance. Annually inspect for leaks and corrosion. In fuel systems, these valves require annual testing of their settings. They can be tested while still in the system or removed and tested in the shop. Regardless, a pressure gauge installed at a location to sense the inlet port pressure is needed to determine at what pressure the valve opens. Make pressure setting adjustments with the adjusting screw as needed. If a pressure relief external body is leaking or you cannot achieve your desired pressure relief setting after adjustment attempts have been made, replace the valve.

Altitude valves

The purpose of an altitude valve is to maintain water distribution system pressure and regulate the water level in elevated water storage tanks to prevent them from overflowing or running dry.

Construction and operation of altitude valves

Altitude valves can be single acting allowing flow to a storage tank or double acting allowing flow to and from a storage tank. Their construction is made up of a main valve body consisting of a diaphragm, tension spring, disc, and seat. External components consist of a pilot control component(s) and control tubing that regulates the opening and closing of the main valve. The pilot control(s) senses the pressures exerted by water systems and/or the varying water levels inside the elevated water tank (fig. 2–18).

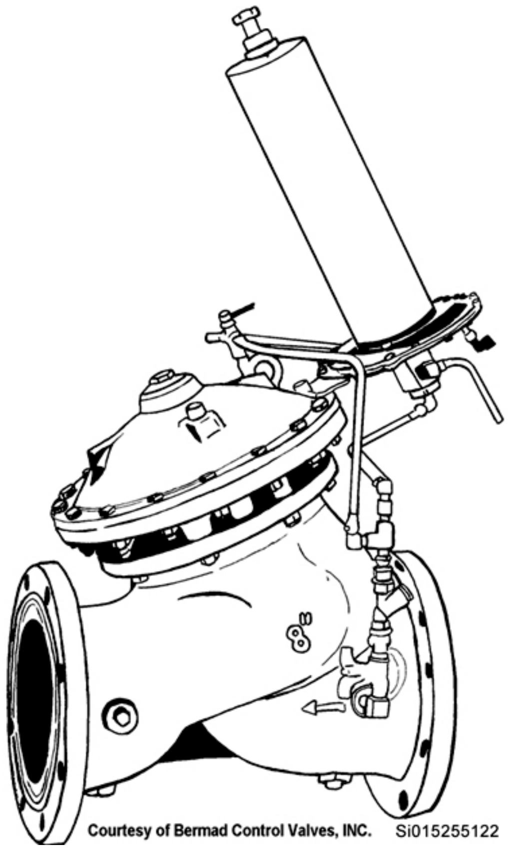


Figure 2–18. Altitude valve.

One-way flow type

This type of altitude valve (fig. 2–18) is used when the inlet (fill pipe) and outlet (draw pipe) to the storage tank are separate. The function of this valve is to open to fill the tank and close when it is full. The valve senses the head pressure in the tank, then opens and closes when the tank's predetermined water levels are reached. When the water level and pressure in the tank drops to a predetermined low level, the water well or commercial water system pumps will turn on. Those pumps will create enough pressure to open the one-way altitude valve to fill the tank. Once the high-level setting is reached, the valve will close preventing overfilling.

Two-way flow type

This type of altitude valve is used when the inlet (fill pipe) and outlet (draw pipe) are the *same* line. In simpler terms, it is a valve that flows in both directions. The two-way altitude valve's first function is to open and close to maintain the water distribution system pressure. The valve opens and allows water from the tank to feed and recharge the system and shuts when normal distribution pressure is achieved or to prevent the tank from running dry. Its second function is the same as a one-way altitude valve, to open to fill the tank and close when full. However, since the inlet line to the tank and outlet line to the distribution system are the same, those pumps will first feed and pressurize the distribution system and then create enough pressure and flow to open the valve, fill the tank, and close before overfilling.

Inspection and maintenance of altitude valves

Inspect altitude valves monthly for external leaks and corrosion. These valves are normally found in valve pits, so also ensure the pits are free of debris and water during the monthly inspection. Test these valves at least once a year to ensure the correct settings of the pilot control. To test the pilot control's low-level setting, monitor the tank as it *empties* to determine the water level the altitude valve closes to prevent the tank from running dry. Adjust the setting as needed. To test the pilot control's high-level setting, monitor the tank as it *fills* to determine the water level the altitude valve closes to prevent over-filling. Again, adjust the settings as needed. To test the pilot control setting that maintains the water distribution system pressure, monitor the system pressure as it drops and note the pressure at which the valve opens to recharge the system. Adjust the pilot control setting as needed. These are general guidelines, so check the manufacturer's manual to ensure proper valve settings.

Valve boxes

Some piping for water service, drains, and dikes are usually buried underground. On these pipelines, manual valves are also buried to periodically isolate these lines. Buried valves will have an extended operator to open or close them that are visible just below the ground surface. Valve boxes are built to enclose these underground valve operators and provide a means of access to insert a valve key to reach the operating nut.

Valve boxes usually consist of three pieces: the base, center section, and top section. They can be made of cast iron or hardened plastic with the center pipe section to be about 6" in diameter. The top section can be:

- Surrounded by cement or asphalt on traveled roadways or sidewalks.
- A raised pipe surrounded earth if not in a traveled area.
- A recessed pipe surrounded by a ground-level box if not in a traveled area.

Some have covers with locknuts to prevent unauthorized access. Valve box dimensions should be large enough to allow for valve operation. Take care when installing the valve box over the pipe valve to achieve proper alignment; otherwise, the valve key will not fit on the valve's operating nut. Never allow the weight of the valve box to rest on the pipe because the valve box assembly is heavy and can damage the pipe. Instead, let the soil around the pipe support the valve box. Inspect valve boxes semiannually for debris, the correct elevation of the top section, and proper alignment. A valve box that is full of debris or not aligned properly does not allow the proper alignment of the valve key on the operating nut. Debris also causes corrosion of metal parts, making it hard to operate the valve.

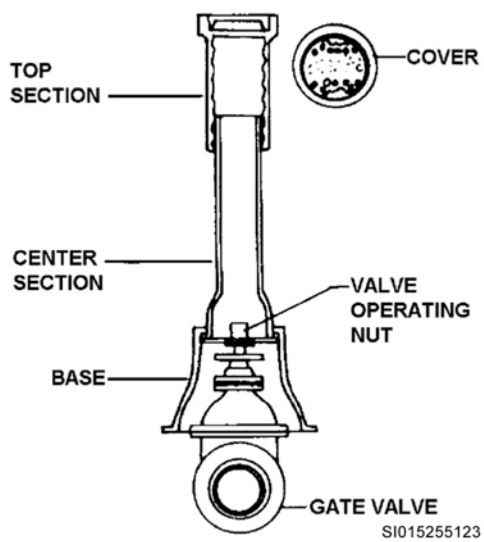


Figure 2–19. Valve box on a gate valve.

NOTE: On fuel pipelines, valves or flanges are never buried because they are deemed weak points. If valves are needed, valve pits or vaults are constructed so maintenance can be performed.

214. Replacing valves

Preparation is the most important part of any job. You don't just sling a toolbox on the back of a truck and take off. There are many things to consider and do before turning wrenches. Take five minutes to think about the job and plan accordingly. A job well planned, is a job well done the first time. Careful planning will save you time and trips back to the shop for forgotten items. Most of the steps and guidelines you will read in this lesson are safety related when removing valves in a fuel system, but the basic procedural and mechanical steps apply to the removal of valves in both water and fuel systems.

Preparing for the job

For water systems, your supervisor will select the appropriate number of personnel for the job. When you are going to work on a fuel system, the two-person (minimum) concept applies.

WARNING: *Never* work on or remove a fuel system component without someone else present.

The second person does not have to be qualified in fuels system maintenance duties; the person can be present just as a *safety* observer.

Notification

We do the maintenance, but we do *not* perform the daily operations of the fuel systems. Base fuels management personnel (the POL) are responsible for the system's operation and minor operator maintenance such as refueling aircraft, draining water from fuel tanks, and cleaning strainers. Therefore, before you can remove any component or interrupt normal operations, you or your supervisor *must notify* the personnel on duty at the fuels resource center (FRC). There are some very good reasons for this notification.

First, you want to find out whether your work will interfere with the base's flying mission. The fuel operators may have to transfer fuel from one part of the system to another before you can start your work. Thus, more or less, you'll be making a fuel maintenance appointment so you will not interfere with the operator's work and they won't interfere with yours.

Second, you do *not* want to start removing a valve while an operator opens valves and starts a pump somewhere else in the system. You'll also need to make sure receiving, transferring, or dispensing fuel operations will *not* cause a fuel spill that will put you and your coworkers' lives in danger. Most mishaps that occur in a fuel system are a direct result of poor communications between POL and WFSM.

For water systems, whenever possible, notify any customers in advance if they will be affected by a water system outage. This will prevent most "no service" calls to CE customer service.

Gathering tools and equipment

Gathering tools and equipment isn't as simple as it might seem. For example, if the valve has bolted flanges, you will need more than a couple of wrenches to remove it. Also, make sure you have the right size wrenches and sockets. If it's a threaded valve, take at least two pipe wrenches. This is because you'll need one pipe wrench to turn the valve and a backup wrench so that the pipe won't turn with the valve. Besides the use of a backhoe to dig up the soil around water valves, the tools needed for replacing the various automatic and manual valves for both water and fuel are the same.

Blind flanges, caps, and plugs

For fuel systems, if you even think you might leave the job site, whatever the reason, you will need to maintain system integrity. By system integrity, we simply mean you need to make sure that no fuel spill can occur. WFSM personnel *must* install blind flanges and gaskets, caps, or plugs when a flanged or threaded component of a fuel system is removed or altered and left unattended. A closed valve upstream that is tagged or locked is *not* considered a "positive shutoff." Finally, make sure you have the right size items.

Locks and tags

Most new valves are designed so that you can lock them. But if the valve does *not* have a locking device, you'll need a chain so that you can lock the valve handles in the CLOSED position. Also, the valves used to isolate the valve being replaced must be secured so that *no* one can accidentally open them and soak you with fuel or water.

As-built drawings

How many valves will you have to close, lock, and tag to isolate your work? Which valves do you close to minimize the amount of fuel you have to drain? You can answer these questions by becoming familiar with the system and using "as-built drawings." Your shop should have these as-built drawings for you to review. Also, these drawings should be available in either the pump or the control room of the fuel system. Look at these two situations. In one, if the valve you are replacing is in a straight section of pipe, you will probably have only two valves to secure. In contrast, if in the second situation the valve is located in a manifold, you might have to secure three, four, or even more valves.

Static bonding wires

In an earlier lesson you learned the importance of bonding and grounding when dealing with fuel systems. Be sure you have enough static bonding wires to do the job. You need one to connect around the valve being removed and another to connect the drip pan to the pipeline before draining fuel. If you are going to use a pump with drums or a fuel truck to drain the line, you'll need even more static bonding wires to connect to each component involved in the fuel transfer.

For water systems, these wires are not needed, but if the water or fuel line is cathodically protected with an impressed current system, then the system will need to be temporarily shut off until the valve replacement is completed.

Calculation of fuel to be drained

Before you can remove a valve, you have to drain the fuel contained in the isolated section of pipe. To determine how much fuel is in that section of pipe, use the volumetric capacity of pipe chart below. Suppose, for example, that the section of pipe to be drained is 6 inches in diameter and 22 feet long. Using the chart, you will discover a 6-inch standard schedule 40 pipe will hold 1.5 gal. per foot. So you multiply the gal. per foot (1.5 gal.) times the length (22 feet), and you get a total of 33 gal.

Pipe Size Inches	Schedule 40 Pipe Gallons Per Foot	Schedule 80 Pipe Gallons Per Foot
1	0.045	0.037
2	0.174	0.153
3	0.384	0.343
4	0.661	0.597
6	1.5	1.354
8	2.599	2.372
10	4.096	3.878
12	5.875	5.631
14	7.163	6.895
16	9.488	9.180
18	12.141	11.791
20	15.067	14.729
24	22.055	21.583

This chart is necessary because fuel, unlike water, cannot be dumped on the ground. Calculating how many gal. need to be drained and transferred will help you decide if a drum (55 gal.), a bowser (a tank on wheels, 150–400 gal.) or a POL fuel truck used to reclaim fuel (1,200–6,000 gal.) is needed to put the drained fuel in.

Draining the fuel

For fuel, when you have all of your equipment and FRC has been notified, isolating the system is the *first* task you and your co-worker must complete. Begin by relieving all pressure on the line and closing off and locking all valves you have determined are involved.

Then you must install the static bonding wires around the valve to be removed and from the pipeline to the drip pan. Why? Because fuel spraying out of a flange is just like free-falling fuel; it creates its own static electricity. Most drip pans will not hold a large amount of fuel; so you have to use either a hand or pneumatic pump to evacuate the fuel from the drip pan to a drum or bowser. Again, static bonding wires are extremely important.

Next, you're going to drain the line. If you're lucky, there will be a drain valve at a low point in the system. If there is a low-point drain line, simply connect one end of a hose to the drain line and the other end to a hand or pneumatic pump. The pump's discharge hose is then placed in a drum or bowser, or hooked up to a product recovery tank connection. If there is no low-point drain line, you'll have to loosen the *bottom* nuts and bolts on a flange and drain the fuel into a drip pan. It is very important to loosen the *bottom bolts first*. If you do this, the fuel will drain downward toward the drip pan and not up into your face. This also keeps you from working in the path of the draining fuel.

After draining for only a short time, you may find that the fuel will stop flowing. This stoppage is due to the fuel drawing a vacuum on the line. To break the vacuum, you must find a way to let air into the pipeline. You can do this by removing a pressure gauge, disconnecting a pressure relief line, or loosening the top nuts and bolts on the flange of the valve you're going to remove. Once air is in the line, the fuel will flow again. Watch out, though! It may drain faster than you expected. When the remaining fuel coming out of the line has been reduced to a trickle, you can use a flange spreader to widen the gap between the flanges and allow the last of the fuel to drain into your bonded drip pan. When all fuel is drained, remove the flange spreader and clean up any spilled fuel before removing the valve.

For water, after the line has been isolated and before removing a water valve, the need for pumping equipment must be evaluated to remove excess water that may impede work or weaken a trench wall. Loosen the valve bolts so that the water drains from the bottom of the water valve and begin pumping operations.

Removing the valve

Removing the valve or any other component can be easy or difficult. For example, while steel and aluminum pipe are rigid, both will expand, contract, and possibly shift over time. This shifting can cause the line to be "sprung" loose or tight. Depending on which way the line is sprung, the valve may just roll out of the line or be squeezed tightly in place. After draining is completed, loosen all the nuts and bolts and start removing them, leaving one bolt installed on the bottom of each flange. If the pipeline has sprung loose, these two bolts will act as a hinge and allow you to rotate and remove the valve. If the pipeline is sprung tight, you are going to need jacks or a come-along to pull or move the pipe so that the valve will be free to roll out of the line.

If your shop is fortunate enough to have a portable engine lift or overhead pulley system to support the valve from above, then removing the valve becomes that much easier. For water line valves, attach the proper size chain securely to the backhoe bucket to lift valves out of a trench.

Remember, for fuel systems, if you must leave for any reason at all, no matter how long or briefly you will be gone, you have to maintain the system integrity. If the valve is out of the line, then you must blind flange, cap, or plug any open ends as necessary. If the valve is still in the line, tighten all the nuts and bolts.

CAUTION: Whatever you do, do *not* be the cause of a fuel spill incident.

Installing a valve

On threaded metal pipe, wrap Teflon tape around the threads in the direction you will be turning the valve. For small threaded fuel connections with good threads, the Teflon tape is usually all you need to make a leak-proof seal. For threaded water connections with good threads, using Teflon tape and/or pipe dope (sealing paste) on the threads will create a leak-proof seal when tightening the connections.

You install a bolted valve in much the same way as you remove it. Remember to use a static bonding wire when replacing valves in a fuel system. With the pipe flanges spread enough to accept the valve, lift the bottom of the valve high enough to insert a bottom bolt in the same hole on each flange. With the two bottom bolts installed, you will be able to swing the valve into place and insert another bolt in the lower holes of each flange. This method is much easier than manually lifting the entire valve and balancing it while trying to insert bolts. If you are lowering the valve into place, keep your fingers away from the flanges when guiding the valve into place, then insert at least two bottom bolts in each flange.

As you have learned in earlier lessons, metal does not seal well to metal, and such a connection will not hold very much pressure. Consequently, you will have to use a gasket of an approved material to keep any flanged connection from leaking. Insert a few more bolts in the side flange holes leaving the top holes open to install a gasket between each flange. Center the gaskets on the flange mating surfaces, insert the remaining bolts, and tighten the nuts and bolts in a crisscross pattern, drawing the flanges together evenly. There are no torque requirements for tightening the nuts and bolts; however, they should be tightened equally.

Pressure testing

After installing the valve, check your work. The pipeline will have a large amount of air in it, and depending on the particular section of the system, you may have to remove that air manually. For instance, if fuel flows from that line through a F/S or a meter, you should try to bleed as much air from the line as you can because air can cause unusual noises or cause components to operate improperly when trapped in the system. One way of doing this is to remove a pressure gauge and use its isolation valve to bleed the air. Be very careful when the line is full; fuel will spray from the isolation valve. You could also connect tubing or pipe to the gauge valve and direct the airflow into a drip pan. In any case, when the line is full of fuel, close the valve and reinstall the pressure gauge.

