An Introduction to Water Supply Systems Operation & Maintenance

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J. Paul Guyer, P.E., R.A., Fellow ASCE, Fellow AEI

Continuing Education and Development, Inc.
22 Stonewall Court
Woodcliff Lake, NJ 07677

P: (877) 322-5800
info@cedengineering.com

An Introduction to Water Supply Systems Operation and Maintenance

J. Paul Guyer, P.E., R.A.
Editor

Paul Guyer is a registered civil engineer, mechanical engineer, fire protection engineer, and architect with over 35 years of experience in the design of buildings and related infrastructure. For an additional 9 years he was a senior advisor to the California Legislature on infrastructure and capital outlay issues. He is a graduate of Stanford University and has held numerous national, state and local positions with the American Society of Civil Engineers and National Society of Professional Engineers. He is a Fellow of ASCE and AEI.

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1. INTRODUCTION This publication deals with maintenance inspections and general maintenance services required at domestic water supply systems. In addition, this section contains tables specifying tools and equipment, lubricants, and materials and supplies required to perform general and specific equipment maintenance tasks.

2. MAINTENANCE INSPECTIONS.

2.1 TYPES OF INSPECTION AND REPAIR. Water supply system personnel are concerned with three categories of inspection and, to some degree, with overhaul and repair.

2.1.1 OPERATOR'S INSPECTION. Regular inspection of equipment is part of an operator's routine duties to ensure proper functioning of the system. Such inspection includes lubrication, minor adjustments, and renewal of parts that do not require major overhaul or repairs. The operator's inspection also entails detecting and reporting (to the proper authority) any abnormal conditions (appearance, leaks, unusual noises, etc.).

2.1.2 PREVENTIVE MAINTENANCE INSPECTION. Cleaning, lubricating, adjusting, and renewing parts that do not require major overhaul and repairs, plus detecting and reporting (to the proper authority) any abnormal conditions (appearance, leaks, unusual noises, etc.) also comprise preventive maintenance inspection. Such inspections may be conducted by personnel who have been assigned specific areas of inspection responsibility or by personnel operating a particular piece of equipment or system.

2.1.3 CONTROL INSPECTION. Scheduled examinations or tests of public works and public utilities are made to determine their physical conditions. These examinations are termed control inspections and are performed jointly by engineering and operating personnel. Control inspection includes electrical, mechanical, and structural.

2.1.4 MAJOR OVERHAUL AND REPAIRS. As a rule, major overhaul and repairs are not made by operating personnel. This work is usually performed under contract.

2.2 PERSONNEL. It is generally best if well-trained personnel perform inspections, repairs, and preventive maintenance tasks. Personnel assigned to these tasks should

possess a thorough knowledge of the functions and operations of the equipment and the procedures for servicing it safely.

2.3 MAINTENANCE INFORMATION. Water supply system personnel need ready access to equipment O&M information. Keep this information on file and update it as necessary. The best sources of maintenance information are the manufacturers' instruction manuals provided with each piece of equipment. This material should be bound and organized according to equipment type and be kept in good order for quick reference. The following information is typically included in these manuals: descriptive literature (catalog cuts and data sheets); parts lists; instructions for installation, operation, maintenance, and repair; performance data (i.e., pump performance curves); electrical diagrams; and schedules of required lubricants and chemicals. It is normally recommended that operating personnel be familiar with each piece of equipment through careful examination of these instruction manuals. The material contained here is designed as a general overview of maintenance requirements and may not contain answers for specific maintenance questions. Consult the manufacturers' instruction manuals for specific maintenance information. The specifications, shop drawings, and as-built drawings, which should also be kept on file, show dimensions of each piece of equipment and provide information on pipe sizes and materials, valve types, equipment types, etc. They are available to plant personnel if the schematic drawings and valve and equipment schedules in this manual do not provide sufficient information.

2.4 MAINTENANCE MANAGEMENT SYSTEM. Regularly scheduled preventive maintenance is essential for keeping equipment in good running order. Daily tasks may be incorporated into the sampling and laboratory testing routine to make the most efficient use of the operator's time. If possible, perform routine tasks on the same day of the week or month to avoid confusion about when they were last performed. For example, each Monday can be set aside for performing weekly tasks, and the first Tuesday of the month can be set aside for monthly tasks. Annual lubrication can be performed during January. Since operating personnel cannot be expected to remember the service requirements for

every piece of equipment, a system of preventive maintenance is essential. To ensure the system is successfully implemented and maintained, it should be relatively simple to operate, producing maximum output for minimum input. The following paragraphs describe the components of a good maintenance system.

2.4.1 GOALS. An effective maintenance management system is designed to achieve the following goals:

- Provide periodic, timely, standardized, and complete equipment maintenance
- Prevent excessive maintenance, such as over greasing bearings
- Increase system reliability by preventing or providing early detection of equipment malfunction
- Improve the efficiency of equipment operation
- Extend equipment life
- Improve safety by reducing unexpected breakdowns and by providing safety precautions along with maintenance and service procedures
- Reduce overall maintenance costs
- Provide a complete record system covering equipment history, maintenance costs, and workloads.

2.4.2 COMPONENTS. The following components are necessary for a maintenance management system:

- Complete equipment records and maintenance history
- Preventive maintenance scheduling
- Corrective maintenance cost reporting
- Standardized preventive maintenance procedures
- Management reports on maintenance costs, overdue tasks, and employee utilization.

2.4.3 MAINTENANCE PERSONNEL. Another component of an effective maintenance management system is efficient organization of maintenance personnel. This includes providing adequate staffing, developing job descriptions and an organizational chart, providing maintenance training programs, and holding periodic staff meetings. Job descriptions are often developed for use in assessing the skill level required to perform particular tasks in a maintenance program. Depending on the size of the facility, complexity of equipment, and size of the maintenance department, various skill levels may be required (for example, Operator I and II, Mechanic, Electrician, etc.). In many facilities, specialized equipment maintenance may require the use of outside contractors.

2.5 SPARE PARTS AND STOCK CONTROL. Keep sufficient types and quantities of materials and stock on hand to ensure practical, economical, and continuous service. A review of the equipment and the manufacturers' recommendations will aid in determining which spare parts and miscellaneous supplies should be included in the inventory.

2.5.1 EXPENDABLE STOCK. Stock levels for expendable items used at a fairly uniform rate (such as pump packing, treatment chemicals, and laboratory reagents) are based on maintenance experience and operating reports. However, levels may be modified for reasons of economy. Thus, savings can sometimes result if treatment chemicals are bought in large quantities.

2.5.2 STANDBY ITEMS. Seldom-used materials needed to safeguard health, ensure uninterrupted operation of installation facilities, or prevent destruction of property are classed as standby items. Typical examples are chlorinator parts, such as a spare flowmeter, auxiliary chlorine valves, and cylinder connections. Hold materials to be stocked as standby items to a minimum, based on a detailed study of the water supply system. Consider these issues in setting up stocks of standby items:

- Non-critical parts immediately available from nearby installations, municipalities, or supply houses are not stocked. Critical parts are stocked.

- Much repair work at pumping stations and treatment plants can be anticipated, and parts for these repairs can be secured when needed.
- Only major sizes of pipe and fittings are stocked in large amounts.
- If the plant has several similar units, parts that are interchangeable need not be stocked for each unit.
- As soon as an item is drawn from standby stock, a replacement is ordered.

2.5.3 SUPPLY OF MATERIAL. Watch stock levels closely and order essential materials far enough in advance to ensure continuous service. It is recommended that supervisors be familiar with normal and alternate sources of supply and the time each source usually needs to make delivery. Supervisors generally will follow up orders and help supply personnel find alternate supply sources if delivery is delayed. Supplies will be obtained according to normal supply procedures.

2.6 REMOVING EQUIPMENT FROM SERVICE

2.6.1 SHORT PERIOD. Take precautions to prevent damage to equipment removed from service for a short time. Factors to be considered and precautions to be taken depend on the type of equipment and outside conditions. If the outage is likely to last more than a week, test operate the equipment once a week during that time.

2.6.2 PROTRACTED PERIOD. Special precautions are necessary for equipment that is to be out of service for long periods. Failure to retire or adequately protect equipment may cause serious damage during idleness or on resumption of operation. When it is known that the outage will be protracted, dismantle the equipment, if practical, and protect it against corrosion and other damage with suitable greases, oils, and rust-preventative compounds or coverings.

2.7 OPERATING UNDER WINTER CONDITIONS. Protecting operating and standby equipment against damage is especially important in cold climates. Make sure lubricants

are changed to winter grades. Drain equipment that is temporarily out of use or on standby service, or provide proper antifreeze coolant to prevent units (such as the housings of pumps, radiators, piping and similar items) from freezing or bursting.