Using a pressure gauge line is not the only way to remove air from a pipeline. Look around, be innovative, but always keep safety foremost in your thoughts. If you are not sure, contact your supervisor.

If the flow through the line goes directly into a storage tank, or if the line has an air eliminator, you won’t have to bleed the air manually just to pressurize the pipeline. All you want to do is to make sure the threaded or flanged connections do not leak. Depending on the system, you can use static pressure from a tank or the installed pumps. Of the two, by using the static pressure from an aboveground tank, the pressure will be lower and the flow into the section you are refilling will be easier to control. If there are leaks, tighten the connections as necessary.

Cleaning up

Once you are sure that the valve doesn’t leak, collect the tools and clean them as necessary. Clean up your work area and repaint as needed. Then contact FRC and notify them that the work is complete. At the same time, find out what the FRC wants you to do with the fuel you have drained out of the line. Finally, inform your controller that the work is complete.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

213. Specialized valves

1. What are the two designs of check valves in large and small piping?

2. When used in fuel systems, what standard requires that a check valve's seat and disc must be removable without removing the entire valve from the line?

3. What is the *primary* purpose of a check valve?

4. Which manual valve can be installed in *small* places between two flanges?

5. What position *must* the butterfly valve be in before you can remove it from the system?

6. How does the pilot control govern the main valve of a pressure reducing valve?

7. What should happen when a pressure reducing valve's pilot control senses an increase in downstream pressure?

8. When does a pressure relief valve open?

9. During pressure relief valve testing, what is needed to determine when the valve opens?

10. What is the purpose of altitude valves?

11. What should you use to ensure that an altitude valve is properly set?

12. What is the purpose of valve boxes?

13. Why is cleaning debris out of a valve box important?

214. Replacing valves

1. Who must you notify before removing any fuel system component?
2. When you remove threaded valves, how many pipe wrenches should you have? Why?
3. If you are leaving the job site, what *must* be installed on a pipeline in place of a valve you have removed?
4. Where can you look to determine how many valves you will need to close and isolate the system?
5. How much fuel is in a 50-foot section of 16-inch schedule 80 pipe?
6. Why should you leave one bolt installed on the bottom of each flange of a manual valve when removing the valve from the pipeline?
7. How should you bleed the air from a pipeline if the pipeline goes through a filter separator?

Answers to Self-Test Questions

209

1. Makes it possible to send line scrapers through long runs of pipeline without interference.
2. Rising and non-rising stem gate valves.
3. Rising-stem gate valve.
4. Non-rising stem gate valve.
5. Close slowly; this prevents hydraulic shock.
6. Two.
7. Packing gland nut.
8. In fuel systems—quarterly; in water systems—semiannually. Operate the valves, check for leaks, adjust the packing gland if needed, lubricate the gear housing, inspect for visible external damage and ensure corrosion control.
9. Troubles are limited to failure of seat, sticking, and stem leakage. Foreign matter can sometimes be removed by opening the valve slightly and flushing; otherwise, disassembling and clean seats. Minor seat damage can be lapped to repair. Tighten packing gland nut for stem leakage or replace packing.

10. Turn handle to maximum travel, then back off a little to relieve strain on valve stem.

210

1. Because they have a high flow resistance.
2. Body, wheel, stem, packing, packing nut, cover, disc, and seat.
3. The product flow will be controlled or limited.
4. Upstream. The flow of fuel will come under the valve seat and disc. This allows repacking under pressure.
5. Closed.
6. Either replace the removable disc and seat or by lapping the disc to the seat.

211

1. Non-lubricated.
2. Lift-plug, movable-seat, resilient-liner, and DBB.
3. The gearing and locking devices built into the valve.
4. A movable-seat plug valve.
5. Leakage past the hub.
6. Proper opening and closing of the valve, lubricating the operator through the grease fitting using the manufacturer's recommended lubricant, checking for leaks, and corrosion control on a quarterly basis. Replace seating slips if determined they are not sealing during bleed test.
7. Remove the old packing and replace it with new.
8. A screw-jack device that provides mechanical advantage to "lift and turn" the plug, reseat the plug and apply pressure to the seals when closing the valve.

212

1. First design requires only a quarter turn of the valve stem to rotate the ball 90 degrees to fully open or close the valve. The second design requires the turning of a hand wheel to slowly rotate the ball 90 degrees to fully open or close the valve.
2. Trunnion-type support bearings. They provide a centered pivot point for the heavier balls.
3. Non-lubricated plug valve.
4. Fuel valves-quarterly, water valves-semiannually; for ease of operation, leaks, and corrosion.
5. Replacement of packing, packing rings, gaskets, seals, and ball.

213

1. Flapper (swing) or lift check.
2. API Spec. 6D.
3. To control the direction of the product flow by trapping it in a line or in parts of a system, thus preventing reverse flow.
4. Butterfly.
5. Closed.
6. By sensing the downstream pressure and applying more or less back pressure onto the top of the main valve cover chamber.
7. The main valve should throttle down.
8. When enough pressure is exerted to overcome the spring tension setting.
9. A pressure gauge installed at a location to sense the inlet port pressure.
10. To maintain water distribution system pressure and regulate the water level in elevated water storage tanks.
11. Manufacturer's manual.
12. To enclose underground valve operators and provide a means of access to insert a valve key to reach the operating nut.
13. A valve box that is full of debris does not allow the proper alignment of the valve key on the operating nut, and can cause corrosion of metal parts making it hard to operate the valve.

214

1. Personnel at the FRC.
2. At least two: one to turn the valve and one to hold the pipe.
3. Blind flanges and gaskets, caps, or plugs.
4. As-built drawing.
5. 459 gal.
6. If the pipeline has sprung loose, these two bolts will act as a hinge and allow you to remove the valve more safely.
7. Remove a pressure gauge and use its isolation valve to bleed the air.

Complete the UREs before reading the next unit.

Unit Review Exercises

Note to Student: Consider all choices carefully, select the *best* answer to each question, and *circle* the corresponding letter.

20. (209) Gate valves are found in cross-country pipelines because
    a. they can be closed very quickly.
    b. their position can be seen from a long distance.
    c. they allow line scrapers to pass through them.
    d. they can regulate the flow through the pipeline.

21. (209) How many different basic designs of gate valves are there?
    a. 1.
    b. 2.
    c. 3.
    d. 4.

22. (209) How often do you perform gate valve inspections in fuel/water systems?
    a. As required.
    b. Semiannually/annually.
    c. Quarterly/semiannually.
    d. Bi-monthly/bi-annually.

23. (209) During repacking, you should place a gate valve in what position?
    a. Open.
    b. Closed.
    c. Either open or closed.
    d. Intermediate between open and closed.

24. (210) What type packing is *most* commonly used on globe valves?
    a. Nylon.
    b. Viton.
    c. Teflon string.
    d. Graphite string.

25. (211) Non-lubricated plug valves generally fall into four main types including lift, movable-seat, resilient-liner, and
    a. check.
    b. globe.
    c. butterfly.
    d. double block and bleed (DBB).

26. (211) Which item prevents leakage past the hub of the resilient-liner plug valve?
    a. O-ring.
    b. Diaphragm seal.
    c. Asbestos gasket.
    d. Graphite packing.

27. (211) What type valve does *not* have to be removed during hydrostatic testing?
    a. Double block and bleed (DBB) plug valve.
    b. Resilient liner plug valve.
    c. Gate valve.
    d. Ball valve.

28. (211) What inspection and maintenance items are performed on a double block and bleed (DBB) plug valve during a routine scheduled interval?
    a. Check for leaks and proper operation.
    b. Operator lubrication, bleed test, and corrosion control.
    c. Proper operation, operator lubrication, checking for leaks, and corrosion control.
    d. Proper operation, checking for leaks, corrosion control, and replacement of the sealing slips.

29. (211) A 12-inch nonlubricated plug valve will have what type of operator?
    a. Lever.
    b. Chain.
    c. Wrench.
    d. Worm gear.

30. (211) What is the *first* step in removing a General Twin Seal plug valve operator?
    a. Drain the line.
    b. Close the main valve.
    c. Open the main valve.
    d. Open the manual bleed valve.

31. (212) What type valve used in fuel systems must operate from fully closed to fully open with a 90-degree rotation?
    a. Gate.
    b. Ball.
    c. Plug.
    d. Globe.

32. (213) What type of valve is used to control the direction of flow in a system, but does not affect the rate of flow?
    a. Ball.
    b. Gate.
    c. Check.
    d. Butterfly.

33. (213) The seat and disc of which valve must be removable without removing the entire valve from the pipeline?
    a. Gate.
    b. Plug.
    c. Globe.
    d. Check.

34. (213) You *slightly* open a butterfly valve before relieving the line pressure to
    a. equalize the pressure on both sides of the valve.
    b. increase valve clearance.
    c. equalize static potential.
    d. loosen the flange seals.

35. (213) What *must* you do before you can remove a butterfly valve from a pipeline?
    a. Remove the handle.
    b. Place it in the fully open position.
    c. Place it in the fully closed position.
    d. Notify the major command (MAJCOM) fuels engineer.

36. (213) What is the *first* step when checking the pilot control setting on a pressure-reducing valve (PRV)?
    a. Drop the pressure upstream of the valve.
    b. Drop the pressure downstream of the valve.
    c. Ensure a pressure gauge is installed upstream of the valve.
    d. Ensure a pressure gauge is installed downstream of the valve.

37. (213) What do you do if a pressure-relief valve is still malfunctioning after attempting pressure setting adjustments?
    a. Replace the valve.
    b. Use a different pressure gauge.
    c. Send it back to the manufacturer.
    d. Send it to the Precision Measurements Equipment Laboratory (PMEL).

38. (213) When testing the high-level setting of an altitude valve, you must monitor the
    a. water distribution system pressure.
    b. tank water level when it is being filled.
    c. tank water level when it is being emptied.
    d. flange float assembly on the side of the tank.

39. (213) Why must care be taken when installing a valve box over a pipe valve?
    a. To ensure proper alignment of the valve key to the valve operating nut.
    b. So that the valve box is not installed upside down.
    c. To ensure the valve box fits snugly on the pipe.
    d. To prevent debris from entering valve box.

40. (213) Why should you *never* allow a valve box to rest on a pipe?
    a. The pipe will damage the valve box.
    b. The valve box may damage the pipe.
    c. Access to the operating nut will misaligned.
    d. The metal to metal contact will cause corrosion.

41. (214) Who *must* you notify before starting work on a fuel system that could interfere with the base flying mission?
    a. Wing safety.
    b. Base operations.
    c. Fuels resource center.
    d. Command fuels engineer.

42. (214) What specialized equipment *must* you have to ensure system integrity when removing a valve from the system?
    a. Locks.
    b. Drip pans.
    c. Blind flanges.
    d. As-built drawings.

43. (214) When removing a manual valve from a fuel pipeline, which bolts on the valve should you loosen *first* to drain the fuel into a drip pan?
    a. Top.
    b. Bottom.
    c. Left side.
    d. Right side.

44. (214) When reinstalling a manual valve, which bolts should you insert *first*?
    a. Top.
    b. Bottom.
    c. Left side.
    d. Right side.

45. (214) The fuel system configuration that would *not* require you to manually bleed air out of the pipeline after a valve is replaced, involves pumping
    a. through a meter.
    b. through a fill stand.
    c. through a filter/separator (F/S).
    d. directly into a storage tank.

Please read the unit menu for unit 3 and continue ➔

Unit 3. Pumps

DURING YOUR CAREER as a WFSM craftsman, you will encounter many variations of several different types of pumps manufactured by both American and foreign companies. However, to simplify our discussion, we can categorize pumps as either positive displacement or non-positive displacement.

3–1. Positive Displacement Pumps

In WFSM systems, positive displacement pumps are widely used as offloading and transferring pumps for fuels, as well as portable sump pumps to remove liquids from low-lying areas and water from dig sites. Three types of positive displacement pumps are found more than others: (1) *gear*, (2) *rotary-vane*, and (3) *diaphragm*. The gear pump is commonly found in self-contained automotive fuel dispensing units and is occasionally used as a portable pumping unit. The rotary-vane pump is also found in some self-contained automotive fuel dispensing units. It is commonly used as the priming component inside the self-priming centrifugal pump and for tanker truck offloading systems. The diaphragm pump is a portable pump and a standard piece of equipment for WFSM shops to transfer water and fuel.

The term "positive displacement" describes how liquid or air is drawn into the pump's inlet connection, then trapped between the sections of the pump's moving components and the pump inner housing wall, and finally forced to the pump's outlet connection. The reason air is also mentioned is because the moving components of the positive displacement pump form a seal against the inner housing wall to trap and move a product from inlet to outlet. Thus, if air is in the inlet line, it will also be trapped. This ability to trap a product and send it through the pump gives the positive displacement pump the capability of creating a vacuum at the pump's inlet. While positive displacement pumps will usually have a flooded suction (liquid supplied to the pump's inlet from an aboveground source), it has the ability to draw a liquid up and out of a sub-surface source if the suction lift isn't too great.

The output or discharge rate of a positive displacement pump is determined by the size of the pump and the number of revolutions per minute (rpm). For example, if one cycle or revolution of the pump traps one gal. of liquid and the pump makes 100 rpms, then the output is 100 gallons per minute (gpm). As the liquid is being force to the outlet of the pump and into the hose or piping beyond, pressure is also being generated. Since the generated pressure can build up but cannot be relieved back through the pump, a relief valve and a bypass line *must* be installed downstream from this type of pump to relieve excess pressure preventing damage to downstream components.

215. Gear pumps

There are two different kinds of gear pumps: external and internal. The *main* difference between the two is where the liquid flows. In the external gear pump, the flow of liquid is between the pump housing and the gears; in the internal gear pump, the flow of liquid is between the gears. Other differences will show up as we cover the two different types of pumps.

Construction and operation of the external gear pump

Look at figure 3–1, which illustrates an external gear pump. Note that the product moves from the inlet port around the outside of each gear to the outlet port. The product is trapped in the spaces between the gear teeth. As the gears mesh on the outlet side, the product is forced out of the space into the discharge port. If the flow of product is stopped at some point downstream (discharge side) and the pump continues to run, the positive displacement of product to the discharge side of the pump will generate increased pressure. This increased pressure, if left unchecked, will eventually rupture the line, the pump housing, or some component on the downstream side. This explains the necessity for the bypass relief line to protect the system.

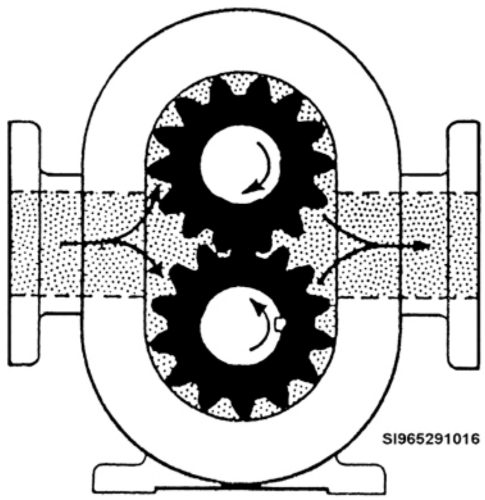


Figure 3–1. External gear pump.

The bottom gear, shown in figure 3–1, is designated as the driving gear because this gear is connected to the pump/motor shaft. The top gear is designated as the driven gear because it is turned by the driving gear. When the pump is turned on, the motor transfers power to the pump either through a straight shaft or through a gearbox that determines the rpms the pump will turn. The number of gpm that the pump will deliver will depend on the rpms turning the pump and the amount of space around the gears.

Construction and operation of the internal gear pump

Figure 3–2 illustrates an internal gear pump. Looking first at figure 3–2, A, you see the cutaway housing of the pump. This housing contains a shaft and a crescent-shaped stationary partition. The pump shaft drives the spur gear, and the spur gear drives the cage gear. You can visualize the housing better by looking at the view in figure 3–2, B. Note that the pump shaft is off-center to the housing. In figure 3–2, C, you see the addition of the spur gear. This spur gear is mounted on the pump shaft. In figure 3–2, D, you can see how the two gears mesh on the upper left side of the housing. The cage gear is much larger than the spur gear and rides freely within the housing. The teeth of the spur gear rotate the cage gear, which passes on the outside of the stationary partition and re-meshes with the spur gear at the top of the pump. As is true of the external gear pump, liquid passes around the housing in the spaces between the gear teeth. In this case, the pump output is quite high for its physical size because of the two sets of teeth and extra spaces provided by the cage gear.