3. ELECTRICAL EQUIPMENT. The following maintenance instructions are general. Perform maintenance of individual pieces of equipment according to the recommendations of the manufacturer. Operating procedures and ambient conditions, such as dirt and vibration, may dictate maintenance schedules different from those recommended here.

3.1 GENERAL. Major electrical equipment is best maintained by qualified, experienced electricians and in accordance with the manufacturer's recommendations. Water system personnel may perform some inspections, lubrication, and simple routine maintenance. In general, do not open an electrical control panel unless the job requires it. De-energize electrical equipment at the motor control center and at the equipment itself before working on it. Always tag the open breaker and, if possible, lock it in the "open" position.

3.2 ROUTINE INSPECTIONS. Visually inspect electrical equipment every day. Keep area clean. Look for the source of any leaks or unusual heat, noise, or odors. On rotating equipment with sleeve bearings, check the oil level and see that oil rings turn with the shaft. On rotating equipment with slip rings or commutators, check for excessive sparking. Inspect motors on rotating equipment weekly. Be sure that the shaft is free of oil and/or grease from the bearings and start the motor to make sure it comes up to speed in normal time. Check the bearings for excessive heat or noise. Check slip rings and commutators for excessive sparking during starting. Lubricate bearings according to the manufacturer's recommendations. Do not lubricate excessively; lubrication on insulating surfaces will deteriorate the insulation and gather dirt, which decreases the effectiveness of the insulation.

3.3 SWITCH GEAR. Perform the following work items in accordance with the manufacturer's instructions, but not less than once per year. Perform the work more often if the equipment is exposed to excessive dirt or vibration. These maintenance procedures apply to all electrical equipment that has contact-making devices (circuit breakers,

contactors, switches, relays, etc.), electrical coils (transformers, reactors, solenoids, etc.), electrical terminations, insulators, or accessible electrical wiring or busses.

- Open equipment panel and wipe insulators and busses with clean, soft, lint-free rags. Clean interior with soft brushes or a vacuum cleaner.
- Check all accessible electrical terminations and connections, including terminations of power and control cables, bolted bus connections, and all accessible ground connections. Taped connections need not be checked. Check visually and tighten loose connections with a screwdriver or wrench.
- Record the voltage at the secondary terminal of each power and distribution transformer, both loaded and unloaded. Compare this reading with previous readings. Change taps or contact the power company if the voltage is more than 5 percent high or low.
- Inspect contacts on switches, contactors, circuit breakers, disconnects, and relays if the contacts are accessible. Dress or replace contacts if they are pitted or burned. Replace contacts in pairs, not singly.

3.4 ELECTRIC MOTORS. Perform the following work items in accordance with the manufacturer's instructions, but not less than once per year. Perform the work more often if the equipment is exposed to excessive dirt or vibration.

- Blow dirt from the windings. Clean out magnetic particles that may be hanging on poles.
- Drain, wash, and renew oil in sleeve bearings. Clean and renew grease in ball-and-roller bearings. Check air gaps. Inspect bearings for excessive wear.
- Check end play. Under load, machines without thrust bearings should have the rotor within the end play. That is, the rotor should not be riding against the thrust collar of either bearing. This condition can cause heating and failure of the bearing; it can be corrected by shifting the rotor on the shaft or by shifting the laminations. Consult the manufacturer.

- On rotating equipment with commutators or slip rings, check brush tension and brush wear. Make sure brushes are free in the brush holder. Replace brushes as required. Sand-in new brushes. Check commutators and slip rings for wear, scratches, or pitting. Dress as required.
- Megger low-voltage rotating equipment using a 500-volt megger. Megger reading should be 1 megohm at minimum, but readings should be compared with previous readings, since a decreasing megger reading indicates deteriorating insulation or excessive dirt or moisture.
- Check foot bolts, end shield bolts, pulleys, couplings, gear and journal set screws, and keys. Ensure that all covers and guards for pulleys and couplings are in good condition and securely fastened. Observe operation during starting and running.

3.5 STANDBY POWER GENERATORS. Operate emergency generators once a week, if possible, to ensure they will work properly when needed. Operate the generators in accordance with the manufacturer's instruction (operation at full load for at least 1 hour is commonly recommended). Normal power sources must be disconnected to operate standby power at full load. Engine generators should comply with all applicable regulations regarding exhaust emissions.

3.6 INSTRUMENTATION AND CONTROLS. The following paragraphs address maintenance and calibration issues.

3.6.1 REGULAR MAINTENANCE. If kept in the proper environment, modern electronic equipment requires only periodic cleanings. Every 3 months, instruments should be opened or withdrawn from their cases, inspected, and cleaned with a soft brush. Instruments with moving parts should be lightly lubricated in accordance with the manufacturers' instructions. Do not over-lubricate. Check for interferences between moving parts. Fill ink wells on recorders as needed. Look for source of unusual heat, sound, or odors.

3.6.2 CALIBRATION. Check calibration annually on instruments, gages, and pressure switches. If possible, calibrate equipment in place using the piping, wiring, and fluids of the processes and calibrate a whole subsystem at once. Since this method does not require removing the instrument, it avoids errors such as bad connections and leaks on reinstallation. The disadvantages are that in-place calibration may disrupt the process, and it may be difficult to get sufficient accuracy and range. Calibrate pressure gages and pressure switches by connecting them to a pressure header with a bleed valve and a pressure valve connected to an air tank. Use a gage of known accuracy and recent calibration for a reference. Check set points of pressure switches on increasing or decreasing pressure. Gages and pressure switches should be checked annually.

3.7 TOOLS AND EQUIPMENT. In order to maintain, repair, and troubleshoot electrical equipment and circuits, the proper tools are required. In addition to a normal complement of small hand tools, a voltage tester with sufficient range to measure the highest voltage expected, a clamp-on type ammeter, a megger (a device for checking the insulation resistance), and an ohmmeter or circuit tester are required.

4. MECHANICAL EQUIPMENT. The following maintenance instructions are general. Maintain individual pieces of equipment according to the recommendations of the manufacturer. Operating procedures and ambient conditions, such as dirt and vibration, may dictate maintenance schedules different from those recommended here.

4.1 AERATORS. Maintenance frequencies for aeration equipment are summarized in Table 1.

4.2 RAPID-MIX BASINS AND EQUIPMENT. Because rapid-mix devices revolve at great speed, do not attempt to check the rotation of the mixer paddles during operation, except by visual observation. When the mixing basin is empty, check the condition of the paddles, bearings, drive shaft, and motor. Then clean, lubricate, and paint as necessary. Table 2 presents a summary of maintenance procedures for rapid-mix basins.

4.3 FLOCCULATORS. Table 2 covers flocculator maintenance.

4.4 SEDIMENTATION BASINS AND CLARIFIERS. All types of settling basins require the same basic maintenance (lubrication, cleaning, flushing, and painting). Maintain basins that incorporate proprietary mechanisms or devices according to the manufacturer's instructions. Table 2 presents a summary of maintenance procedures for sedimentation basins.

4.4.1 NON-MECHANICALLY CLEANED SEDIMENTATION BASINS. Clean these sedimentation basins at about 3-month intervals, or when development of an odor or rising floc particles indicates development of septic sludge conditions. Basins with mechanical equipment for removing settled sludge usually clean themselves satisfactorily during normal operations. However, it may be necessary at times to drain them and to clean the tank and mechanism with a high-pressure water hose.

Inspection	Action	Frequency (1), (2)
Waterfall type aerators (cascade)	Inspect aerator surfaces; remove algae; clean.	D
Waterfall type aerators (tray)	Clean and repair trays; clean coke or replace.	SA
Waterfall type aerators (cascade)	Repair or replace surfaces as necessary.	A
Packed tower aerators (strippers)	Inspect packing for scale buildup.	W
Packed tower aerators (strippers)	Clean with acid. (3)	Biweekly or as required
Diffuser type aerators		
Porous ceramic plate or tube	Check discharge pressure. If clogging is evident, dewater tank and clean diffusers.	V
Porous ceramic plate or tube	Drain aeration tank. Check for joint leaks, broken diffusers, and clogging. (4)	SA
Water side of ceramic diffusers	Clean with acid in place or remove and soak in acid. (3)	SA
Air side of ceramic diffusers	If plates are clogged with iron oxide, treat with 30% HCl; if clogged with dust, soot, oil, etc., remove diffusers and burn off extraneous material in a furnace following the manufacturer's instructions.	SA
Porous saran-wound tube diffusers	Inspect and clean as required. (5)	SA
Injection nozzles	Inspect and clean.	SA