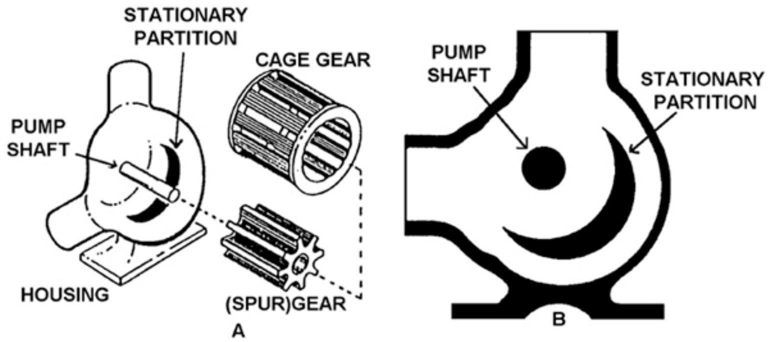


Figure 3–2. Internal gear pump.

216. Rotary-vane pumps

The most widely used positive displacement pump found in offloading and fuel transfer pumphouses is the rotary-vane pump. For our purposes, we will discuss the Blackmer rotary vane pump since it is one of the most widely used rotary-vane pumps in the AF inventory.

Construction and operation of rotary-vane pumps

The Blackmer rotary-vane pump can handle all liquid fuels and oils efficiently. The gpm capacity of the pump depends on the pump size and pump rpms. If you look at figure 3–3, you will notice the gear reducer. The gear reducer makes it possible to adjust the pump's rpms. To change the pump's rpms and gpm flow rate, you must physically change the size of the gears inside the gear reducer.

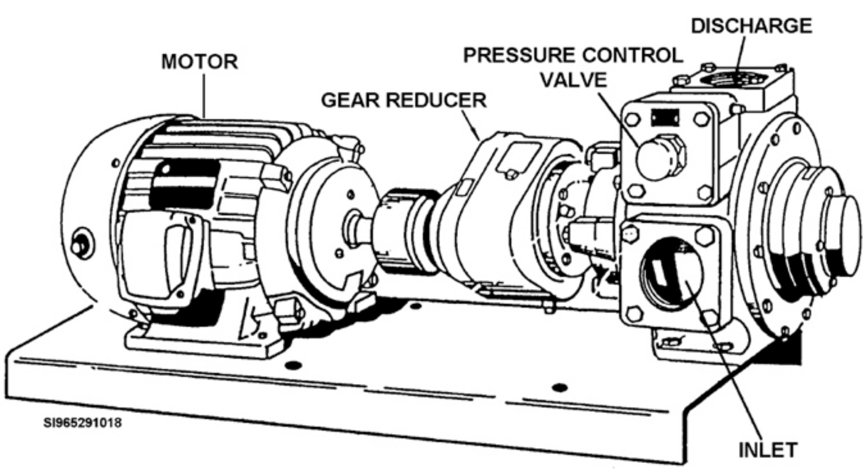


Figure 3–3. Rotary-vane pump.

Looking at figure 3–4, you can see that as fuel enters the pump at the inlet of the pump, the vanes move it between the pump rotor and the pump housing. The push rods hold the vanes against the housing. As the fuel reaches the discharge side of the pump, the rotor and pump housing "squeeze" the fuel out of the pump. This pump has a built-in pressure control valve to relieve excessive fuel pressure on the discharge side of the pump. A pressure gauge can be installed in place of the gauge plug to check the operating pressure of the pump and aid in the setting of the pressure control valve.

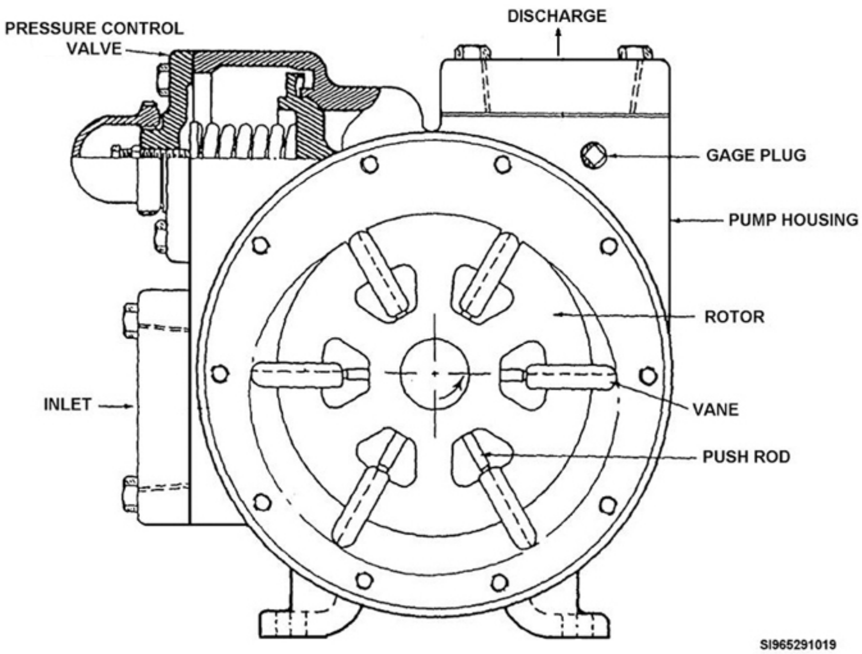


Figure 3–4. Construction of the rotary-vane pump.

Figure 3–5 shows the pressure control valve of the Blackmer pump and its components. Excessive fuel pressure under the disc of the valve will overcome the spring tension and open the valve, relieving the excessive pressure from the discharge side of the pump back to the inlet side.

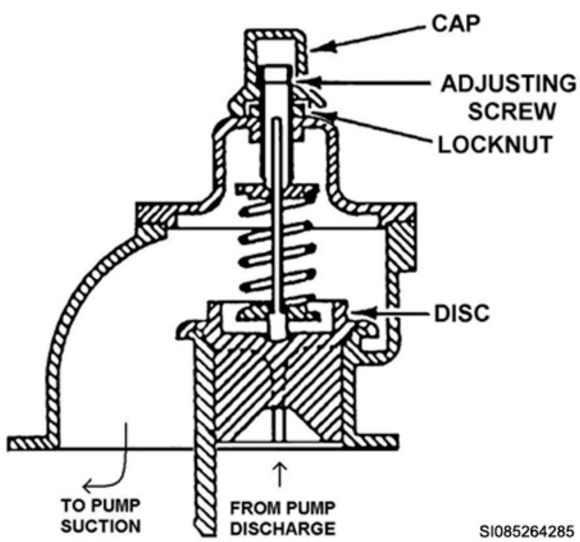


Figure 3–5. Pressure control valve.

A rotary-vane pump can be wired to run in reverse to evacuate a line or hose.

CAUTION: If the pump is ever run in *reverse*, the pressure control valve *will not* relieve excessive pressure.

Inspection and maintenance of rotary-vane pumps

Operationally inspect rotary-vane pumps quarterly for leaks, vibration, gear alignment within the gear reducer, overheating of pump and motor, and lubrication of the pump bearings. The bearings are sealed and greased in accordance with the applicable manufacturer's manual. Apply lithium-based grease with a hand-pressure gun until the grease starts to escape from the grease relief. You may find some grease escaping from the drain holes under the bearing chamber the first time or two the pump is run after greasing. This is normal. It does *not* indicate seal failure.

Rebuild of rotary-vane pumps

It is easy to disassemble the Blackmer pump for maintenance. You remove the gear reducer unit by removing the clamp plugs and loosening the setscrews. Rotate the reducer and pull it off the pump.

You remove the bearing seals and bearings as a unit by removing each head. You may have to tap or pry the heads a little to "break them loose." Just do it gently. It's also easy to remove the individual seals and the rings. After removing the bearing cover from the head, use a screwdriver to push the seals and bearings from the head. The head and seals are shown in figure 3–6.

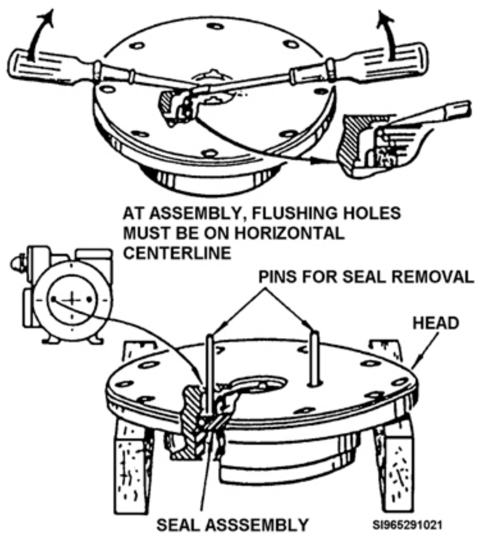


Figure 3–6. Seal and bearing removal.

You remove vanes by taking off one of the bearing heads and then pulling the vanes from their slots. If you must use pliers, be careful. If the vanes are swollen or have been damaged, you may have to remove both heads and drive the vanes from the slots. Exercise care and judgment when you have to drive out any pump component. Normally O-ring seals are replaced each time a pump is opened. If you don't have a new one, be sure the old seal is clean and undamaged. Oil the ring lightly and reinstall it. The pressure-control adjustment is set to relieve excess pressure at 10 percent above normal operating pressure (NOP). This adjustment is made the same as for any pressure-relief control valve. To adjust the delivery pressure of the pump, remove the cap, loosen the locknut, and turn the adjusting screw clockwise to increase (or counterclockwise to decrease) the delivery pressure. Then tighten the locknut, and replace the cap.

217. Diaphragm pumps

The diaphragm pumps found in WFSM shops are portable and used for a variety of pumping tasks. The two most common types are the double diaphragm pump and the "mud hog" diaphragm pump. The double diaphragm is pneumatically driven, and the mud hog is driven by a gas engine.

Double diaphragm

The double diaphragm pump is particularly popular for evacuating large lines and tanks for maintenance. It comes in various designs and sizes, is portable, and has low maintenance requirements. Being air operated, it also is less dangerous than electric or gasoline-operated portable pumps making it the right piece of equipment for pumping fuels.

Operation

The double diaphragm pump (fig. 3–7) gets its name from the two diaphragms on each side of the actuator valve. It is like two pumps working together. As we go through the pump's operation, keep in mind that each diaphragm has two sides—a compressed-air side and a liquid side. As the diaphragm assembly moves from side to side, the ball check valves (CV) that sit on resilient seats on the bottom of the pump lift up to allow fluid to be pulled in. The actuator valve slides to allow compressed air to pressurize one side of the first diaphragm. The pressurized side of the first diaphragm pushes the liquid contained on the other side of the same diaphragm up through the check ball on the top of the pump. The actuator valve slides again, letting air pressurize the second diaphragm on the other side of the pump, pulling the first diaphragm back in and pulling liquid up through the check ball on the bottom. This cycle repeats as long as the actuator valve is supplied with compressed air.

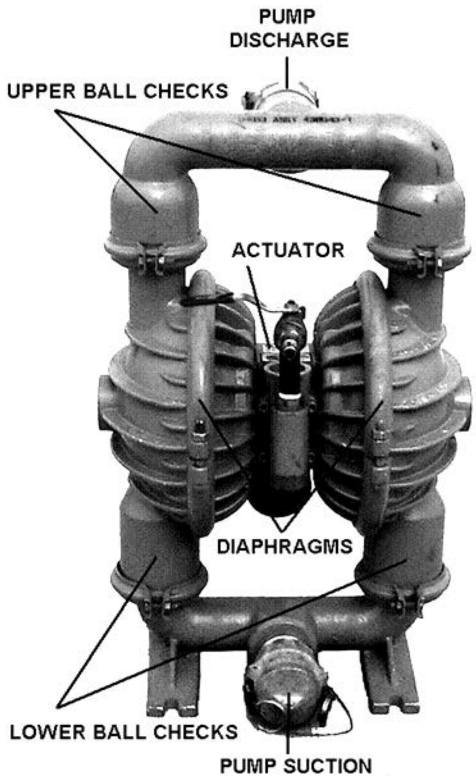


Figure 3–7. Double diaphragm pump.

Troubleshooting the double diaphragm pump

When a double diaphragm pump fails, it is usually due to one of three causes: debris preventing the check balls from seating, a failed diaphragm, or a jammed actuator valve. If you can hear the pump reciprocating but no liquid is being pumped, the check balls are most likely stuck off their seats. If the pump stalls and air is blowing out of the pump discharge, the diaphragm has ruptured. If the pump stalls and no air is being discharged, either the pump inlet or outlet is blocked or the actuator valve is jammed.

Rebuilding the double diaphragm pump

To disassemble the double diaphragm pump, first disconnect the air line from the actuator valve inlet. Turn the pump upside down in order to unseat the check balls and drain the pump. Then remove the clamps connecting the outlet on the top of the pump to the pump body. Inspect the check ball chambers to ensure small rocks or other debris is not preventing the check balls from seating. Next, remove the clamps connecting the pump body to the inlet on the bottom of the pump. Inspect the check balls and seats for debris. Remove the large clamps that hold the pumping chamber on the outside of the pump body to the air chamber on the inside of the pump body. You will be able to see the diaphragm piston plates and diaphragms. Unscrew the entire diaphragm assembly from the pump shaft. The diaphragm assembly on one side will remain connected to the pump shaft. To remove it, pull the shaft out of the pump and clamp it between blocks of wood to prevent marring the shaft. Then the diaphragm assembly may be unscrewed.

The actuator valve may be removed without disassembling the rest of the pump. Unscrew each of the four bolts holding it to the pump body. Pull the air valve spool out by using one of the four bolts as an extractor. Check the valve body for grime and seal damage. The air valve seals are not replaceable, so replace the entire assembly as a unit.

The pilot spool is located in the pump body. To remove the pilot spool, remove the retaining rings with snap ring pliers. Remove the air chamber bolts with a hex wrench. Then slide the pilot spool out notched end first. Only the O-rings on the pilot spool and center block shaft can be replaced. If the seals on the spool are damaged, the entire spool must be replaced. The pilot spool should be reinserted small end first to prevent cutting the O-rings on the sleeve ports.

"Mud hog" diaphragm pump

The mud hog diaphragm pump (fig. 3–8), commonly found in WFSM shops, is used to pump a variety of water and waste jobs. But because of its gasoline engine and the possibility of generating sparks, it cannot be used to pump fuel.

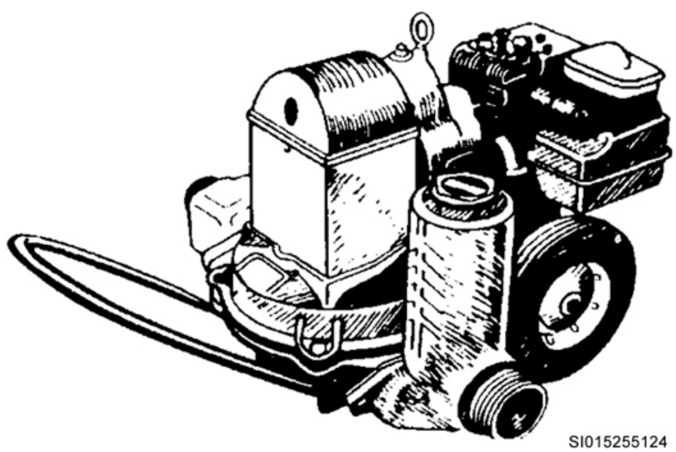


Figure 3–8. Mud hog diaphragm pump.

Operation of the mud hog diaphragm pump

The pumping element of the model shown in figure 3–8 consists of a flexible rubber diaphragm, housing, and a set of replaceable clapper valves. The pump engine turns a rotating cam to lift the diaphragm that draws a vacuum within the pump, creating suction at the pump's inlet. The vacuum opens the inlet clapper valve to allow water to be sucked into the pump. Another rotation of the cam forces the diaphragm down closing the inlet clapper valve and pushes the water to open the outlet clapper valve to exit the pump's outlet. The cycle then repeats itself. The clapper valves are the most important components of the mud hog pump. They allow water to enter the pump at the inlet, briefly trap the water in the diaphragm chamber, and allow the water to be expelled through the pump's outlet. The mud hog may have to be primed to start pumping operations. Simply unscrew the fill cover of the priming cylinder at the suction end of the pump and fill it to the top. Screw the cover back onto the priming cylinder tight enough so that the rubber seal of the screw cover prevents air from entering the priming cylinder.

Troubleshooting the mud hog diaphragm pump

Before and after use, inspect the mud hog for damage and leaks to the pump and engine. Always check engine gas and oil levels before operating.

CAUTION: Never fill the gas tank while the engine is running because spilled gas is easily ignited by a hot engine.

If a mud hog is not operating efficiently, the first two places to look should be for a stuck clapper valve or a missing hose gasket. The diaphragm is also susceptible to damage from the debris in the water pumped. It may be necessary to dismantle the pump to remove large debris from the pump's inlet or outlet sections and to inspect or replace the diaphragm or clapper valves. Always refer to the manufacturer's manual for proper breakdown procedures. When maintaining the engine, always remove the ignition wire from the spark plug before you make adjustments that require turning the engine by hand. This procedure prevents the engine from starting accidentally. Before starting the engine, make sure the blower screen, flywheel vanes, and cylinder cooling fins are kept clean to prevent the engine from overheating.

Portable pump hoses

Both the centrifugal and the diaphragm pumps use non-collapsible hoses at the suction end, but only the diaphragm type pumps also use non-collapsible hoses at the discharge end. This is because, in the diaphragm pump, there is a brief negative suction created on the discharge end until the discharge check balls on the double diaphragm pump or the clapper valves on the mud hog close. Without a non-collapsible hose on the discharge end, the diaphragm pump will not pump efficiently. The centrifugal pump, on the other hand, can use a collapsible hose because there is always a positive discharge pressure exerted. Be sure to always mark fuel hose ends with white spray paint just below the coupling collar to indicate when the hose is slipping out of the collar. Mark water hoses with red spray paint to indicate for non-potable use and with green for potable water use.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

215. Inspections and maintenance for gear pumps

1. Explain the difference between the internal and external gear pumps.

2. What gear is designated the *driven gear* in an internal gear pump?

216. Rotary-vane pump construction, inspections, and maintenance requirements

1. What does gear reducer do for the rotary vane pump?

2. How is fuel moved by the rotary-vane pump?

3. What inspections are made on the rotary-vane pump?

4. How are rotary-vane pump bearings lubricated?

5. What do you remove from the head of a rotary-vane pump with a screwdriver?

217. Double diaphragm pump

1. Describe the flow of liquid through a double diaphragm pump.

2. What is the most likely cause of a double diaphragm pump not pumping if you can hear the pump reciprocating?

3. Why would you turn a double diaphragm pump upside down?

4. What are the most important components of the mud hog diaphragm pump?

5. What do you fill with water to prime the mud hog pump?

6. What steps do you take to prevent the engine on the mud hog pump from overheating?

3–2. Non-positive Displacement Pumps

Positive and non-positive displacement pumps have similar construction. Each pump has an attached motor, bearings, gaskets, seals, and a turning mechanism to move product. The main difference you will find lies in the fact that the non-positive displacement pump does *not* require any pressure-relief or control valves. This type of pump will only put out so much pressure and then spin in the product and will not discharge any more. The two main types of pumps we cover include the *horizontal-mounted centrifugal pump* (plain or self-priming) and the *vertical deep-well turbine pump.* The deep-well pump also uses centrifugal force to move product, but it is constructed for the vertical lifting of a product from a tank or water well.

Centrifugal and turbine pumps do *not* have a fixed or predetermined output (discharge) at all times. The rated capacity of the pump in gpm represents the capacity at maximum pump efficiency. Non-positive displacement pumps use centrifugal force to create a vacuum at the pump's inlet piping to draw product inside and uses the same centrifugal force to "throw" the product out the discharge piping.

218. Centrifugal pumps

The horizontal centrifugal pump is found at various locations in WFSM systems for a variety of purposes. All centrifugal pumps work on the same principle. We will first discuss their basic construction; then the principles concerning centrifugal pumps; and finally the variations in construction, inspection, and repair. There are several manufacturers of centrifugal pumps, so we will cover only a few that are common in the AF inventory.

Basic construction of centrifugal pumps

Figure 3–9 illustrates a basic centrifugal pump with part of it cut away. The essential parts are identified. A centrifugal pump moves liquid by centrifugal force created by the vanes inside the impeller. As the impeller spins within the pump case, the vanes scoop up liquid at the pump inlet and through centrifugal force throws the product out the discharge of the pump.

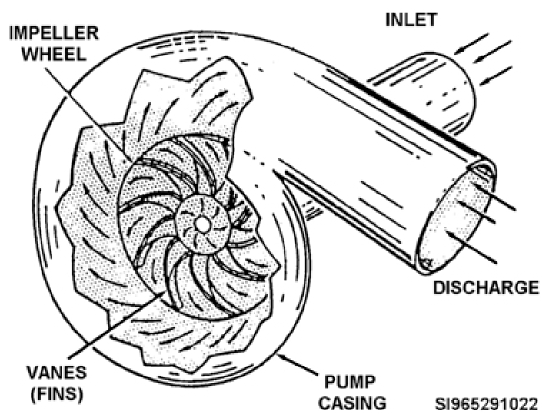


Figure 3–9. Simple centrifugal pump construction.

There are two basic types of centrifugal pumps. The first is the *plain* (or simple) *centrifugal pump*, which is used as a transfer and booster pump. This type of pump needs a flooded suction (i.e., liquid supplied to the pump's inlet from an aboveground tank) to operate properly. This type also has a tendency to "vapor lock" when air can enter the suction side of the pump. This air gets caught in the eye of the impeller and cannot be forced through the pump because of the loss of pressure at the inlet and outlet. With this type of pump, air in the system definitely causes problems. The pump has to be shut off, and as much air as possible, has to be bled off.

The second type is the *self-priming centrifugal pump*, which has a component (discussed later) to eliminate air and the vapor lock problem. You will find self-priming pumps used primarily on fuel offloading headers or on systems where air in the line is common.

As we said earlier, several variations of the centrifugal pump exist. The primary differences lie in the design of the impeller and the case. Three types of impeller are used in centrifugal pumps—*open*, *semiopen*, and *closed* (fig. 3–10). Closed impellers develop higher efficiencies and pressure which is why they are used most frequently. The closed impeller is used primarily in high-speed, high-pressure centrifugal pumps. Pumps can also be single-stage, two-stage, or multiple-stage. This will indicate how many impellers are contained within the pump casing. Depending on the design, the two-stage or multiple-stage will either move the liquid from one impeller to the next or all impellers will draw liquid at the inlet and move it to the discharge.

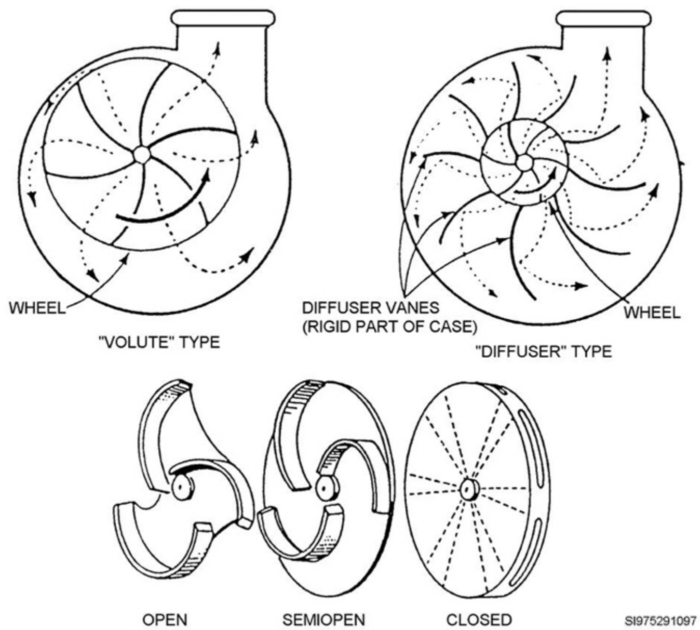


Figure 3–10. Pump cases and impellers.

The two different pump case designs (fig. 3–10) are the *volute* and the *diffuser*. The volute pump case is basically a curved funnel increasing in area to the discharge port. As the area increases, the speed of the liquid reduces, and the pressure increases. One of the main purposes of a volute casing is to help balance the hydraulic pressure on the pump shaft when running at its recommended capacity. When the liquid leaves the impeller on the diffuser pump case, it is guided by fixed vanes to the pump's discharge. This provides a more controlled flow and a more efficient conversion of velocity head into pressure head.

Principles of centrifugal pumps

We have talked about centrifugal force, but what is it? We know that, in nature, an object in motion tends to move in a straight line unless some external force is applied to change its direction. When a moving body is forced to change direction, a force is felt. You have felt this force many times in an automobile, especially when the driver has turned a corner. The force we are speaking of is the tendency to fly outward, or centrifugal force.

On a constructional basis, the impeller size and type, the pump case configuration, and the pump rpm govern the centrifugal pump's output. But there are other factors that affect a pump's output. If the discharge line is partially restricted, the amount of liquid that can move out of the pump is reduced. This liquid backs up within the pump and reduces the amount of liquid that can move off the impeller. Naturally, if all of the liquid *cannot* leave the spinning impeller, additional liquid *cannot* enter at the inlet. If we were to close off the discharge line, no liquid could leave the impeller, even though it is still spinning. The impeller would simply rotate or "churn" without actually moving any liquid out of the pump. If the impeller continues to churn in this manner, cavitation can occur causing damage to the pump.

Cavitation

Any time the pump is not operating within its best efficiency zone, the impeller is spinning in the liquid without the liquid exiting the impeller. This is called cavitation and can be caused by an insufficient supply of liquid at the inlet of the pump (suction cavitation), or restricting the outlet of the pump (discharge cavitation).

Suction cavitation

Suction cavitation occurs when the pump suction is under a low-pressure/high-vacuum condition where the liquid turns into a vapor at the eye of the pump impeller. This vapor is carried over to the discharge side of the pump, where it no longer sees vacuum and is compressed back into a liquid by the discharge pressure. This imploding action occurs violently and attacks the face of the impeller. An impeller that has been operating under a suction cavitation condition can have small bits or large chunks of material removed from its face, causing the impeller to look sponge-like. Either type of impeller damage will cause premature failure of the pump bearings and seals. Suction cavitation is often identified by a sound of gravel or marbles inside the pump housing.

Discharge cavitation

Discharge cavitation occurs when the pump discharge pressure is extremely high and normally occurring in a pump that is running at less than 10 percent of its best efficiency point. The high-discharge pressure causes the majority of the fluid to circulate inside the pump instead of being allowed to flow out the discharge. As the liquid flows around the impeller, it must pass through the small clearance between the impeller and the pump housing at extremely high velocity. This velocity causes a vacuum to develop at the housing wall (similar to what occurs in a venturi), which turns the liquid into a vapor. A pump that has been operating under these conditions shows premature wear of the impeller vane tips and the pump housing. In addition to the high-pressure conditions, discharge cavitation can also cause premature failure of the pump bearings and seals. Under extreme conditions, this can warp or break the impeller shaft.

Static head

Static head is the vertical distance measured from the centerline of the pump to the height of the liquid level inside the tank. We use the height of the liquid in the tank because it provides additional pressure to the inlet of the pump. This system specification is expressed in feet.

Dynamic or system head

As the liquid flows through piping, valves, and filter separators, it encounters friction caused by the components and texture of the interior finish. These restrictions cause the dynamic head to be less than the static head. As the gpms increase, the dynamic head can go from positive to negative, meaning the pump is no longer being supplied with liquid but now has to draw the liquid from the line. Dynamic head is also known as head loss in the system. The dynamic head will be negative if you are lifting liquid from below the pump suction, as in an underground tank. It will be positive if you are pumping from a tank located aboveground if there is not too much piping restriction.

Discharge head

Discharge head is the amount of pressure or head that the pump will add to the dynamic head. If you have a positive dynamic head, then add it to the discharge head. If the dynamic head is negative, then subtract it from the discharge head. A centrifugal pump will create a pump curve that will resemble the one in figure 3–11, whereas a positive displacement pump curve will be a straight line.

Each pump will have a best efficiency point (BEP)—that is, the most efficient design point on the pump curve. The BEP is the ideal point to operate the pump.

By using dynamic and discharge head, you can determine your system curve and will have a better understanding of your system capabilities. This information will be essential if you ever have to order a new pump for your system. Pressure recorders installed at the pump inlet and outlet will give a better picture of the system or dynamic head.

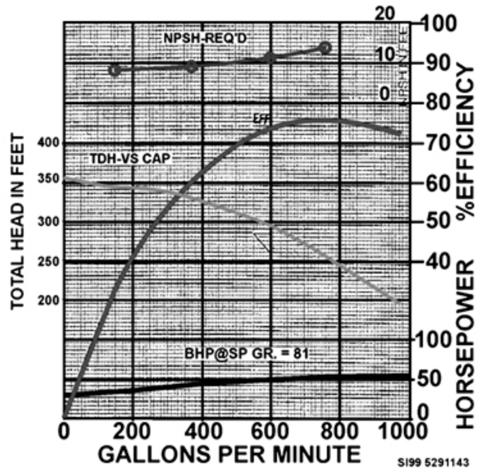


Figure 3–11. Pump curve.

Pump curves

Figure 3–11 shows a typical centrifugal pump curve. The bottom row of numbers in the figure represents gpm output, and the left vertical numbers represent total head in feet. Total head in feet is the amount of pressure the pump puts out, measured in feet of water. To convert feet of water to psi, you simply multiply the feet of water times .433 (psi exerted by 1 foot of water), take the total, and multiply it by the specific gravity of the liquid you are pumping. In our example, we will use JP–8, which has a specific gravity of .81.

Example: 100 feet of water $\times$ .433 = 43.3 psi; then 43.3 $\times$ .81 = 35 psi.

When a centrifugal pump is ordered for a particular application, you will get a certified pump curve with the pump. Every pump is built to meet the specification of the application for which it is to be used. Look at figure 3–11; this particular pump has a deadhead pressure of 355 feet of head. At 600 gpm output, the pump delivers 295 feet of head (103 psi) when driven at 3,600 rpm.

Every pump curve indicates an *efficiency curve* of the pump. Refer to figure 3–11. The efficiency curve (EFF) uses the gpm and % efficiency axis. If you follow the 600 gpm line upward until it intersects the EFF line and if you then draw a line to the right over to the % efficiency scale, you will see that this particular pump has a 73.5 % efficiency when pumping 600 gpm.

Working closely with your mechanical engineer and pump manufacturer will ensure that your new pump meets your needs. The mechanical engineer will help you determine your system curve and the manufacturer will match a pump curve by varying a pump case, impeller diameter, impeller width, and pump rpm to match your system curve. Where the curves intersect each other is where your pump will operate. Ideally, this will be at the pump's BEP but not always.

Construction and operation of the Peerless centrifugal pumps

Several designs of the Peerless centrifugal pump are in current use. Many of them vary only in such things as shaft seals (packing rings or mechanical seal), drive, and bearing arrangements. Two configurations are used in our systems: (1) the *single-suction impeller* and (2) the *double-suction impeller*. This simply means that product is pulled into the center of the impeller either only from one side or from both sides. An impeller of the same diameter can move more product per minute with a double-suction impeller. A Peerless double-suction pump is shown in figure 3–12. Note that the impeller is closed and has an entry from each side. This pump also has a higher suction lift than a single-suction impeller pump.

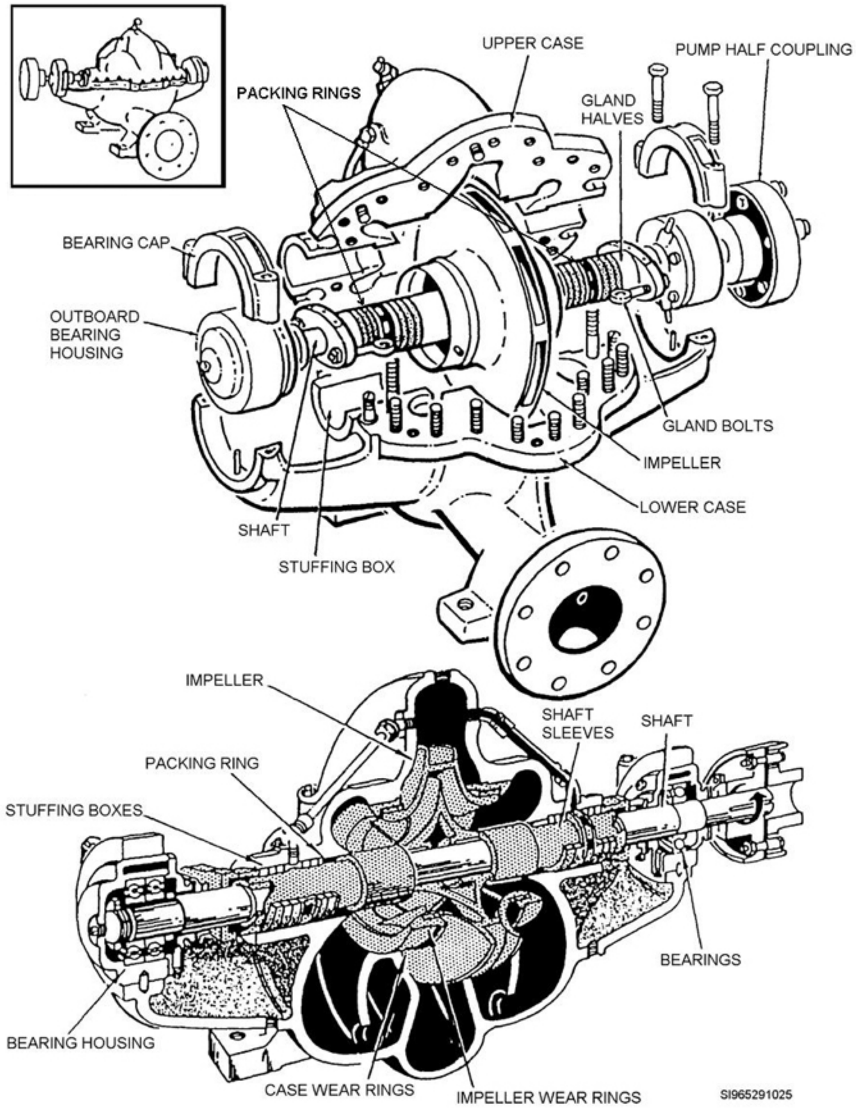


Figure 3–12. Peerless centrifugal pump.