Table 1

Maintenance Checklist for Aeration Equipment

Inspection	Action	Frequency (1), (2)
Spray nozzle aerators		
Nozzles	Check for clogging. Clean, removing nozzles if necessary. (6)	W
Manifolds	Remove caps and clean out sediment. Check pipe supports and repair as necessary. Paint as necessary.	Q
Spray fence	Paint.	A
Blowers and accessory equipment		
Compressor or blower	Lubricate. Check output pressure for indications of clogging.	D
Air filters	Clean, repair, or replace.	W
Compressor or blower	Open, inspect, clean, repair, and paint exterior surfaces.	A

(1) D-Daily; W-Weekly; Q-Quarterly; SA-Semiannually; A-Annually; V-Variable, as conditions may indicate.
(2) The frequencies shown are suggested frequencies that may be modified by local command, as individual installation conditions warrant.
(3) Caution: Handle acids very carefully. Particularly, do not pour water into sulfuric or chromic acid, as it will boil violently and splatter the acid over you. Such acid will cause severe burns to the skin and clothes. Perform acid treatment only on the approval of the plant superintendent and under the supervision of a chemist or other qualified personnel.
(4) Note: Chlorine gas introduced into the air line at intervals between inspections helps hold down organic growths. Removable plates should be soaked in 50 percent nitric acid. Plates grouted in place cannot be treated with nitric acid; use chromic acid (made by adding 1 g of sodium dichromate to 50 mL of sulfuric acid). Pour approximately 2 fluid ounces on each plate on 2 succeeding days.
(5) As the component materials cannot be subjected to strong acid or heat, scrub the diffusers with a brush and detergent.
(6) Do not use a pipe wrench for this purpose.

Table 1 (continued)

Maintenance Checklist for Aeration Equipment

Inspection	Action	Frequency (1), (2)
Rapid-mix basins	Drain, wash down walls, flush sediment to waste line. (3)	SA
	Repair spalled spots on walls and bottom. Check valves or sluice gates, lubricate, and paint as necessary.	
Baffled mixing chambers	Clean baffles and repair as necessary.	SA
Flocculator basins	Check paddle rotation to ascertain whether any flocculators are inoperative.	M
	Clean and lubricate drive, bearings, gears, and other mechanical parts. Check underwater bearings for silt penetration. Replace scored bearings.	SA
Rapid (or flash) mixers	Check paddles. Clean bearings and drive shaft. Lubricate and paint as necessary.	SA
Revolving-sludge-collector basins	Drain tank. Check submerged parts.	SA
Operating parts	Lubricate.	D or W
Speed reducers and oil baths	Remove water and grit. Replace oil as necessary.	W
Drive head	Lubricate (but do not over lubricate).	D
Worm gear	Check oil level. Drain water from housing.	W M
Turntable bearings	Lubricate. Change oil.	M SA

Table 2

Maintenance Checklist for Rapid Mix,

Flocculation, and Sedimentation Basins

Inspection	Action	Frequency (1), (2)
Chains	Drain off water, add oil as necessary.	M
	Change oil.	SA
Annular ball bearings	Lubricate.	D
	Inspect condition.	M
Center bearings, shaft bearings, bushings, etc.	See manufacturer's instructions.	V
Tank equipment	Tighten bolts and nuts. Check for excessive wear. Flush and backblow sludge line. Check motors, couplings, and shear pins. Check rakes. Clean and paint equipment.	A
Conveyor-type-collector basins	See above, and consult manufacturer's instructions.	V
Upflow or solids-contact clarifier	See manufacturer's instructions.	V

(1) D-Daily; W-Weekly; Q-Quarterly; SA-Semiannually; A-Annually; V-Variable, as conditions may indicate.
(2) The frequencies shown are suggested frequencies that may be modified by local command, as individual installation conditions warrant.
(3) Caution: Do not allow cross-connections to the drinking water supply system.

Table 2 (continued)

Maintenance Checklist for Rapid Mix,

Flocculation, and Sedimentation Basins

4.4.2 LUBRICATION REQUIREMENTS. Regular lubrication is required when the basin is in continuous operation. Intermittent operation may allow an increase in the lubrication interval. If operating periods are intermittent and infrequent, operate the mechanism briefly between operating periods and lubricate accordingly. Devices subject to wide seasonal temperature variations will require seasonal changes in lubricant grades, especially when summer grade oils thicken at lower temperatures and reduce the flow capability. Daily or weekly lubrication of operating units is part of the operator's inspection. The choice of lubricant and its frequency of application are established by the manufacturer or by local command. Inspect the speed reducer each week to make sure that the oil is at the proper level, is free of water and grit, and is of a suitable viscosity. If a reducer runs hot during its operation, the oil level may be too high or too low. When the reducer is out of service for extended periods, make sure that it is filled completely to prevent seals from drying out. Replace oil when necessary.

4.4.3 OVERLOAD ALARM. If the equipment has an overload alarm, check it for operation. If the alarm sounds at any time, shut off the equipment, locate the source of trouble, and rectify the situation. Disabling the alarm switch is not recommended. It is important that the alarm provide continuous operation under overload (high-torque) conditions. If the overload is caused by a sludge buildup leading to cut-out of the starter switch or pin shearing, drain the tank and flush out the sludge.

4.4.4 UPFLOW CLARIFIERS AND SOLIDS CONTACT UNITS. These are all proprietary items; maintain them according to the manufacturer's instructions. Devices that use rotating parts have motors and gears that require maintenance.

4.4.4.1 OPERATOR'S INSPECTION. Check for leaks in valves and piping each month. Make sure that sludge valves function properly. Also check time clock and other accessories that control sludge valve operation.

4.4.4.2 CLEANING MAINTENANCE. Drain unit, clean, and inspect wearing parts twice a year. Remove encrustation where it may interfere with operating parts; follow the manufacturer's instructions in this operation. Check chemical feed lines to make sure that they are not clogged and are in good condition.

4.5 GRAVITY FILTERS. This paragraph deals with maintenance of conventional or rapid filters, formerly known as "rapid sand filters." Media commonly used in rapid filters include graded sand, crushed anthracite, GAC, and garnet or ilmenite. Media types may be used alone, as in traditional sand filters and deep-bed monomedia filters, or in combination, as in dual and tri- or mixed-media filters. The following maintenance procedures supplement (but do not substitute for) requirements established by the equipment manufacturers. A quick reference guide to maintenance of gravity filters appears in Table 3.

Inspection	Action	Frequency (1), (2)
Filter media	Inspect surface for unevenness, sink holes, cracks, algae, mud balls or slime.	M
	Dig out sand and gravel at craters of appreciable size.	V
	Locate and repair underdrain system breaks.	V
	Chlorinate to kill algae growths.	Q
	Probe for hard spots and uneven gravel layers; if present, treat filter with acid.	SA
	Check wash water rise rate and sand expansion during backwashing.	SA
	Check sand condition for grain size growth; sample sand, determine weight loss on acid digestion, and run sieve test; acid-treat if necessary, or replace sand, if necessary.	A
Gravel	Check elevation of gravel surface.	M
	Examine gravel for encrustation, cementation, alum penetration, or mud balls; if necessary, remove, clean, and re-lay gravel.	SA
Underdrain system	Remove sand from an area 10 feet square (1 sq m) and inspect an area of gravel 2 feet square (0.2 sq m) or larger. If underdrains are deteriorated, remove all sand and gravel, repair underdrains, and replace gravel and sand.	A

Table 3

Maintenance Checklist for Gravity Filtration Equipment

Inspection	Action	Frequency (1), (2)
Underdrain system (continued)	If underdrain is porous and clogged by alum floc, treat with 2 percent NaOH solution for 12 to 16 hours.	V
Wash water troughs	Check level and elevation; adjust.	Q
	Check for corrosion; if present, dry troughs, wire brush, and paint.	SA
Operating tables	Clean table (console or panel) inside and out.	W
Cables	Adjust tension.	V
Hydraulic lines (or pneumatic)	Check for leakage; repair as required.	V
4-way transfer valves	Adjust; tighten packing glands or add new packing.	M
	Lubricate with grease.	M
	Adjust valve position indicator, if necessary.	M
	Disassemble, clean, lubricate, and replace worn parts.	A
Table	Paint inside.	A
Rate controllers		
Direct-acting		
General	Clean exterior, check diaphragm leakage, tighten packing, and check freedom of movement and zero differential.	W
Diaphragm pot	Disassemble, clean, and replace.	A or V

Table 3 (continued)

Maintenance Checklist for Gravity Filtration Equipment

Inspection	Action	Frequency (1), (2)
Controller mechanism	Disassemble and service; clean venturi; paint surfaces needing protection.	Every 3 years
Indirect-acting		
General	Clean outside; adjust packing; lubricate and tighten fittings; check knife edges; check piston travel; repack as necessary.	W
Pilot valves	Disassemble, clean, and lubricate; check piston travel; clean piping and strainers; check for leaks in diaphragm.	A
Controller mechanism	Disassemble and service; clean venturi; clean hydraulic cylinders; paint as necessary.	Every 3 years
Mechanically operated loss-of-head gages	Check zero setting; adjust stop collars or cable; release air from float chamber.	M
Mud leg	Flush out sediment.	M
Float chamber	Remove float and clean; replace mercury if necessary; check pressure pipelines; paint interior and exterior.	A
Diaphragm-pendulum loss-of-head unit	Check zero setting; purge diaphragm cases of air; check cable at segment; remove dirt from knife edges; tighten cam hubs on shafts; drain mud from mud leg.	M
Pipelines to diaphragm	Check for free flow and absence of encrustation.	SA

Table 3 (continued)

Maintenance Checklist for Gravity Filtration Equipment

Inspection	Action	Frequency (1), (2)
Diaphragm-pendulum unit	Check for leakage; disassemble unit, clean, and lubricate; check working parts and cables; repack stuffing box; check knife edges.	A
Mercury-float-type rate-of-flow gages	Check at zero differential; adjust indicator arm and recording pens; check stop collars on cables.	M
	Check accuracy and percent error; if greater than ±3 percent, adjust.	SA
Pressure lines	Check and clean as necessary.	SA
Float chamber	Clean float and check mercury; paint all parts requiring protection.	A
Piping and valves	Check for joint leaks; check pipe hangars and replace, if necessary; paint as necessary.	M

(1) W-Weekly; M-Monthly; Q-Quarterly; SA-Semiannually; A-Annually; V-Variable, as conditions may indicate.
(2) The frequencies shown are suggested frequencies that may be modified by local command, as individual installation conditions warrant.

Table 3 (continued)

Maintenance Checklist for Gravity Filtration Equipment

4.5.1 FILTER MEDIA

- Each month, drain the filter to the surface of the filter medium. Inspect the surface for unevenness, sinkholes, cracks, and evidence of algae, mud balls, or slime.
  - o If depressions or craters on the surface area are of appreciable size, dig out the sand and gravel, and locate and repair any break in the underdrain system.
  - o Remove mud balls manually or break them up with high pressure sprays.
  - o If severe algae growths exist on media or walls, remove the filter from service and treat it with a strong hypochlorite solution. Add enough hypochlorite to

produce 2 to 4 mg/L of free residual chlorine in a volume of water 6 inches deep above the filter surface. Draw down the filter until the water level is just above the bed surface. Allow the filter to stand 6 to 8 hours, then backwash the surface. Follow this procedure with a complete backwashing. Repeat if necessary.

- On a quarterly basis, probe the filter for hard spots and uneven gravel. Examine the sand below the surface by digging to gravel with the water drawn down to the gravel level. Clogs may appear because sand grains have cemented with mud balls or because grains have increased in size due to calcium carbonate deposit encrustation (for example, in softening plants or where lime and ferrous sulfate are used for coagulation). If so, clean the sand by treating the idle filter with inhibited muriatic acid (hydrochloric acid to which a chemical has been added to reduce corrosion of metal) or sulfurous acid. It is good practice to notify the utility managers before these chemicals are used.

    - Add the inhibited muriatic acid at the surface and allow it to pass downward through the bed and out the filter drain or “rewash” line. Alternatively, add it to an empty filter through a small tap on the bed side of the wash water supply line.
    - Use sulfurous acid as follows. Allow the sulfur dioxide gas from a cylinder to discharge into the filter wash water supply line while slowly filling the filter bed with wash water. Use one 150-pound cylinder with 6,000 gallons of water to produce a 0.3 percent solution. Allow solution to stand for 6 hours.

- Twice a year, usually when seasonal water temperature changes occur, determine any change in the rate of wash water rinse and check sand expansion as follows:

(1) The flow rate of backwash water should be sufficient for cleaning the media but should not provide so much pressure that loss of media results. In general, the backwash flow

rate should be at least 15 gallons per minute per square foot (10 liters per second per square meter [Lps/sq m]), which is equivalent to a rise rate of 2 feet per minute (600 mm/min) as measured by a hook gage. Higher rates may be required for some types of filter media, but rapid sand filters typically backwash at a rise rate of about 2.0 to 2.5 feet per minute (600 to 750 mm/min). The highest rate for each filter should be determined by actual experience at the plant. The rise rate is related to the backwash rate, as illustrated in the following calculation:

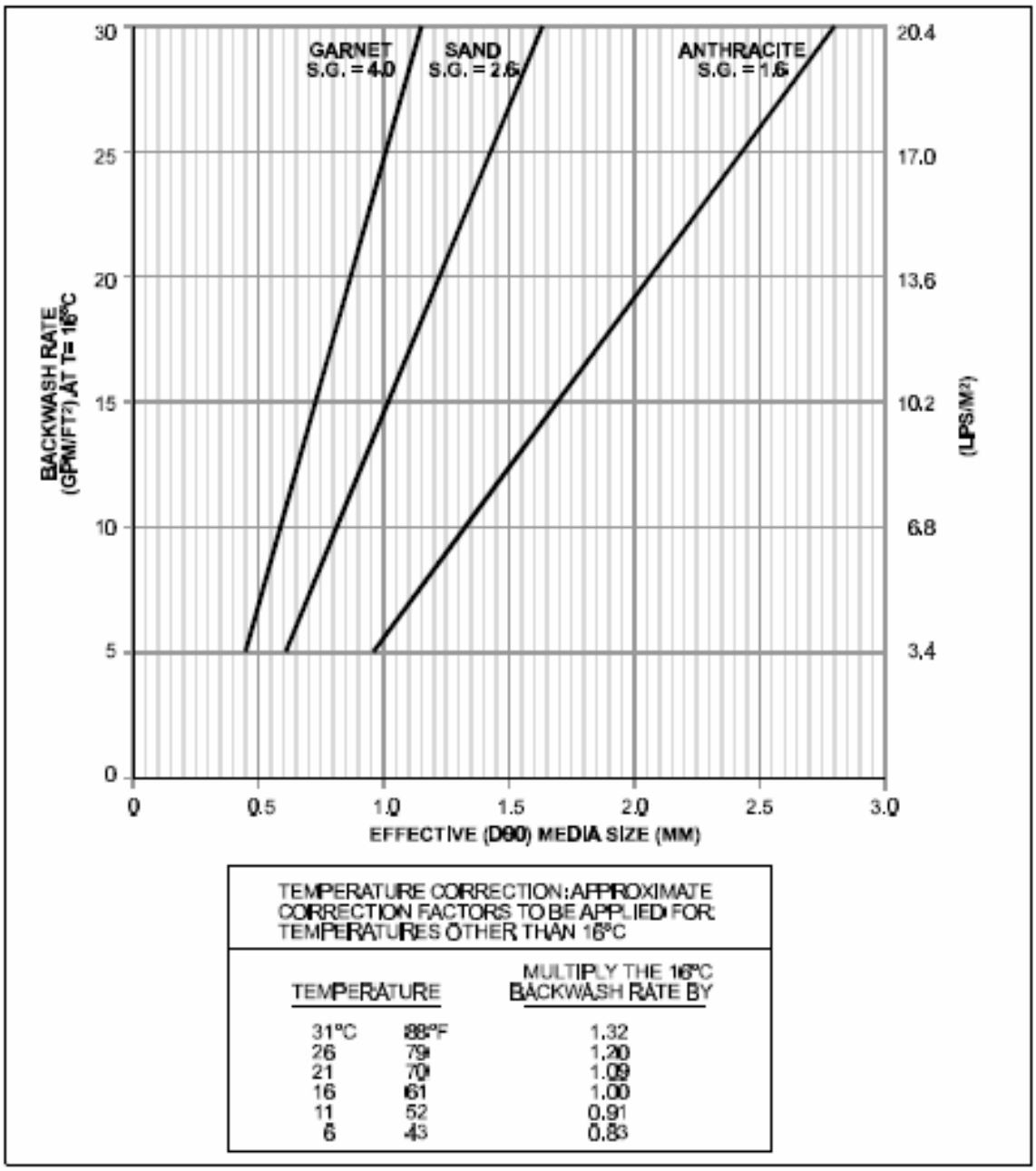
$$\frac{15 \text{ gallons}}{\text{minute x square foot}} \times \frac{1 \text{ cubic foot}}{7.48 \text{ gallons}} = \frac{2 \text{ feet}}{\text{minute}}$$

$$\frac{10 \text{ liters}}{\text{second x square meter}} \times \frac{1 \text{ cubic meter}}{1{,}000 \text{ liters}} = \frac{0.01 \text{ meter}}{\text{second}}$$

$$\frac{0.01 \text{ meter}}{\text{second}} \times \frac{60 \text{ seconds}}{\text{minute}} = \frac{1{,}000 \text{ mm}}{\text{meter}} = \frac{600 \text{ mm}}{\text{minute}}$$

a. Media Expansion. Filter media should be expanded at least 20 to 25 percent for good cleaning action, although a greater expansion may be optimum in some cases. Higher expansions risk washing out some filter media along with the accumulated solids. The degree of expansion is affected by many variables associated with the filter media and the water. Filter media variables include size and gradation as well as shape and density. Water variables include viscosity and density which, in turn, vary with water temperature. Media cleaning is also affected by interparticle abrasion, although the bulk of the cleaning action is due to the force of the rising backwash water. Expansion can be measured by attaching cups to a pole at suitable intervals, then dipping the pole into the backwashing filter bed; the highest cup that contains sand indicates the height of bed expansion. A waterproof flashlight attached to a pole works well to show the top of the sand, but only after the backwash water becomes relatively clear. See Figure 1.