Opening the pump is a relatively simple task because of the horizontal split-case construction. The entire assembly, except the shaft bearings, is exposed. Once the upper case has been removed, you have only to remove the two bearing caps and disconnect the coupling to free the rotary assembly.

Study the top picture in figure 3–12 for a moment, paying attention to the center shaft on both sides of the impeller. The pressure on the packing rings in the stuffing box is controlled or adjusted by the gland bolts and nuts. Packing leaks are stopped by tightening the gland bolt nuts. The bolt heads are set on pins that will keep them from turning and repositioning. If you draw up the gland bolt nuts you will compress the packing by pulling the gland halves toward the impeller. The nuts are exposed when the pump is fully assembled.

NOTE: Some models of the Peerless pump use mechanical seals in place of the packing rings, so adjustments to them are made according to the manufacturer’s instructions.

Inspection and maintenance of Peerless centrifugal pumps

Operationally inspect this type of pump quarterly for leaks, unusual noise, vibration, adequate discharge pressure, pump/motor shaft alignment, and pump/motor overheating. Grease the bearings quarterly or per the manufacturer’s instructions.

When the packing rings must be replaced, cut the coil packing at a 45-degree angle so that the ends butt together and fit snugly in the sleeve. When replacing the packing rings, the chance of packing leakage is reduced if you stagger the seams of the packing rings' cut ends. In other words, do not line up the seams. If the pump has a mechanical seal, the proper seal must be used for replacement. Follow the manufacturer's manual for proper replacement parts and installation, regardless of whether the pump uses packing or mechanical seal.

Most pumps use wear rings. Wear rings separate the inlet and outlet portions of the casing at the outer edges of the impeller. They also provide the minimal clearance needed to allow the impeller to turn freely within the pump casing and minimize the amount of pressure leakage between the impeller's inlet and outlet. Wear rings are made to take damage when the shaft experiences minor shifts during the pump's operation. They are made of a softer metal than the shaft or the casing. The wear rings are replaceable when they become worn. The rings are fitted rings, and incorrect removal or installation of them may lead to pump damage. Follow the applicable manufacturer's instructions.

Construction and operation of Gilbarco pumps

Gilbarco makes both the plain centrifugal and self-priming centrifugal pumps and are shown in figure 3–13. The pump bodies are volute and both use a closed impeller. The impeller shaft rides on ball bearings. Study both pumps carefully.

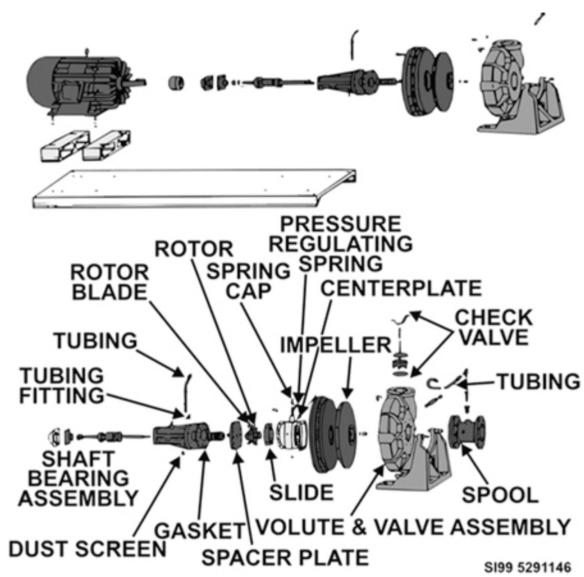


Figure 3–13. Gilbarco centrifugal pump (exploded view).

The self-priming pumps are being used more and more every day in the AF. You will find them as the defuel pumps in the hydrant systems and, at some bases, as the offloading pumps for tank car and tank trucks. Looking at the pump, you can determine what type pump is being used from the pump data plate. The plain pump is an aviation fuel transfer (AFT) series pump; whereas the self-priming pump is an aviation fuel/defuel (AFD) or an aviation fuel/refuel (AFR) series pump.

Looking at figure 3–13, you will notice some additional parts in the middle of the bottom drawing that make up the self-priming feature of the pump. The volute body and valve seat assembly is similar to the one used on the plain pump, with the exception of the valve seat. The CV assembly is installed to prevent air from returning into the pump. The spacer plate provides a sealing point for the mechanical seal, and the housing gasket prevents leaks. The priming pump consists of the rotor, rotor blades, center plate, pressure-regulating spring, pressure-regulating spring cap, and slide.

The most outstanding feature of the self-priming pump is its ability to prime a completely dry line. Let's see how this bit of magic is achieved.

Figure 3–14 shows you the pump in a cutaway view. You can see the priming pump and rotor block right behind the impeller. Now, study figure 3–15. When the pump is turning dry (priming cycle), air and vapors are drawn through holes at the inlet near the eye of the impeller, through tubing to the priming pump (which is a sliding-vane pump). The vapors are compressed and forced out through tubing to the discharge side of the pump. When all of the air and vapors have been pulled out of the line by the priming pump, liquid flowing from the discharge side of the pump (fig. 3–16) is directed back through the priming pump discharge line to the underside of the rotor slide section, centering it. Priming action then ceases.

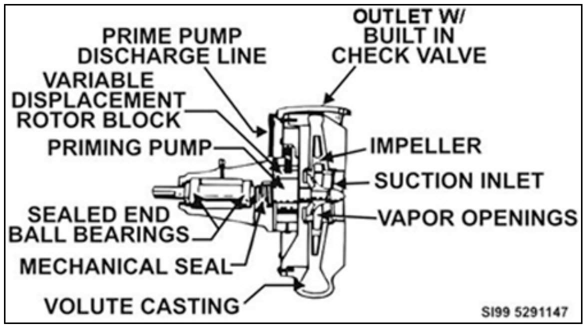


Figure 3–14. Gilbarco self-priming centrifugal pump (cutaway view).

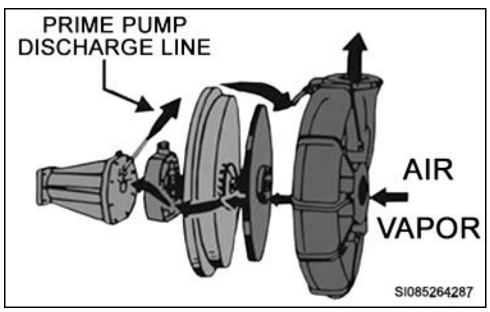


Figure 3–15. Gilbarco self-priming centrifugal pump flow (priming).

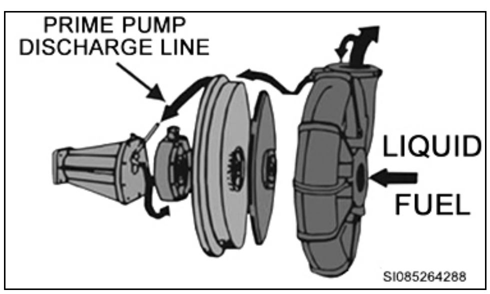


Figure 3–16. Gilbarco self-priming centrifugal pump flow (primed).

The priming pump is shown in three phases of its cycle in figure 3–17. Now reread the last paragraph. You should have no trouble understanding the priming pump operation.

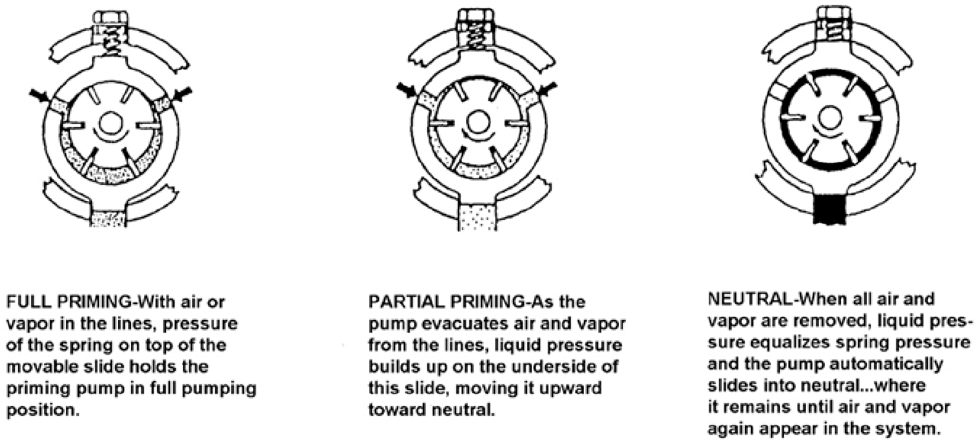


Figure 3–17. Gilbarco priming pump operation.

The priming pump will remove air at the rate of about 18 gpm. It will, for example, prime a 4-inch dry pipe at about two seconds per foot of pipe. It will prime a 20-foot pipe (6 inches in diameter) in about 60 seconds.

Some pump models use an air release (fig. 3–18). This device vents the air that enters from the suction line.

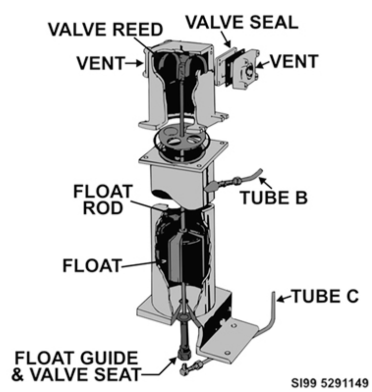


Figure 3–18. Gilbarco air release (Model 10).

Look at figure 3–18 and trace the path of airflow. The air passes through the priming pump, then through tube B into the air release, and on into the atmosphere. (Tube A is *not* shown in the figure because it is located on the pump itself.) The sump valve is closed when the float is down, and the air release is empty of fuel. The reeds are open at this time, allowing air to vent. As fuel fills the downstream piping, pressure builds up, the CV in the discharge side of the pump opens, and fuel flows through the system.

While this is happening, the priming pump is filling the air release sump with fuel. The float rises, opens the sump valve, and lets fuel enter the pump again through tube C. The float rod closes the two reed valves in the head of the air release. When the float rod rises in the sump, the valve rises in the float guide and comes off the seat. Then fuel can go out tube C. The top of the rod forces the reed valves to close off the vents. This shuts off the airflow.

When you are installing a new pump using oil-lubricated bearings, be sure you fill the reservoir with SAE 10 or 20 motor oil. If it is a self-priming pump, remove the $^1/_8$-inch pipe plug and add one-half pint of oil. This ensures lubrication of the primary assembly until the primer has completed its first priming cycle. From then on, it will be lubricated by the product it is pumping. You should also check the bearing housing dust screen, both on initial installation and as part of your routine inspections. It should be kept clean.

Gilbarco pumps use John Crane self-adjusting seals. They are mechanical seals that have a stainless steel stationary face and an impregnated carbon-rotating face. The product passing through the pump cools the seals.

Inspection and maintenance of Gilbarco pumps

Operationally inspect this type of pump quarterly for leaks, unusual noise, vibration, adequate discharge pressure, pump/motor shaft alignment, and pump/motor overheating. Grease the bearings and oil reservoir level (if present) quarterly or per manufacturer's instructions.

Changing impellers is an easy task. When the pump cover (volute casing) is removed, the internal parts of the pump can be removed as a unit. You can then disassemble them more easily. Removal of the priming rotor and housing is a little more difficult. The priming pump housing must be taken off to reach the mechanical seals. *Don't* try to disassemble the pump without following the applicable manufacturer's instructions, or you will end up either shearing dowel pins or cracking a pump housing! Should you have the priming pump apart, be sure to check it (after reassembly) for free rotation before covering it up. If it binds, add a 0.0015-inch paper-thin gasket to give clearance to the rotor.

Construction of API 610 pumps

The API 610 pump is the newest centrifugal pump standard used by the AF in fuel systems. The API 610 pump is not a single style or type of centrifugal pump. But it can be several various pumps made by different manufacturers that adhere to the guidelines set forth in the API Standard (Std) 610 (and International Organization for Standardization [ISO)] 13709: 2009), *Centrifugal Pumps for Petroleum, Petrochemical and Natural Gas Industries*. The three types are: (1) *overhung*, (2) *between bearings*, and (3) *vertically suspended*. The different styles and specification of the three types can be found in API Std 610. The most common type API 610 pump used in AF fuel systems is the overhung type centrifugal, single-stage, horizontally mounted, radial-split case, enclosed impeller, double volute case, with end suction and top discharge as seen in figure 3–19. The pump is designed to permit removal of the impeller, shaft, bearings, and bearing housing as an assembly, without disconnecting the suction or discharge piping. The pump case is designed for 275 psi maximum operating pressure.

The pump stuffing box is designed to accept a single balanced API Std 682, *Pumps-Shaft Sealing Systems for Centrifugal and Rotary Pumps*, mechanical seal. The mechanical seal has three connections labeled *Q* for quench, *F* for flush, and *D* for drain. A non-sparking throttle bushing is pressed into the seal end plate against an outside shoulder to minimize leakage in the event of complete mechanical seal failure. The mechanical seal on the API 610 pump uses no packing material.

The bearing housing contains an oil-lubricated antifriction, radial, and thrust bearing. On the outside of the bearing housing you will find a sight glass on an oil reservoir. You use this sight glass to check the oil level in the bearing housing. The proper oil level must be maintained.

Because of the API 610 pump's operating temperature range (<450^{o}F), the case, cover and shaft will be made of carbon steel. All other parts will be made of cast iron. The total pump shaft deflection (rotating movement in any direction) as measured at the stuffing box must be less than 0.002 inches. The pump shaft and the motor shaft *must* be aligned to within a 0.002-inch tolerance.

The impeller is the closed type and is dynamically and hydraulically balanced. It is keyed to the pump shaft, held in place by a positive lock, and threaded to tighten during normal rotation.

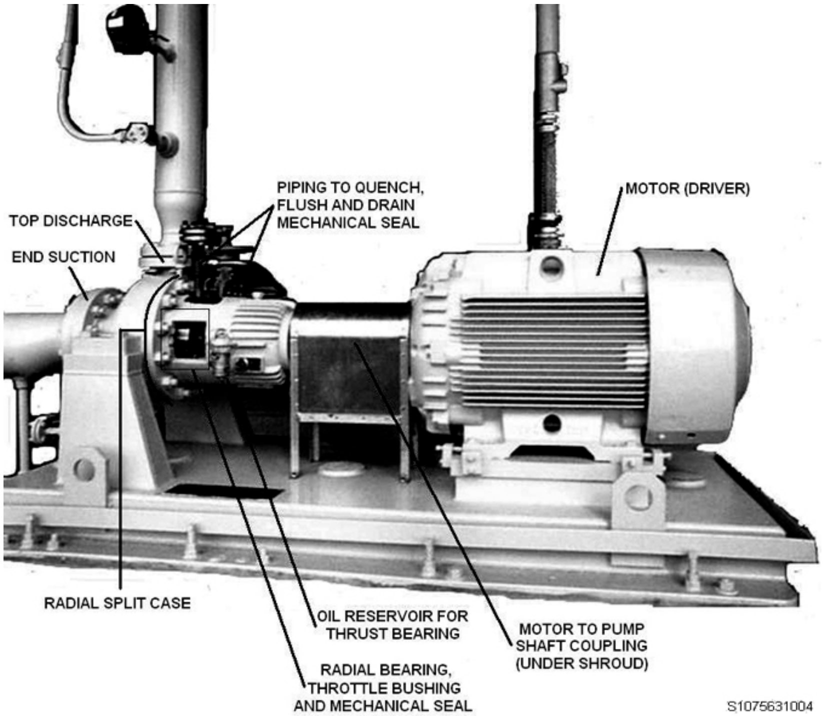


Figure 3–19. API 610 pump.

Inspection and maintenance of the API 610 pump

Operationally inspect this type of pump quarterly for leaks, unusual noise, vibration, adequate discharge pressure, pump/motor shaft alignment, and pump/motor overheating. Grease the bearings and check oil level quarterly or per manufacturer's instructions.

Although the API 610 pump is heavy duty and designed for a long service life, you will on occasion have to replace defective mechanical seals or wear rings. Be sure to follow the manufacturer's instructions because incorrect removal or installation of parts could lead to pump damage.

Use the following table when inspecting an API 610 pump:

Trouble	Probable Causes	Suggested Remedy
Hot bearings	a. Insufficient oil b. Contaminated oil c. Misalignment d. Too much oil	a. Add oil b. Drain and clean reservoir. Refill with clean oil c. Check alignment of pump and driver d. Drain to proper level
Leakage under shaft sleeve	a. Worn shaft sleeve gasket	a. Replace shaft sleeve gasket
Pump does not deliver liquid	a. Pump not primed b. Speed too low c. Plugged impeller d. Clogged suction e. Damaged impeller f. Wrong rotation	a. Prime pump b. Check driver input c. Clean out impeller d. Clean out suction line e. Replace impeller f. Check driver rotation
Capacity or discharge pressure low	a. Air leaks in suction b. Speed too low c. NPSH* too low d. Clogged suction e. Clogged impeller	a. Check suction line for leaks b. Check driver power source c. Check suction source d. Clean out suction line e. Clean out impeller

Trouble	Probable Causes	Suggested Remedy
	f. Impeller damaged g. Wrong direction	f. Replace impeller g. Check driver rotation
Driver overloaded	a. System head lower than rating	a. Check suction and discharge pressure
Excessive oil consumption	a. Leaking bearing cover gasket b. Leaking drain plug c. Oil level too high	a. Tighten bearing cover or replace gasket b. Tighten or replace oil plug c. Drain oil reservoir to proper level
*NPSH = Net Positive Suction Head.		