b. Hook Gage. A multiple hook gage (Figure 2) is a series of vertical, sharp, pointed rods held in a frame that may be hung on the side of the filter. The tips of the sharp, pointed rods are set accurately at 2- or 3-inch (50- to 75-mm) spacings. The hook can be used to check the rate of filtration or backwashing, although its primary use is for measuring backwash flow rate. Hang the frame on the side of the filter and accurately record the time required for the water level to fall or rise between the points. The volume of water in the filter box between the gage points can easily be calculated. From the recorded time, the flow rate can accurately be determined.



TEMPERATURE CORRECTION: APPROXIMATE CORRECTION FACTORS TO BE APPLIED FOR TEMPERATURES OTHER THAN 16°C

TEMPERATURE		MULTIPLY THE 16°C BACKWASH RATE BY
31°C	88°F	1.32
26	79	1.20
21	70	1.09
16	61	1.00
11	52	0.91
6	43	0.83

Figure 1

Backwash rate for media cleaning

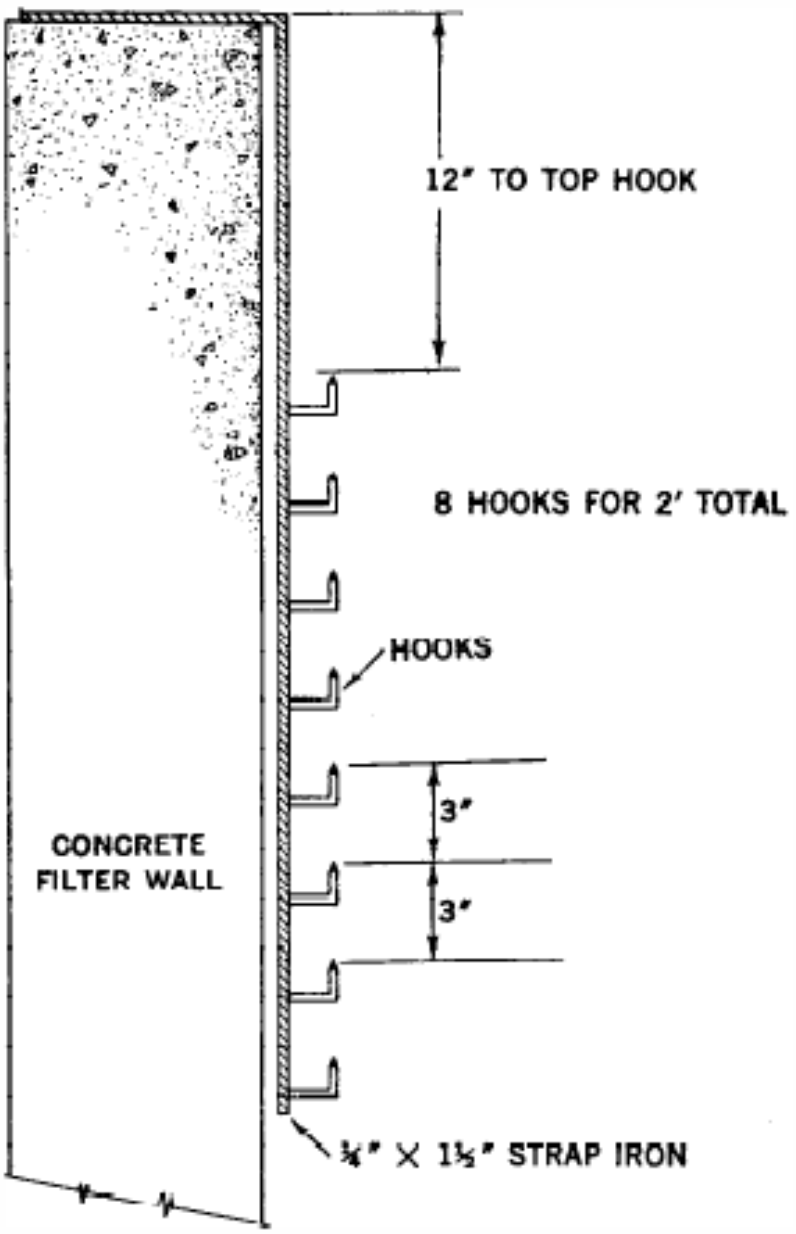


Figure 2

Multiple hook gauge

- d) Inspect the media twice a year. If visual inspection does not reveal the condition of the media, locate the elevation of the top of the bed to determine if the bed has “grown” in depth. Also, remove a media sample and analyze it as follows:

    - Make a sampling tube 12 inches (300 mm) square by 36 inches (1 m) deep. Force a tube into the gravel and drain the bed. Remove the sand from the tube. Collect several such samples from well-scattered locations on the filter bed, mix thoroughly, and reduce sample size by quartering until about 2 pounds (1 kg) remain. Dry this sample and mix, quarter, and reduce it to a usable sample size.

    - Determine the loss of weight of a 10-gram sample during acid treatment. Treat the sample with 10 percent hydrochloric acid in a Pyrex evaporating dish on a water bath for 24 hours. Replace acid loss during treatment period. Wash, dry, and weigh the sand. Determine the weight loss and compare it to the previous analysis.

    - From the rest of the sand sample, remove 100 grams and run a sieve test. Pass the sand through several standard sieve sizes, weighing the sand grains retained on each sieve. Compare the results to a previous test. Retention of greater amounts of sand on the larger sieve sizes indicates growth of the filter media.

    - If visual inspection, weight loss, or sieve analysis shows growth of sand grains to a point that filtration efficiency is impaired, treat the sand as outlined above and adjust the water treatment process as necessary. If treatment is not effective, remove and replace the filter media.

4.5.2 LOSS OF FILTER MEDIA. Media can be washed from the filter along with the backwash water or can filter through the gravel layer along with the product water. Losses of media in the backwash water can be kept to a minimum by controlling the backwash

flow rate, maintaining level backwash troughs at the proper elevation above the media surface, and controlling hydraulic short circuiting as a result of clogged media or gravel. Losses through the filter gravel can be controlled by placing a layer Of coarse garnet or ilmenite between the media and the gravel and by controlling mounding of the filter gravel. Leakage of media can be detected by a small trap located in the effluent line from each filter. Many new filters leak sand for a period and then stop. Such leakage poses no real problem. However, if sand leakage increases over a period, it is probably an indication of mounded gravel.

4.5.3 GRAVEL INSPECTION. Gravel inspection includes the procedures described below.

- At monthly intervals, use a probe to check the gravel bed surface for unevenness. If ridges or sinkholes are indicated, the filter may need overhauling.

    - Probing a Filter during Backwash. This method uses a metal rod long enough that the operator can reach the gravel layer while standing on the top of the filter. The rod has a heavy grade screen attached to the end so that it can penetrate the expanded filter media bed (the rod is stopped by the gravel layer). By probing every few feet along the filter, mounds or holes in the gravel layer can be discovered. A variation in the gravel level of over 2 inches (50 mm) indicates serious problems.

    - Probing a Filter at Rest. The filter can be probed at rest using a metal rod of about 1/4-inch (6-mm) diameter that penetrates the sand layer but not the underlying gravel.

- Remove media from an area of about 3 square feet (0.3 sq m) twice a year, taking care not to disturb the gravel. Examine the gravel by hand to determine whether it is cemented with encrustation or mud balls and whether it is layered improperly.

- If any undesirable conditions exist to a marked degree, remove the media and re-lay the filter gravel. If unevenness or layer mixing is caused by a faulty underdrain system, repair it; if it is caused by faulty backwashing, correct the backwashing procedure.