219. Deep-well turbine pumps

Deep-well turbine pumps are the third type (vertically suspended) of centrifugal pumps mentioned in the last lesson. They are multiple-stage pumps used to transfer liquids from underground storage tanks, wells, and smaller aboveground tanks with vertical suction lines. As you go from one assignment to another, you will see many different types and manufacturers of deep-well pumps. All of them have the same basic design with minor differences. Likewise, the inspections and general maintenance of these pumps do not vary much. However, one difference you will find among deep-well pumps lies in the type of mechanical seal used. This is also where you will meet up with most of your troubles. In this lesson, we will cover the constructional features and the inspection and maintenance of deep-well turbine pumps.

Construction of deep-well turbine pumps

As we stated before, most deep-well turbine pumps are similar in design. Look at figure 3–20 as we review the parts.

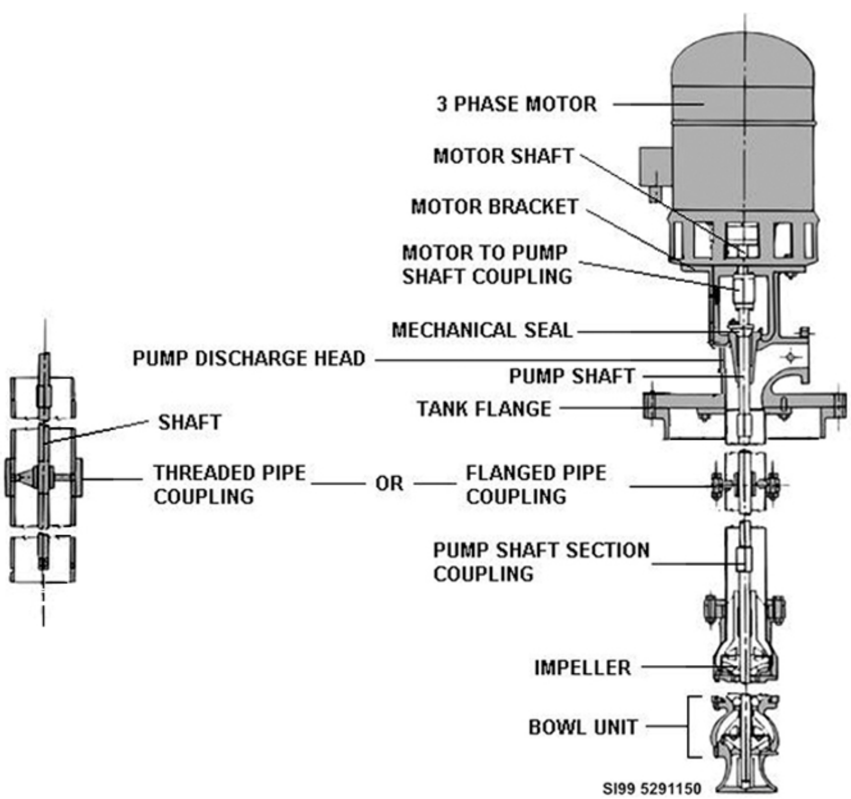


Figure 3–20. Deep-well turbine pump.

Part	Description
3-phase motor	Will have grease or oil reservoir lubricated bearings; may have ratchet anti-rotation assembly; usually designated as vertical hollow shaft (VHS) or vertical solid shaft (VSS) (see motor shafts below).
Motor bracket	Attaches to the pump discharge head.
Motor shaft	Secured inside the motor and attached to the pump shaft. 1. VHS – connected to the top of the motor by an adjustment nut for impeller setting (fig. 3–21 upper left); motor shaft can be removed for mechanical seal replacement without removing the entire motor. 2. VSS – cannot be adjusted from top of motor; requires entire motor removal for mechanical seal replacement; impeller adjustment is done at motor-to-pump shaft coupling The VSS motor's pump has been known to have packing instead of a mechanical seal because of the difficulty encountered when replacing the seal.
Mechanical seal	Seals the pump shaft at the top of the pump discharge head (some pumps may still use packing instead of a mechanical seal).
Pump discharge head (discharge assembly)	Top of the pump piping discharge liquid.
Pump shaft	Top end connects to motor shaft; extends to tank bottom and connects to multiple bowl units.
Tank flange	Extension of the tank bolted to the bottom of the pump discharge head.
Flanged or threaded pipe coupling	Secures sections of tank liquid outlet pipe.
Pump shaft section coupling	Self-explanatory.
Impeller	Located inside the bowl units; moves the liquid to the next impeller and out the pump.
Bowl unit	Houses the impellers; multiple sections bolted together extending to the bottom of the tank; may be of volute or diffuser type.
Motor-to-pump shaft coupling	Figure 3–21 shows three examples of motor-to-pump shaft couplings. The lower left drawing shows a simple threaded coupling with left-handed threads. The spacers are inserted as needed for impeller adjustment. The upper and lower right drawings show bolted couplings to connect the pump and motor shafts. Note the design of the lower right coupling. If this coupling is used on VSS motor, when this coupling is disconnected, there is sufficient space to remove and install a mechanical seal without removing the motor.

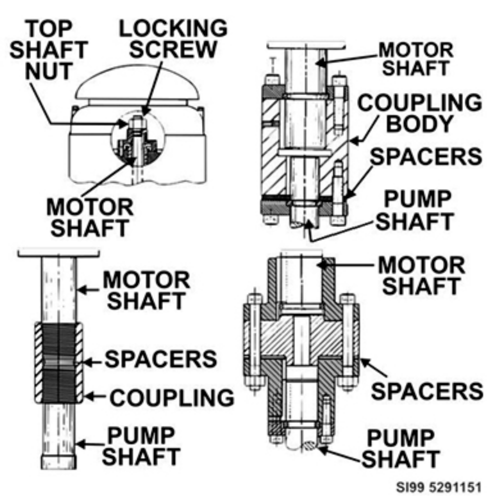


Figure 3–21. VHS motor and motor-to-pump shaft couplings.

Any threaded couplings will have left-hand threads. Since all motors for a deep-well pump have a counter-clockwise rotation, the left-hand threads ensure the couplings will not unthread themselves when the pump and motor are running. In fuel systems, the pump's moving components are designed to be cooled and lubricated by the fuel being pumped. The shaft turns in an open column pipe. This simply means that the pumped fuel is in contact with the shaft and its bushing or bearings. Some pumps have a cooling line that directs fuel to the bottom of the mechanical seal to prevent overheating.

The distance from the pump tank flange to the bottom of the tank determines the length or number of column-shaft sections used between the pump motor and the pump inlet. The clearance between the impeller and the bowl determines the pump's efficiency. You will be required to adjust this clearance when installing or re-installing a pump and/or motor, after replacing a mechanical seal, or if the pump output is off the mark.

Some pumps will have either an *enclosed shaft* or a *semi-open shaft*. Look at figure 3–22, you can see that the shaft in "A" is enclosed, while the shaft in "B" is semi-open. When you find an oil reservoir close to the bottom of the discharge assembly, such as in "A", you know you have an enclosed shaft.

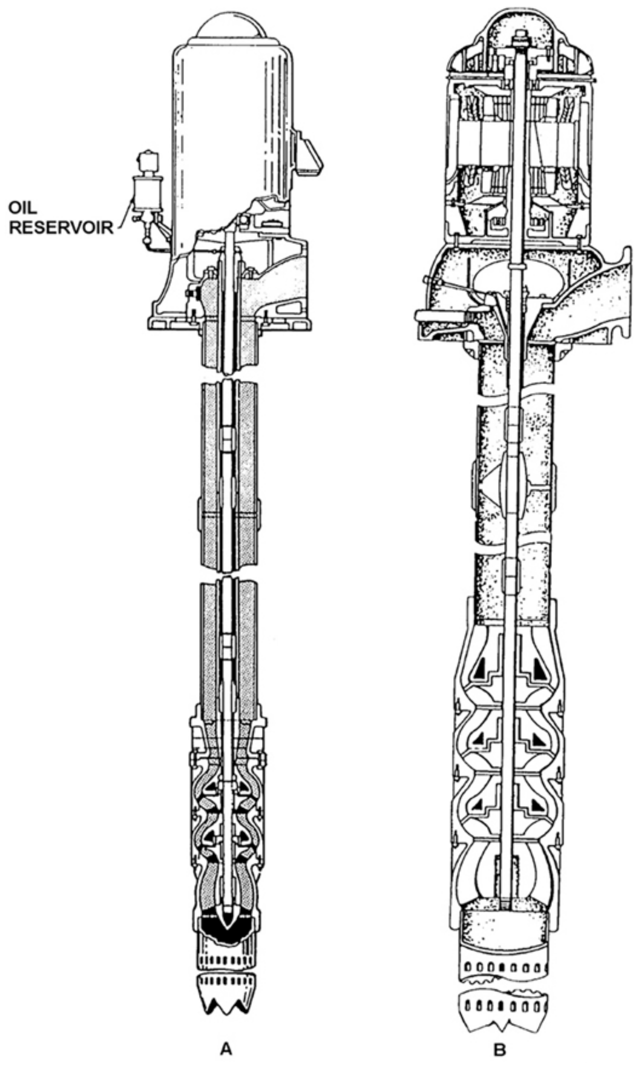


Figure 3–22. Enclosed and semi-open shafts.

Inspection and maintenance of deep-well turbine pumps

The quarterly operational inspection of a deep-well turbine pumps consists of checking for unusual noise or vibration, overheating of the motor and pump, and leaks. Maintenance consists mainly of keeping the pump motor assembly clean, lubrication, adjusting the impellers and adjusting or replacing the packing or mechanical seal.

Follow the manufacturer's instructions to locate grease points and filling oil reservoirs to their proper levels. The instructions will tell you the proper grade of grease and oil to use as well. Some manufacturers require you to periodically drain and change the oil in the reservoirs.

Impeller settings are probably the most important adjustments made to a pump. If not made properly, you can cause serious damage to both the pump and motor. Some manufacturers require that the impellers are set high in the bowl while others are set low in the bowl. These high or low settings give the impellers the minimal clearance needed to create the most efficient suction at the impeller's eye. Adjustment will be made either with the adjustment nut at the top of the motor shaft or at the motor-to-pump shaft coupling.

Depending on the manufacturer's instruction, the impellers are either raised or lowered until the impellers come in contact with the bowl and the pump shaft cannot be turned by hand. Then raise or lower the impellers just enough so that you can turn the shaft by hand (again according to the manufacturer's instructions). This should give you the proper clearance for the most efficient pump output.

220. Replacement and adjustment of mechanical seals

Many different types of seals are used on the pumps we have been covering. Mechanical seals for fuel pumps must meet the minimum requirements set forth in API Std 682. This standard also recommends the seals for pumps in water systems. There will be several manufacturers of mechanical seals for any given pump. As long as it meets the requirements in API Std 682, the seal you use is entirely up to you. In this section, we will discuss two examples of mechanical seals.

John Crane

The John Crane seal, shown in figure 3–23, is a Type A (pusher), single, inside mechanical seal. It consists of a stationary seat inserted in the seal gland against which a corresponding rotary unit operates. The rotary unit on this type of seal consists of a seal retainer, springs, and a rotating seat made of stainless steel. The stationary seat is made of a hard, carbon-like material and is very brittle.

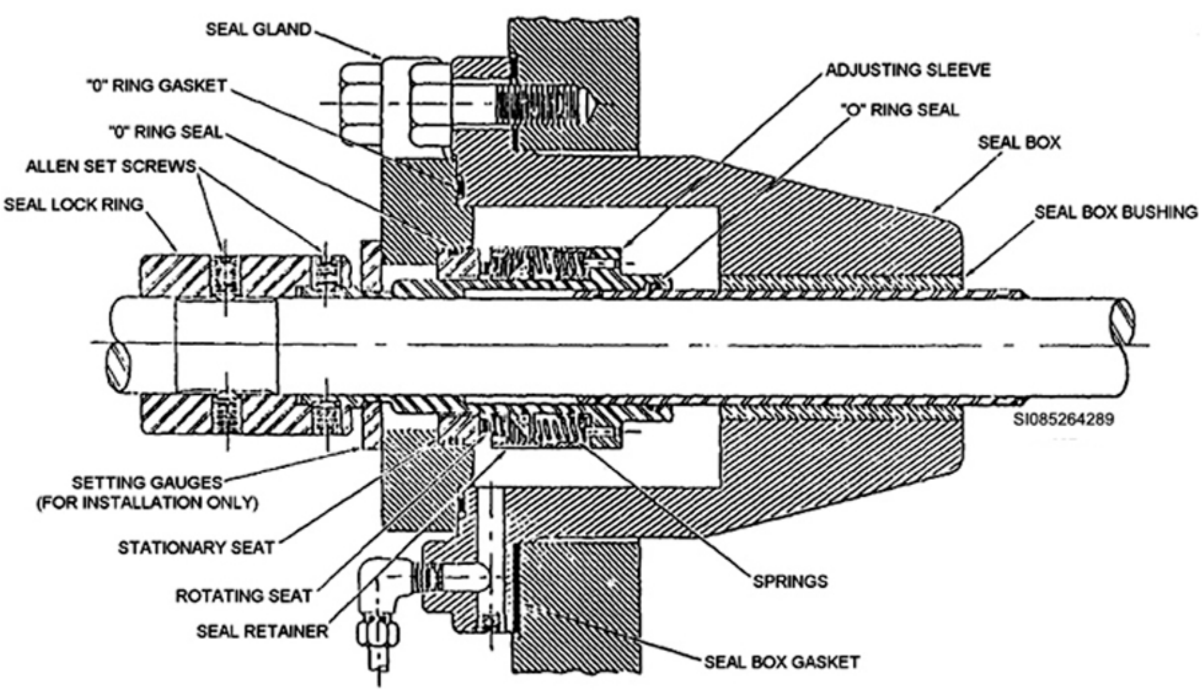


Figure 3–23. John Crane mechanical seal.

When a mechanical seal leaks, you can try to clean and adjust it. While you have it apart, check all parts carefully for wear, nicks, and burrs. Pay particular attention to the mating surfaces of the stationary and rotary seats. If they are scratched or if the stationary seat is chipped, you must replace the entire mechanical seal. You *cannot* lap them. You will also want to check the O-ring seal installed in the stationary seat. You may need to replace only the O-ring. Replacing a mechanical seal requires strict compliance with the applicable manufacturer's instructions and absolute cleanliness of the parts.

To replace any mechanical seal, first isolate the electric pump motor by using your lock-out/tag-out procedures to prevent the accidental operation of the pump. In replacing the mechanical seal you must first remove the old seal by loosening the Allen-head setscrews and lift the seal lock ring. Then you can disconnect the motor-to-pump shaft coupling. If the motor is a VHS, the motor shaft adjustment nut on top needs to be unscrewed first. If it is a VSS motor, plan to remove the entire motor as you disconnect the coupling. Do this slowly, because this lowers the pump shaft and impellers. Remember, all threaded shaft couplings have left-hand threads; to disconnect them, turn the coupling clockwise. Once this is done, remove the seal lock ring and seal gland. Be careful not to touch the sealing surfaces with your bare hand because skin oil will contaminate them. Next, remove the mechanical seal assembly by grasping the adjusting sleeve and lifting. It's a tight fit, so it will come off slowly. With the adjusting sleeve removed, inspect the well inside the seal box for cleanliness. If the mechanical seal is *not* to be replaced immediately, cover the seal box to keep out contaminants.

Fuel leakage between the seal gland and seal box indicates failure of the O-ring gasket. To replace the O-ring gasket, follow the procedures discussed in the previous paragraph, except you must *not* remove the adjusting sleeve. Instead, remove only the seal lock ring. Also, be careful not to damage the stationary seat.

If the seal box gasket leaks, you must remove the adjusting sleeve and seal box. When reinstalling the seal box, see that it fits tightly around the pump shaft. Any looseness means that the seal box bushing is worn and should be replaced. Put a little oil inside the bushing when you install one to help it slide on the shaft better.

When installing a new mechanical seal (stationary seat and rotary unit), place the rotary unit over the adjusting sleeve before you install the sleeve. Replace the O-ring seal in the adjusting sleeve with a new O-ring, coating it lightly with oil before setting it into the groove. Cover the threads on the pump shaft with Teflon tape to protect the adjusting sleeve O-ring. Install the adjusting sleeve, being careful not to damage the parts or get them dirty. Apply a very thin coat of light oil over the sealing surfaces of the rotating seat and stationary seat; install the stationary seat. Replace the O-ring gasket in the seal gland and bolt the seal gland in place.