4.5.4 FILTER UNDERDRAIN SYSTEM. Inspect the filter bottom as needed. Sand boils (during backwashing), sand craters on the surface, or marked unevenness of the gravel layers indicate trouble in the underdrain system. Inspection and treatment procedures are as follows:

- To inspect the bottom, remove the media over an area of about 10 square feet (1 sq m). Select an area where sand boils or other indications of trouble have been noticed. Place planking over the gravel to stand on and remove gravel from areas about 2 feet square (0.2 sq m). Check underdrains for deterioration of any nature. If underdrains need repair, remove all sand and gravel, make repairs, and replace gravel and sand in proper layers.

- Where underdrains are of the porous-plate type and are clogged with alum floc penetration, flood the underdrain system with a 2 percent sodium hydroxide (caustic soda) solution for 12 to 16 hours.

4.5.5 WASH WATER TROUGHS. At quarterly intervals, check the level and elevation of troughs. Draw water below the trough weirs, crack the wash water valve and observe any low points where water spills over the weir before the weir is covered completely.

- Adjust the troughs as necessary to produce an even flow throughout their lengths on both sides.

- Twice a year, inspect the metal troughs for corrosion. If corrosion exists, allow the troughs to dry, clean by wire brushing, and paint with an appropriate protective paint or coating.

4.5.6 OPERATING CONSOLE. Operating controls for filter valves may be mounted on a console, panel, or table. The controls actuate filter valves that may be powered either by hydraulic or pneumatic means. The controls may be connected to the valve mechanism either by cable or chain and operated through electrical, hydraulic, or pneumatic connections.

- Perform these maintenance operations each week:
    - Clean the table, console, or panel inside and out, using soap and water if necessary.
    - If the console is cable-operated, inspect it for leaks and stop any leakage; if it is pneumatically operated, check tubing for possible leakage.
- Perform transfer-valve maintenance as follows:
    - Adjust 4-way transfer valves and handles each month to make sure that all filter valves open at the same rate. Tighten packing glands or add new packing as necessary.
    - Lubricate transfer valves with grease each month. Do not over lubricate the valves; one-half turn of the grease screw is generally sufficient.
    - Inspect the valve position indicator each month and adjust it to read correctly in all positions.

- Disassemble the 4-way transfer valves in the table each year. Clean or replace any worn parts, seats, or washers.

- Paint the inside of the table, console, or panel each year to protect against corrosion.

4.5.7 RATE CONTROLLERS. Rate-of-flow controllers may be either direct-acting or indirect-acting. Maintenance procedures for both types follow:

- Direct-Acting Controllers

  - Each week, clean exterior, check for leakage through diaphragm pot, and lubricate or tighten packing to stop any existing leakage. Also, make sure that both the diaphragm and the control gate move freely between zero differential and the open and closed positions.

  - At regular intervals, remove and disassemble the diaphragm pot, including the rubber diaphragm. If the water does not cause tubercles, this operation may only need to be performed once every 3 to 5 years.

  - Every 3 years, disassemble and service the controller gate and mechanism. Inspect the venturi throat. Paint or apply protective coating, as necessary.

- Indirect-Acting Controllers

  - Each week, clean the outside of the controller, adjust the packing, and lubricate or tighten the fittings as necessary to stop any leakage from the hydraulic cylinder, the controller valve, the piping, or the pilot valve. Make sure that the knife edges seat correctly and are free of paint and other foreign matter. Also,

be sure that the piston has free vertical travel and does not bind. Replace the packing if necessary.

- Each year, disassemble, clean, and lubricate the pilot valve. Remove foreign matter from the piston with a cloth. Do not use an abrasive to clean the piston. Make sure that the piston is moving freely. Disconnect and clean the pilot valve piping and strainers; make sure that no foreign matter enters the pilot valve during the cleaning operation. Check for leaks or cracks in the diaphragm.

4.5.8 GAGES. Indicating and recording instruments mounted on the operating table or control panel may include a filter rate controller, loss-of-head gage, flow-rate gage, water level, backwash flow rate meter, wash water rise indicator, and summation gage for total filter output.

- Mechanically Operated Loss-of-Head Gage. The equipment that operates the indicator, or indicator recorder instrument, requires the maintenance operations described in the following paragraphs. The inspector should follow these instructions in general and consult the manufacturer's instructions for detailed adjustments.

  - Each month, check the zero setting in the following way. Open the equalizing valve on mercury float-type head gages and make certain that the indicator arm and the recording pen return to zero. Note the reason for any incorrect reading, and adjust the stop collar or wire cable, if necessary, to bring the indicator to the proper zero reading. On floats and float chambers that are so equipped, release the air. (On some models it is possible to release the air by jerking the wire cable lightly.)

  - Each month, remove the float from the float chamber, wash the float, and remove encrustations. Use care not to mar the float. Replace the mercury, if

necessary, avoiding any spillage. When replacing the mercury, be sure that the amount is correct. Also, paint the interior and exterior of the float chamber and other parts each year to prevent corrosion. In addition, check the pressure pipelines to the float chamber and remove any encrustation. Caution: Mercury fumes are poisonous. Handle mercury carefully since a spill creates a continuing health hazard and is difficult to clean up.

- Diaphragm-Pendulum Unit Loss-of-Head Gage. When the actuating mechanism is of this type, the following general maintenance procedures apply. For a more detailed discussion of the procedures, consult the manufacturer's instruction.

  - Each month, purge the diaphragm cases of air and check the cable to be sure that it leaves the segment at a tangent to the lower end when the unit reads zero. Remove dirt from the knife edges; if necessary, tighten the cam hubs on their shafts. Drain mud from the mud leg as described in par. 11.5.5.8(a)(2) above.

  - Check the pipelines to the diaphragm twice a year to make sure that they are open and free of encrustation.

  - Inspect the diaphragms each year for leakage. Replace if necessary. Note: Spare diaphragms should be kept underwater.

  - Disassemble the unit in order to clean and lubricate it when necessary. Check the working parts and the cables (they should be free of knots, splices, or fraying). Repack the stuffing box if it is leaking. Make sure that the knife edges rest solely on their edges when the pendulum is hung vertically and be sure thatall cable ends are knotted tightly.

- Mercury-Float-Type Rate-of-Flow Gages. General maintenance procedures are outlined below. For more detailed procedures, consult the manufacturer's instructions.

    - Once a month, check the unit by opening the equalizing valve to eliminate the differential pressure in the gage. Adjust the indicator, the recording pens, and the register to zero. Check the position of the stop collars on the cables. Also, inspect and clean the stops on the indicator and recording pen.

    - Every 6 months, check the accuracy of the rate-of-flow gages in the following way. Determine the exact time for the water to drop 1 foot (30 cm), using hook gages. Determine the amount of water in this 1-foot (30-cm) depth (calculate, allowing for inlets, gullets, structural members, etc., or measure the input, if possible, from the wash water rinse or the drop in the level of the wash water tank). During the period timed for the drop in the water level of 1 foot (30 cm), note and record the reading of the flow rate. Calculate the rate of flow and percent error, according to the following equations:

$$\text{Gallons per minute} = \frac{V \times 60}{T}$$

Where:

V = volume in 1 foot depth of water (gallons or liters)

T = drop time (seconds)

$$\text{Percent} = \frac{F_1 - F_2}{F_2} \times 100$$

Where:

Percent = percent of error

F1 = indicated flow rate (gpm or liters per minute [L/min])

F2 = measured flow rate (gpm or L/min)

Note: If the error is greater than ±3 percent, make the necessary adjustments.

- Twice a year, check the pressure pipelines to the float chamber and clean and remove encrustation to allow for free flow.

- Once a year, clean the float and check the mercury for replacement. If necessary, paint the interior and the exterior of the float chamber and other parts to protect against corrosion.

4.5.9 PIPING AND VALVES. Each month, check for leaks at the joints. Also check the pipe hangers and replace any that have deteriorated. Paint piping, valves, and hangers if necessary to prevent corrosion.

4.5.10 MAINTENANCE SCHEDULE. The maintenance operation frequency and schedule of inspections for filtration are presented in Table 3.

4.6 PRESSURE FILTERS. Pressure filters need the same care and attention as gravity filters. Open these filters regularly and inspect them carefully. The following maintenance procedures apply:

- Inspect piping and valves for leaks each week. Lubricate and repack valves if necessary.

- Open the pressure shell and inspect the filter bed surface each month. Follow procedures described in (1) through (6).

    - Use a garden rake or probe during backwashing (while the manhole is open) to test for mud balls in the lower part of the filter bed and for evenness of the gravel layer surface.

    - Determine whether the sand bed level has changed since the last inspection by comparing the bed surface elevation with some reference point.

    - If the filter does not have a surface wash system and shows evidence of mud balls, backwash it at the highest rate possible while jetting the surface with a stream of water from a high-pressure hose. Install a permanent surface wash system.

    - Open the filter each year and remove the sand from an area large enough to allow inspection of the gravel. If the sand or gravel distribution indicates non-uniform distribution of backwash water, the filter media and gravel may need to be removed and the underdrain system checked.