Do not use excessive force on the gland bolts; you can obtain a good seal between the gland and seal box merely by tightening these bolts snugly. Now look at figure 3–22 and find the setting gauges for installation. There are two setting gauges. These two gauges must be inserted into the top groove of the adjusting sleeve. You may have to raise the sleeve and compress the springs to get the gauges into place.

Now install the seal lock ring, but do not tighten the setscrews yet. Before tightening them, install the motor-to-pump shaft coupling, and then adjust the pump impellers. After having adjusted the impellers properly, lock the adjusting sleeve to the pump shaft, using the four setscrews in the lock ring. Tighten these setscrews firmly. Now you can remove the setting gauges. Keep these gauges in your shop for future use. Do not lose them. If you ever readjust the impellers, you must first install the setting gage and loosen the four setscrews. These gauges maintain the correct spring force against the rotary seat. The setting gauges are also used for adjusting the mechanical seal.

Dura seal

The Dura seal is also a Type A, single mechanical seal. In figure 3–24, we show two types of Dura-seals: "A" is an *inside seal* (similar to the John Crane model), and "B" is an *outside seal.* Note the difference between them. The seal ring and the collar (rotary unit) on the inside seal are *within* the housing and *below* the stationary insert and the gland. In contrast, on the outside seal, the seal ring and collar are *above* the insert and the gland. You will find both types of seals on various deep-well pumps. The inspection and maintenance are alike for both types; however, the adjustments for these seals are a little different.

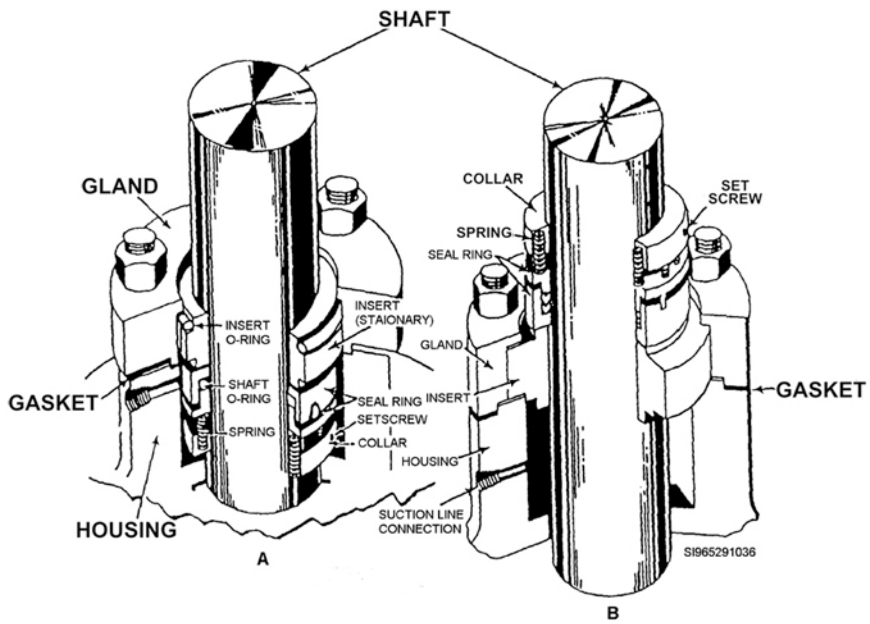


Figure 3–24. Dura seal.

To adjust the outside seal, you place a setting gauge or spacer between the collar and seal ring to adjust the spring tension, and then you tighten the setscrew on the collar. The gauge usually comes with a new seal. Keep the gauge for future use. If you lose the gauge, you can use an inside caliper to measure the clearance between the collar and the seal ring. The specified clearance is stamped on the collar. When using the gauge or caliper, make sure you measure equally all of the way around the rotary unit.

Because the adjustment of the inside Dura seal is quite complicated, it will not be covered in this discussion.

Now look again at figure 3–24, “A”. You will see that the sealing surface pressure is provided by springs. Pump fuel pressure surrounds the seal ring. Compression of the shaft O-ring provides a seal, preventing fuel leakage past that point. The inserted O-ring prevents leakage between the stationary insert and the seal gland. Also note that, in figure 3–24, “B”, each seal has a suction line connection to aid in cooling the seal. To replace the gland gaskets on either seal, follow the same general procedures we have discussed previously.

After you have replaced a mechanical seal and adjusted the pump impellers, start the pump and check the seal for leakage. The thin film of oil you put on the sealing surfaces will provide initial lubrication. If the seal leaks slightly at startup, allow a reasonable amount of time for the seal to adjust itself. When a seal starts out with a slight leak and the leakage gradually decreases, you have a good sign that the sealing surfaces will seal themselves as the pump continues to run. When leakage occurs right away and remains constant and unaffected by running, it usually means that the O-ring or a sealing surface is damaged. Improper adjustment of the seal also will cause leakage. However, unless absolutely necessary, do *not* separate the sealing surfaces on a seal that is *not* leaking. After a seal has been running, a wear pattern is formed between the sealing surfaces. You cannot mate the two surfaces in their original wear pattern. If you disturb the seal in any manner, it results in setting a new pattern.

REMINDER: If your maintenance task is only an impeller adjustment and the mechanical seal is still good, the mechanical seal must still be loosened before any adjustment can be made to prevent damage to the seal. Once the impeller adjustment is completed, adjust the mechanical seal. If the mechanical seal needs replacing, the mechanical seal must be put on the pump shaft before the motor-to-pump shaft coupling. The mechanical seal is not adjusted until the impellers have been set.

Troubleshooting mechanical seals

The troubleshooting of seals can be nearly as involved as the troubleshooting of an entire system. We have listed the more common troubles and their causes in the table below. Generally, the resolution of the problem is identification and replacement of the defective part. This table also lists troubles that are correctable by other means. You can apply the information provided in this table to most types of mechanical seals.

Trouble	Cause	Corrective Action
Seal spits and sputters during operation.	Fuel is vaporizing due to seal overheating.	Check seal bypass for possible clogging.
	Wrong seal for type seal.	Check manufacturer's manual.
Seal drips steadily.	Gland gasket lacks proper compression.	Readjust the compression on the gland gasket.
	Sealing faces not flat–gland bolts too tight or unevenly tightened. Warped gland and insert.	Replace defective parts as required.
	O-ring nicked or pinched during installation.	Replace O-ring.
	Carbon insert cracked or face of insert chipped during installation.	Replace seal.
	Foreign particles between seal faces.	Replace seal.
	Leakage under shaft sleeve.	Replace seal.
Seal squealing and carbon dust on outside of gland.	Bypass line restricted or too small.	Check bypass line. Enlarge if necessary.
	Inadequate lubrication on sealing surfaces.	Check bypass for fuel flow.
	Stuffing box pressure too high for seal type.	Contact manufacturer.
Seal leaks and nothing appears to be wrong.	Faces are not flat. Can be detected by wear pattern on seal face.	Replace affected parts.
	Carbon inserts face distorted.	Replace affected parts and replace gland.
	Improper or excessive tension on gland bolts. Apparent from wear patterns.	Readjust tension.
	Shaft vibrating caused by misalignment, impeller unbalanced, or bad bearing.	Check each possible cause and correct.

Pump/driver alignment

Pump/driver alignment is even more important with the application of mechanical seals because of the smaller tolerances involved. Misalignment is a major cause of premature mechanical seal failure. Packed pumps are more forgiving of misalignments. Also, before beginning an alignment, always check the pump and motor bearings. If the bearings are worn on either unit, you will not be able to maintain alignment. Unusual noise coming from the bearing housing is an indication of bearing wear.

Since the pump is usually rigidly attached to the system piping, it is the motor or driver that must be moved to align the motor and pump shafts. Each pump and coupling has different tolerances that, when taken into account, will determine the amount of tolerance from perfect alignment.

There are various methods of pump alignment depending on pump and driver configuration. The latest technology uses laser emitters attached to the pump and driver shafts. The data from the lasers is analyzed by a laptop computer, and a graphic readout tells you where to place shims or make adjustments to bring the units into alignment. It is sometimes more economical to hire a professional if you do not have the expertise or equipment to do this job. Dial indicators can be attached to each shaft and the driver tapped until it is within manufacturer's tolerance, but this can be a slow process. After tightening the driver hold-down bolts, remember to recheck the alignment to see whether anything has shifted.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

218. Centrifugal pumps

1. How is liquid moved by a centrifugal pump?

2. Name the two basic types of centrifugal pumps.

3. Name the two different centrifugal pump case designs.

4. What are the two types of cavitation?

5. How is the packing in the stuffing box of the Peerless centrifugal pump controlled or adjusted?

6. When replacing the packing on the Peerless pump, how do you reduce the chance of packing leakage?

7. What type of pump is used as a priming pump inside a self-priming centrifugal pump?

8. What inspections are required for the Gilbarco pumps?

219. Deep-well turbine pumps

1. What type of motor will a deep-well turbine pump have?

2. What is the difference between a motor listed as VHS and a motor listed as VSS?

3. Why do threaded couplings on deep-well pumps have left-handed threads?

4. How will you know if a deep-well turbine pump has an enclosed shaft?

5. What operational inspections are made on deep-well turbine pumps?

220. Replacement and adjustment of mechanical seals

1. Specify the type(s) of mechanical seals that fits the following description or adjustment:

   a. Its specified clearance is stamped on the collar.

   b. Four Allen screws must be tightened to secure the seal lock ring.

   c. The proper adjustment is made by using gauges.

   d. Has both an inside and outside seal types.

2. If you notice that the seats on a mechanical seal are scratched during an inspection or while being installed, what must be done to correct the problem?

3. While you are adjusting the John Crane mechanical seal, the setting gauges must be inserted into what part of the seal?

4. In order to protect the adjusting sleeve O-ring when replacing mechanical seals, what should you do?

5. After you install a new seal, it starts to leak slightly and then leakage gradually decreases. What does this indicate?

6. The latest technology uses what to align the pump and driver shafts?

3–3. Operation and Maintenance of the Nonsurge Check Valve

The most common automatic fuel valve installed downstream of a pump is the 81AF or the 81AF–8 nonsurge CV. These valves prevent surges downstream of the pump by opening slowly, and they prevent reverse flow.

221. Nonsurge check valves

Figure 3–25 shows the major components of the 81AF nonsurge CV. Study this figure as we discuss the valve.

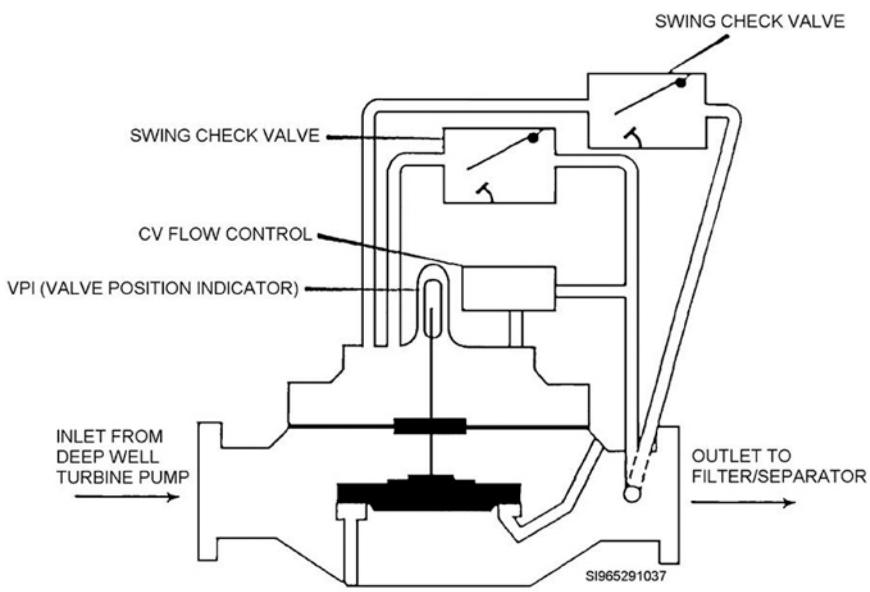


Figure 3–25. 81AF, Nonsurge CV.
(By courtesy of Cla-Val Co.)

Operation of the 81AF nonsurge CV

The valve consists of a main valve body (MVB), CV flow control, two swing-type CVs, a valve position indicator (VPI), and necessary tubing. When the pump is turned on, fuel under the main valve diaphragm pushes the disc up off the seat. Fuel coming off the top of the diaphragm goes through the CV flow control and out the discharge side of the main valve. Figure 3–26 shows a cutaway view of the swing CV. The swing CV controls the direction of flow. Looking at figure 3–26, you can see that flow is allowed by the flappers being hinged, and as fuel flows from left to right, the flapper is lifted off its seat. When reverse flow occurs, from right to left on figure 3–26, the flapper disc is seated and no flow can get by.

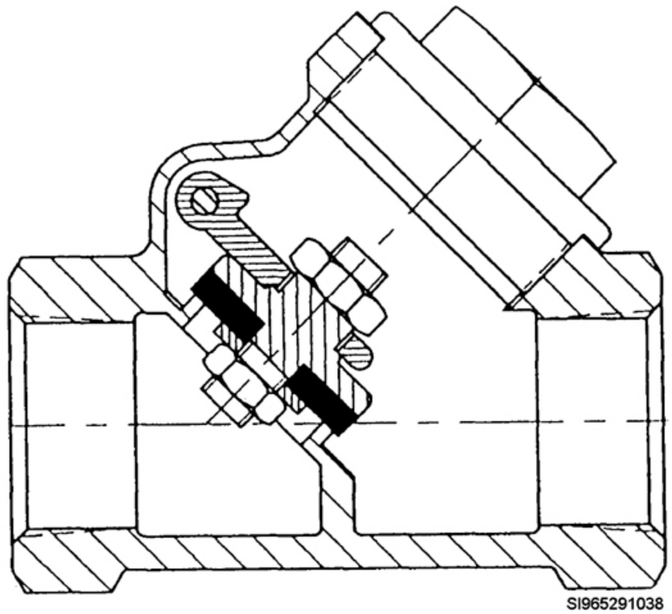


Figure 3–26. Swing CV.
(By courtesy of Cla-Val Co.)

Figure 3–27 shows a cutaway view of the CV flow control. Port B is connected to the main valve cover chamber. The opening time of the main valve is controlled by the CV flow control. Fuel being pushed off the main valve passes between the needle valve and disc.

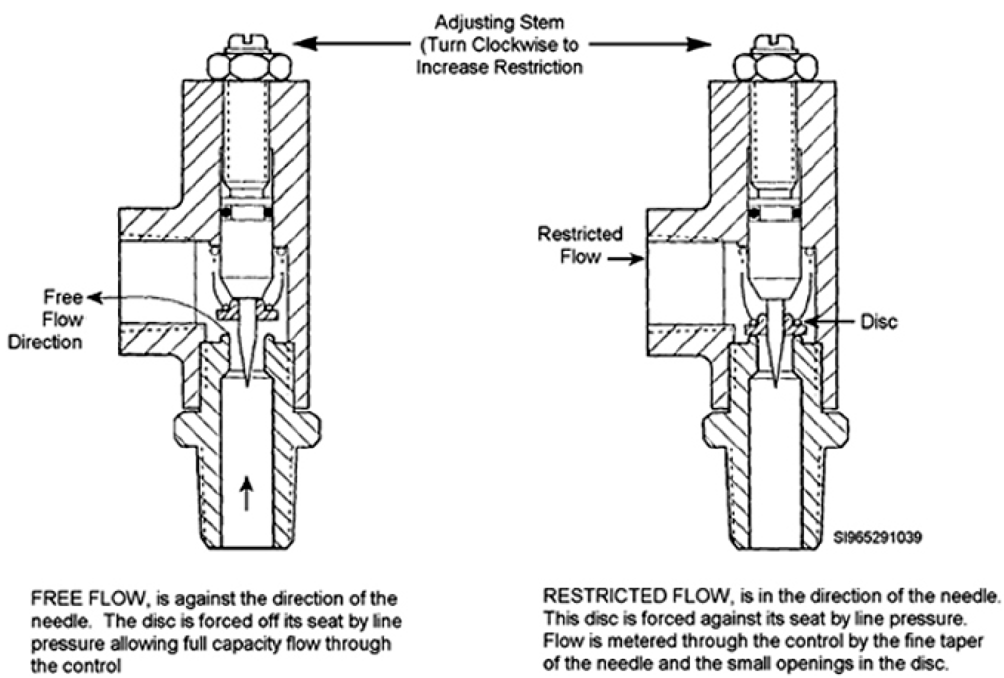


Figure 3–27. CV flow control.
(By courtesy of Cla-Val Co.)

When the pump is stopped, fuel in the line may start to flow back into the deep-well pump. Fuel pressure on the discharge side of the nonsurge CV will enter the control tubing, open both swing CVs, and pressurize the cover chamber of the main valve. This action will cause the main valve to close and stop any further reverse flow in the fueling line.

Adjusting the CV flow control

When you adjust the opening rate of the 81AF valve, you want the valve to open quickly, but without causing any vibration and sudden pressure surges downstream. Each base decides on the settings of its 81AF valves, but the standard to follow is a 20-second opening time. The spring-loading CV flow control in the pilot control system allows for adjustment of valve opening rates within a range of 5–60 seconds. Start the pump and time the opening rate of the main valve. Adjust the control accordingly. To decrease the opening rate (take less time to open), turn the adjusting screw counterclockwise; to increase the opening rate, turn the adjusting screw clockwise. After each adjustment, you must recheck the opening rate.

Maintenance of the 81AF nonsurge CV

When preparing to do maintenance on this or any other automatic valve, you must determine the cause of the problem before disassembling the valve. When you become more familiar with the operation of the automatic valves, you will find that only specific things can cause a valve to malfunction in a specific manner. An example of this is that, if the nonsurge CV fails to open slowly, you will *not* have to check the diaphragm; the trouble is either in the flow control or in the CVs. We have supplied a listing of the possible troubles, probable causes, and remedies in this table:

Trouble	Probable Cause	Remedy
Fails to open.	Flow control clogged.	Overhaul valve.
	Diaphragm failure.	Replace diaphragm.
	Closed manual valve downstream.	Open valve.
Valve opens and then closes.	Loose diaphragm nut.	Tighten.
Fails to close.	Obstruction in main valve between disc and seat.	Clear obstruction.
Pulsation.	Air in main valve cover chamber.	Bleed cover chamber.
No opening control.	CV flow control stuck open.	Clear obstruction.
	Swing CV not seated.	Overhaul as necessary.
	CV or CV flow control installed backwards.	Remove and install.
Pipeline vibrating on startup	Main valve opening too fast.	Adjust flow control to decrease opening time.

Operation of the 81AF–8 nonsurge CV

Figure 3–28 shows the major components of the 81AF–8. The valve consists of a 100AF MVB, CV flow control, two *hytrol CV*s, a VPI, and necessary tubing. The only thing that changed from the 81AF to the 81AF–8 is the replacement of the two swing CVs with two hytrol CVs. Figure 3–29 shows a cutaway of the hytrol CV. The hytrol CV also controls the direction of flow. Looking at figure 3–29, you see that fuel flow enters the hytrol check from the right and applies pressure under the diaphragm. This raises the seat off the disc, allowing full flow through the control. When reverse flow occurs, from left to right on figure 3–29, fuel flows through the drilled passage to the cover chamber. This applies pressure on top of the diaphragm, closing the hytrol check and preventing reverse flow through the control. The opening time of the 81AF–8 is also controlled by the CV flow control. Fuel being pushed off the main valve passes between the needle valve and disc.

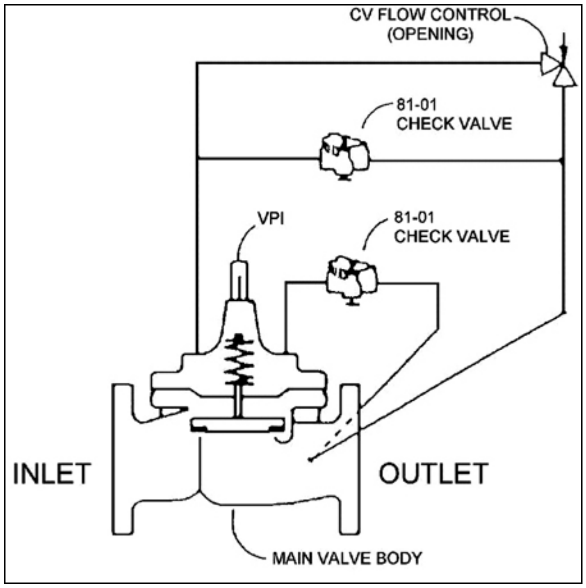


Figure 3–28. 81AF–8, Nonsurge CV.
(By courtesy of Cla-Val Co.)

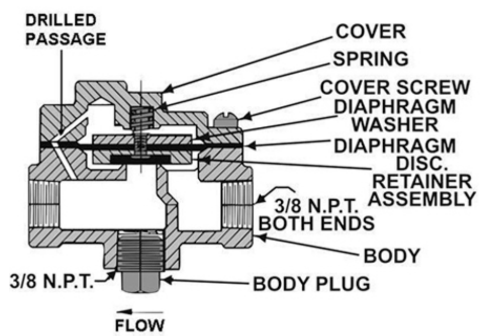


Figure 3–29. 81–01, Hytrol CV.
(By courtesy of Cla-Val Co.)

Adjusting the CV flow control

The CV flow control adjustment is the same as for the CV flow control on the 81AF. To increase the opening rate, turn the adjusting screw clockwise. After each adjustment, you must start the pump and recheck the opening rate. The standard opening rate should be 20 seconds.

Maintenance of the 81AF–8 nonsurge CV

As with the 81AF, you must determine the cause of the problem before disassembling the 81AF–8 valve. We have supplied a listing of the possible troubles, probable causes, and remedies in the following table:

Trouble	Probable Cause	Remedy
Fails to open.	Flow control clogged.	Overhaul valve.
	Diaphragm failure.	Replace diaphragm.
	Closed manual valve downstream.	Open valve.
Valve opens and then closes.	Loose diaphragm nut.	Tighten.
Fails to close.	Obstruction in main valve between disc and seat.	Clear obstruction.

Trouble	Probable Cause	Remedy
Pulsation.	Air in main valve cover chamber.	Bleed cover chamber.
No opening control.	Flow control disk stuck open.	Clear obstruction.
	Hytrol check installed backwards.	Remove and reinstall.
	Hytrol check diaphragm ruptured.	Replace diaphragm.
Pipeline vibrating on startup.	Main valve opening too fast.	Adjust flow control to decrease opening time.
Main valve fails to check.	Hytrol check installed backwards.	Remove and reinstall.
	Hytrol check stuck off its seat.	Remove obstruction.

The nonsurge CV, while simple in construction for an automatic valve, performs a vital function in the fuel system. Improperly adjusted, the pump could create a damaging pressure surge on startup or run outside of its pump curve due to a long length of empty fuel line.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

221. Nonsurge check valves

1. Explain the operation of the 81AF nonsurge CV.

2. Explain how to adjust the CV flow control.

3. List the probable causes for the following troubles on the 81AF–8 nonsurge CV:

   a. Valve fails to open.

   b. Valve pulsates.

   c. No control of opening rate.

4. Explain how the 81AF–8 nonsurge CV operates.

5. Explain what would happen to the 81AF–8 if the hytrol checks were installed backward.

Answers to Self-Test Questions

215

1. The external gear pump moves the liquid between the pump housing and the gears, while the internal gear pump moves the liquid between the gears.
2. The bottom gear.

216

1. It makes it possible to adjust the pump's rpms.
2. The vanes move the fuel between the pump rotor and housing. As the fuel reached the discharge side of the pump, the rotor and pump housing squeeze the fuel out of the pump.
3. Inspect quarterly for leaks, vibration, gear alignment within the gear reducer, overheating of pump and motor, and lubrication of pump bearings.
4. With a hand-pressure gun until lithium-based grease starts to escape from the grease relief.
5. The seals and bearings.

217

1. The bottom ball checks lift to allow fluid to be pulled into the pump liquid chambers, then the diaphragms push the fluid out through the top check ball to the top outlet.
2. A check ball stuck off its seat.
3. To unseat the check balls and drain the liquid from the pump.
4. The clapper valves.
5. The priming cylinder.
6. Clean the blower screen, flywheel vanes, and cylinder cooling fins.

218

1. Vanes in the impeller create centrifugal force to move the liquid.
2. Plain and self-priming.
3. Volute and diffuser.
4. Suction and discharge.
5. By the gland bolts and nuts.
6. Stagger the seams of the packing rings' cut ends.
7. Vane-type pump.
8. Leaks, unusual noises, vibrations, adequate discharge pressure, pump/motor shaft alignment, and pump/motor overheating.

219

1. 3-phase.
2. The VHS motor will have a vertical hollow shaft connected to the top of the motor by an adjustment nut for impeller setting; the motor shaft can be removed for mechanical seal replacement without removing the entire motor. The VSS motor has a vertical solid shaft that requires the removal of the entire motor for mechanical seal replacement; impeller adjustment is done at the motor-to-pump coupling; may have packing instead of mechanical seal.
3. To keep the couplings from unthreading, because all deep-well pumps have a counter-clockwise rotation.
4. It will have an oil reservoir at the bottom of the discharge assembly.
5. Unusual noise and vibration, motor and pump overheating, and leaks.

220

1. a. Dura seal.
   b. John Crane.
   c. Dura seal, John Crane.

d. Dura seal.

2. Replace the whole mechanical seal.
3. The top groove of the adjusting sleeve.
4. Cover the threads on the pump shaft with tape.
5. This is a good sign that the sealing surfaces will seal themselves as the pump continues to run.
6. Laser emitters.

221

1. Fuel pressure under the main valve diaphragm forces the fuel off the top of the diaphragm at a preset rate determined by the CV flow control's opening the valve slowly. When fuel starts to flow in reverse in the line, it passes through the CVs and closes the main valve.
2. The CV flow control is adjusted by removing the cap, loosening the lock nut, then turning the adjusting screw clockwise to increase the opening time of the valve, or counterclockwise to decrease the opening time.
3. a. CV flow control clogged; ruptured main valve diaphragm; closed manual valve downstream.

   b. Air in the main valve cover chamber.

   c. CV flow control disc stuck open; hytrol check installed backward; hytrol check diaphragm ruptured.
4. Fuel flow enters the hytrol check from the right and applies pressure under the diaphragm. This raises the seat off the disc and allows full flow through the control tubing. When reverse flow occurs, fuel flows through the drilled passage to the cover chamber. This applies pressure on top of the diaphragm, closing the hytrol check, preventing reverse flow through the control. The opening time of the 81AF–8 is also controlled by the CV flow control. Fuel pushed off the main valve cover chamber passes between the needle valve and disc.
5. You would have no control of the opening rate of the 81AF–8 and the main valve would not prevent reverse flow.

Unit Review Exercises

Note to Student: Consider all choices carefully, select the *best* answer to each question, and *circle* the corresponding letter. When you have completed all unit review exercises, transfer your answers to the Field-Scoring Answer Sheet.

Do not return your answer sheet to the Air Force Career Development Academy (AFCDA).

46. (215) What determines the gallon per minute (gpm) delivery of a gear pump?
    a. Motor revolutions per minute (rpm) and gear size.
    b. Size of pipe and number of gears.
    c. Size of pump and diameter of discharge.
    d. Space around gears and rpms turning the pump.

47. (216) What type of pump has a built-in pressure control valve?
    a. Centrifugal.
    b. Rotary-vane.
    c. External gear.
    d. Deep-well turbine.

48. (216) What type of lubricant is used and how is it applied to the Blackmer pump ball bearings?
    a. Silicon-based grease; by hand.
    b. Lithium-based grease; by hand.
    c. Silicon-based grease; hand-pressure gun.
    d. Lithium-based grease; hand-pressure gun.

49. (217) How would you troubleshoot a double diaphragm pump that is reciprocating but no liquid is being pumped?
    a. Check the check balls’ seating.
    b. Replace the ruptured diaphragm.
    c. Clean the dirt off of the actuator valve.
    d. Replace the seals on the actuator valve.

50. (217) What component(s) of the mud hog diaphragm pump allows water to enter the pump at the inlet, traps the water, and then allows the water to be expelled at the pump’s outlet?
    a. Ball checks.
    b. Clapper valves.
    c. Rotating engine cam.
    d. Diaphragm assembly.

51. (218) If a centrifugal pump develops 600 gallons per minute (gpm) at 350 feet of head, how much pounds per square inch (psi) is developed at 600 gpm when pumping JP–8?
    a. 12.3 psi.
    b. 34 psi.
    c. 43.3 psi.
    d. 123 psi.

52. (218) What type of impeller is the *most* efficient and develops the highest pressure?
    a. Open.
    b. Closed.
    c. Semiopen.
    d. Combination.

53. (218) What should you do if the centrifugal pump binds after you have replaced parts in the self-priming pump portion of a Gilbarco pump?
    a. File the rotor.
    b. File the vanes.
    c. Add $^1/_4$-inch spacers.
    d. Add a paper-thin gasket.

54. (218) What is the *most common* type American Petroleum Institute (API) 610 pump used in Air Force (AF) fuel systems?
    a. Single-stage centrifugal, radial-split case, with end suction and top discharge.
    b. Two-stage centrifugal, radial-split case, with end suction and top discharge.
    c. Single-stage centrifugal, radial-split case, with end suction and discharge.
    d. Two-stage centrifugal, radial-split case, with end suction and discharge.

55. (218) What component is installed on an American Petroleum Institute (API) 610 pump to minimize leakage in case of complete mechanical seal failure?
    a. O-ring seal.
    b. Bearing end cap.
    c. Teflon packing rings.
    d. Non-sparking throttle bushing.

56. (218) The total measured shaft deflection allowed when aligning an American Petroleum Institute (API) 610 pump shaft and motor shaft must be less than how many inches?
    a. 0.001 inches.
    b. 0.002 inches.
    c. 0.003 inches.
    d. 0.004 inches.

57. (218) How often is an American Petroleum Institute (API) 610 pump operationally inspected?
    a. Monthly.
    b. Quarterly.
    c. Semiannually.
    d. Annually.

58. (219) The number of column-shaft sections a deep-well turbine will have is determined by the
    a. capacity of a tank.
    b. pump output capacity.
    c. distance between the tank roof and tank bottom.
    d. distance between the pump tank flange and the tank floor.

59. (219) When adjusting a deep-well pump's impellers, the proper setting will give the *minimal* clearance needed to create the *most efficient* suction at the
    a. impeller's eye.
    b. bottom of the tank.
    c. impeller's discharge.
    d. pump discharge head.

60. (220) You are replacing a mechanical seal on a deep-well turbine with threaded couplings. With what do you cover the shaft threads to protect the mechanical seal's O-ring?
    a. Grease.
    b. Teflon tape.
    c. Electrical tape.
    d. Paper sleeve.

61. (220) What action should you take if you notice a slight leak on a mechanical seal you have just installed?
    a. Replace the O-ring.
    b. Replace the seal and O-ring.
    c. Stop the pump, restart, and see what happens.
    d. Allow reasonable time for the seals to adjust.

62. (220) In order to align a pump and motor, usually you need to
    a. move the pump.
    b. move the motor.
    c. adjust the shaft coupling.
    d. loosen the mechanical seal.

63. (221) The components of the 81AF nonsurge check valve (CV) are one CV flow control, a valve position indicator (VPI), and
    a. one hytrol CV.
    b. two hytrol CVs.
    c. one swing CV.
    d. two swing CVs.

64. (221) What is the standard opening rate for the 81AF–8, nonsurge check valve (CV)?
    a. 10 seconds.
    b. 20 seconds.
    c. 30 seconds.
    d. 40 seconds.

65. (221) What would cause the 81AF–8, nonsurge check valve (CV), to fail to open?
    a. Loose diaphragm washer.
    b. Hytrol check installed backwards.
    c. Closed downstream manual valve.
    d. Air in the main valve cover chamber.

Glossary of Abbreviations and Acronyms

° C	degrees Celsius
$2H_2SO_4$	two molecules of sulfuric acid
AF	Air Force
AFD	aviation fuel/defuel
AFI	Air Force instruction
AFR	aviation fuel/refuel
AFT	aviation fuel transfer
API	American Petroleum Institute
BCE	base civil engineer
BEP	best efficiency point
BOM	bill of materials
C	carbon
CE	civil engineering
CEMAS	Civil Engineer Material Acquisition System
CES	civil engineering squadron
CES/CEOE	civil engineering squadron/operations engineering element
CES/CEOF	civil engineering squadron/facility systems element
CES/CEOH	civil engineering squadron/heavy repair element
CES/CEOI	civil engineering squadron/infrastructure systems element
CO_2	carbon dioxide
cu ft.	cubic foot
CV	check valve
DBB	double block and bleed
DIN	Do-It-Now
EFF	efficiency curve
F/S	filter/separator
FRC	fuels resource center
ft.	foot
gal.	gallon
gpm	gallons per minute
H	hydrogen
H_2O	chemical formula for water (two parts hydrogen, one part oxygen)
H_2SO_4	sulfuric acid

IAW	in accordance with
IMT	information management tool
ISO	International Organization for Standardization
IT	information technology
IWIMS	Interim Work Information Management System
lb.	pound
MAJCOM	major command
MAS	maintenance action sheet
MVB	main valve body
Na	sodium
NaOH	sodium hydroxide
NOP	normal operating pressure
NPSH	net positive suction head
O	oxygen
O&M	operations and maintenance
OH	hydroxyl ion
OJT	on-the-job training
pH	potential hydrogen
PM	preventive maintenance
PMEL	Precision Measurements Equipment Laboratory
PMTL	preventive maintenance task list
POL	petroleum, oil, and lubricants
PRV	pressure-reducing valve
psi	pounds per square inch
PVC	polyvinyl chloride
ROI	return on investment
RPIE	real property installed equipment
rpm	revolutions per minute
SAE	Society of Automotive Engineers
Spec	specification
Std	standard
USAF	United States Air Force
VHS	vertical hollow shaft
VPI	valve position indicator
VSS	vertical solid shaft

WFSM	water and fuel systems maintenance
WIMS	Work Information Management System

Student Notes

Student Notes

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