    - Clean and paint the exterior of the shell each year.

- Every 3 years (or more often if necessary), remove the filter medium and gravel and check the underdrain system for wash water distribution. Repair if necessary. Clean the underdrain system, and paint it or apply a protective coating to all parts subject to corrosion, including the inside of the shell. Replace the gravel and the filter media.

4.7 PRECOAT FILTERS. In general, the maintenance procedures for cleaning the filter element are the same for both pressure- or vacuum-filter types. The following procedures apply:

- Each month, or as often as operating conditions require, check the filter elements. The need for cleaning is evident when the precoat shows bare spots on the elements. Iron oxide deposits, manganese dioxide deposits, and algae growths cause element clogging.

  - For iron oxide removal, treat the elements with a 0.5 percent solution of oxalic acid. Information is available from the manufacturer on the amount of oxalic acid to use for units of different sizes. The following procedures are used:

    a. Start with an empty filter after a regular washing.
    b. Close the drain valve and the main outlet valve; open the recirculation valve.
    c. Fill the tank to a level covering the top of the elements.
    d. Add the proper quantity of oxalic acid and recirculate for 1 hour.
    e. Drain and hose down the elements and the tank interior.
    f. Close the drain valve; refill, circulate a few minutes, and then drain again. If the cleaning is not completely effective, repeat the procedure.

  - The procedure for manganese dioxide removal is the same as the procedure for iron oxide removal, except that anhydrous sodium bisulfite is added to the

solution rather than oxalic acid (see the manufacturer's instructions for the correct amount).

- To remove algae growths, add a 12.5 percent hypochlorite solution to the tank volume after filling the tank to the proper level (see the manufacturer's instructions for the proper amounts to use for units of different sizes).

- b) Check the piping and valves and appurtenant equipment twice a year, including the body-feed equipment. Make any adjustments the manufacturer's instructions indicate are necessary.

- Clean and paint all exterior surfaces, if necessary.

4.8 ION-EXCHANGE EQUIPMENT. Ion-exchange maintenance schedule is summarized in Table 4.

4.8.1 OPERATING CONDITIONS. Determine the operating condition of the softener each quarter. Refer to operating records and make such tests and meter readings as are necessary to determine the following information:

4.8.1.1 FLOW RATE. Natural ion exchangers can operate satisfactorily at a flow rate of 5 gpm per square foot (3.5 Lps/sq m); synthetic resins operate at a rate of 6 to 7 gpm per square foot (4 to 5 Lps/sq m). Rates higher than these cause undesirable head loss through the bed and bed packing. Adjust the controls of the flow rate each quarter.

4.8.1.2 BACKWASH RATE. The rate of backwash should be 6 to 8 gpm per square foot (4 to 6 Lps/sq m) of bed surface. Rates below this value do not clean the bed properly. Rates too high wash some of the resin out of the softener and reduce its softening capacity. Adjust the flow rate control to produce the best backwash rate each quarter.

4.8.1.3 PRESSURE. Each quarter, check operating records for any change in the difference between inlet and outlet pressure. Any change in head loss through the softener indicates a problem. A decrease in pressure drop may indicate improper valve closure or a channelized bed. An increase in pressure drop may indicate a valve not completely opened, a dirty bed, clogged gravel, or a clogged underdrain system.

4.8.1.4 SOFTENING EFFICIENCY. Each quarter, check the records to determine the softening capacity between the regeneration periods. Compare the current amount of hardness removal with that recorded when the ion-exchange resin bed was new, and calculate the efficiency based on the original capacity as 100 percent. A decrease in efficiency may be caused by a dirty bed, coated resin grains, loss of ion-exchange bed, or improper regeneration (either by weak brine solution or under-regeneration or overregeneration). Replace resin bed if the efficiency has decreased by 25 percent and it cannot be almost completely restored by cleaning and using special procedures recommended by the manufacturer.

Inspection	Action	Frequency (1), (2)
Softener unit		
Shell	Clean and wire brush; paint.	A
Valves and fittings	Check for obstructions, corrosion, and fastness.	Q
	Check for leaks; repack if necessary.	SA
Ion-exchange medium	Check bed surface for dirt, fines, and organic growths; remove foreign matter and add resin to desired level.	Q
Gravel	Probe through resin to determine gravel surface; level gravel surface with rake during backwash flow; replace gravel when caked or if resin is being lost to effluent; wash and grade gravel and place in four separate layers; use new lime-free gravel at discretion of inspector.	Q
Underdrains	Check pressure drop through underdrains; if necessary, remove manifold or plate underdrains; clean and replace.	A or V
Regeneration equipment		
Salt-storage unit	Clean tank as necessary to remove dirt.	V
Brine tank	Clean out dirt and insolubles; allow to dry; paint both exterior and interior surface.	SA
Ejector	Clean, disassemble, check erosion and corrosion; clear clogged pipes; assemble and replace.	A

Table 4

Maintenance Checklist for Ion-Exchange Softening Units

Inspection	Action	Frequency (1), (2)
Operating conditions		
Flow rates	Check rate of flow through bed; adjust controls to optimum rate, depending on type of resin.	Q
Backwash rates	Check rate and adjust controls to optimum rate.	Q
Pressure	Check difference between inlet and outlet pressures; if undesirable changes in pressure drop have occurred, seek cause and remedy.	Q
Efficiency	Compare total softening capacity with previous inspection; determine cause of decrease, if any, and remedy situation.	Q
Out-of-service softeners	Drain; keep synthetic resins damp; do not regenerate before draining.	V
Demineralization equipment	Maintain according to manufacturer's instructions.	V

(1) Q-Quarterly; SA-Semiannually; A-Annually; V-Variable, as conditions may indicate.

(2) The frequencies shown are suggested frequencies that may be modified by local command, as individual installation conditions warrant.

Table 4 (continued)

Maintenance Checklist for Ion-Exchange Softening Units

4.8.2 DEMINERALIZATION EQUIPMENT. Ion-exchange equipment used for demineralization is highly specialized. Maintain it according to the manufacturer's instructions.

4.9 RECARBONATION EQUIPMENT

4.9.1 COMBUSTION UNITS. Maintenance of combustion units depends on the equipment used, fuel impurities, the effectiveness of the scrubber and drier, and the materials of construction. Consult the manufacturer's instructions for maintenance of the compressor or blower.

4.9.1.1 OPERATOR'S INSPECTION. Each day, check burners, compressor, gages, and traps. Adjust the equipment to ensure top-level operation.

4.9.1.2 DRIER, SCRUBBER, AND TRAPS. Each month, check material in the drier and replace as necessary. Adjust the spray and clean out connecting piping; clean the gas traps.

4.9.1.3 CORROSION INSPECTION. Every 6 months, inspect all equipment for internal and external corrosion. Repair the equipment if necessary, and paint it or use protective coatings.

4.9.2 CARBON DIOXIDE GAS FEEDERS AND EVAPORATOR UNITS. Maintenance of carbon dioxide gas feeders and evaporator units will generally follow the procedures outlined for vacuum operated gas feed chlorinators and liquid chlorine evaporators. Consult the manufacturer's instruction for specific maintenance requirements.

4.10 DISTILLATION EQUIPMENT

4.10.1 MULTIPLE-EFFECT EVAPORATORS. These evaporators may be of two types:

4.10.1.1 SUBMERGED-TUBE EVAPORATORS. As a general practice, remove scale from the evaporator tubes as soon as it becomes 1/16-inch thick, regardless of the model or manufacturer.

4.10.1.1.1 THERMAL CRACKING OF SCALE. In the tube model, the scale may be cracked by suddenly flooding the shell with cold water after the tubes have been preheated with steam at the first effect coil steam pressure. This method of cracking is the most satisfactory when the scale is less than 1/16 inch thick.

4.10.1.1.2 MECHANICAL CRACKING OF SCALE. Where thermal cracking is not effective, mechanical cracking may be used.

4.10.1.1.2.1 TUBE MODEL. Crack the scale by inserting a bar between the lines of tubes.

4.10.1.1.2.2 COIL MODEL. Manually crack the scale by bouncing the coils on a hardwood block in order to crack the heavier coating, then wire brush the coils. Consult the manufacturer's instructions for specific instructions. Caution: Using a chipping hammer to remove the scale may seriously damage the coils.

4.10.1.1.2.3 ACID CLEANING. In the coil model, scale generally may be dissolved quickly by immersing the coil in a 20 percent solution of inhibited muriatic acid (commercial hydrochloric acid). Wash the coils thoroughly in water before reinstalling them in the evaporator.

4.10.1.1.2.4 ZINC PLATE REPLACEMENT. Replace the zinc plates when they have been reduced to about one-quarter of their original size.

4.10.1.1.2.5 CONDENSER AND COOLER TUBE CLEANING. Clean these tubes (if used) by flushing, wire brushing or scraping, and flushing again before reinstalling them.

4.10.1.1.2.6 SHUTDOWN PROTECTION. If the plant is to be shut down for an indefinite period and is subject to freezing conditions, remove all water from all parts of the evaporator.

4.10.2 FLASH-TYPE EVAPORATORS. Specific maintenance instructions are provided by the manufacturer. The following procedures are the recommended minimum:

- Check the evaporator stages for corrosion or encrustation each quarter; clean and repair the evaporator as necessary.

- Check the steam tube side of the evaporator twice a year and repair it if necessary.

- Each year, inspect all parts of the unit (both interior and exterior) for signs of deterioration, and inspect the piping and valves. Repair or renew parts as necessary; paint interiors.

4.11 VAPOR-COMPRESSION DISTILLATION UNITS. Detailed maintenance procedures are found in the manufacturer's instructions. The following procedures are the minimum required:

- After 200 to 400 hours of operation, check the evaporator for corrosion or encrustation. If the tubes are encrusted, use either chemical or mechanical means for scale removal. Mechanical cleaning is used for hard scale that cannot be removed by chemical treatment.

    - For chemical treatment, add sodium bisulfate directly, or in solution, to the evaporator. Sulfuric acid and inhibited muriatic acid are better than sodium bisulfate; however, in general they should be used only if approved by the utility managers. The amount of acid to be added varies depending on the size and type of the unit. Consult the manufacturer's instructions. Generally, the acid

cleaning is continued during a 2-hour recirculation period; methyl orange is used as the indicator to show when the acid is spent. After treatment, drain the unit, flush well, rinse with alkaline solution to neutralize any remaining acid, and return to service.

- (2) The equipment needed to remove scale formation mechanically includes an electric drill with bit and wire brush attachments that fit the evaporator tubes. The tubes must be wet before the drilling is started. Water is fed through the drill bit during operation. Drill each tube and then wire brush. Remove scale from the evaporator shell or head by scraping; remove all dislodged particles of scale from the evaporator. Reassemble the evaporator and return it to service. Note: For safety, ground the electric drill used for removing scale, and protect the operator from electrical shock resulting from using an electric drill in a wet environment.

- Check all mechanical controls, fuel lines, electrical connections, lubrication points, and valves each quarter.

- Check the engine, vapor compressors, vent condensers, heat exchanger, cooler system, and instrumentation twice a year. Clean, adjust, and repair this equipment as necessary.

- Check the entire system. Clean, repair each year, and paint as necessary.

4.12 MAINTENANCE PROCEDURE SCHEDULE. Maintenance operation frequencies and the schedule of inspection for distillation equipment are summarized in Table 5.

4.13 ELECTRODIALYSIS EQUIPMENT. When establishing maintenance procedures, follow the detailed instructions provided by the equipment manufacturer.

4.14 REVERSE OSMOSIS EQUIPMENT. Membrane equipment is very specialized. Maintain it in accordance with the manufacturer's instructions.

4.15 BACKFLOW PREVENTERS. See manufacturer's directions.

4.16 VALVES AND PUMPS. See manufacturer's instructions.

4.17 COMPRESSORS. Table 6 is a checklist of the procedures for maintaining compressors. Note that these procedures are general. Always read and follow the manufacturer's instructions for mechanical equipment.

Inspection	Action	Frequency (1), (2)
Distillation equipment		
Multiple-effect evaporators		
Submerged tube		
Tubes or coils	Remove scale by cracking or acid wash (see manufacturer's instructions).	V
Zinc plates	Remove and replace when reduced to one-quarter of their original size.	V
Condenser or cooler tubes	Clean, as necessary, by wire brushing and flushing.	V
Flash-type evaporators		
Evaporator stages	Check for corrosion or encrustation; clean and repair as necessary.	Q
Stream side of evaporator	Clean and repair.	SA
Entire unit	Check for signs of deterioration; repair or renew parts as necessary; paint exterior.	A
Vapor-compression distillation units		
Tubes in evaporator	Clean.	Every 200 to 400 hours
	Chemically.	V
	Mechanically.	V

Table 5

Maintenance Checklist for Distillation Equipment

Inspection	Action	Frequency (1), (2)
Mechanical and electrical controls	Inspect, clean, and repair or replace worn parts.	Q
Engine, vapor compressors, vent condenser, heat exchanger, cooler system, etc.	Inspect, clean, repair, and adjust.	SA
Entire unit	Check, clean, repair, and paint as necessary.	A

(1) Q-Quarterly; SA-Semiannually; A-Annually; V-Variable, as conditions may indicate.

(2) The frequencies shown are suggested frequencies that may be modified by local command, as individual installation conditions warrant.

Table 5 (continued)

Maintenance Checklist for Distillation Equipment

Inspection	Action	Frequency (1), (2)
Intake Filters	Inspect the compressor filter. Inspect more frequently (daily) in areas with severe dust. (3)	M
	Clean or replace as indicated for each filter type.	SA
Impregnated paper filter	Replace when dirty.	
Cloth filter	Wash with soap and water, dry, and reinstall. Keep spare filter on hand for use when main filter is being washed.	
Wire mesh and oil-bath filter	Clean with a standard solvent; reoil or drain and refill oil bath; reuse.	
Bearings	Inspect bearings and lubricate if necessary. Most compressors have bearings that require oiling.	D
Crankcase reservoir	Examine the reservoir dipstick or sight glass for oil level. Keep reservoir full but do not overfill as excess oil can lock up or damage compressor. (4)	D
	Change compressor oil when necessary. If there are filters in the oil system, change these regularly as well.	Q
Drip-feed oiler	Check drip rate.	D
Force-feed oiler	Check pressure.	D
Grease fittings	Ensure fittings are greased.	Q
Cylinder or casing fins	Clean with compressed air or vacuum to ensure proper cooling of the compressor.	W

Table 6

Maintenance Checklist for Compressors

Inspection	Action	Frequency (1), (2)
Unloader	Check that compressor comes up to speed and that the unloader changes at start of the compression cycle. Listen for a change in sound. When the compressor stops, you will hear a small pop and the air bleeding off the cylinders. If the unloader is not functioning properly, the compressor will stall when starting, fail to start, or (if belt driven) burn off the belts.	D
Safety Valves	Test weekly. Do not change pre-set cutoff settings in high-pressure cutoff switches, low oil pressure switches, and high temperature cutoff switches. If any of these safety switches are not functioning properly, correct the problem before starting the compressor again. Record the safety switch settings and maintain record in the equipment file.	W
Air receiver	Drain the condensate from the air receiver using the valve located at the bottom of the tank. If the air receiver is equipped with automatic drain valves, inspect periodically for proper functioning.	D
Belts	Inspect the belt tension by pressing the belt down approximately 3/4 inch between the two pulleys. Make sure the compressor is locked off before performing this test. Do not over tighten belts.	SA

Table 6 (continued)

Maintenance Checklist for Compressors

Inspection	Action	Frequency (1), (2)
Operating Controls	Examine regularly. Make sure compressor is stopping and starting at the proper settings. For dual installations, make sure compressors are alternating (if so designed); inspect gage for accuracy. Compare readings with recorded startup values or other known, accurate readings.	Q
Tool oilers	If your compressor has a tool oiler on the receiver, check the reservoir and fill with rock drill oil when necessary.	W
Entire unit	Clean all compressors thoroughly at least once a month. Dirt, oil, grease, and other materials should be cleaned off the compressor and surrounding area. Compressors have a tendency to lose oil around piping, fittings, and shafts; therefore, diligent cleaning is required by the maintenance operator to ensure proper and safe operation.	M

(1) D-Daily; W-Weekly; M-Monthly; Q-Quarterly; SA-Semiannually; A-Annually; V-Variable, as conditions may indicate.
(2) Service frequencies shown are suggested. Always follow the manufacturer's service schedule if known. Service frequencies may be modified by local command, as individual installation conditions warrant.
(3) Note: Never operate a compressor without the suction filter because dirt and foreign materials will collect on the rotors, pistons, or blades and cause excessive wear.
(4) Heat from the compressor tends to break down oil quickly. Thus, most compressor manufacturers specify particular oils for their equipment and frequent oil changes are recommended.

Table 6 (continued)

Maintenance Checklist for Compressors

5. LUBRICATION

5.1 GENERAL INFORMATION. Proper lubrication prevents damage to wearing surfaces, reduces the maintenance required, and cuts power costs and equipment outages. The instructions that follow list the recommended lubricants for various uses. Directions for lubricating specific equipment are presented in tabular form and, where desirable, are repeated in the text that applies to the specific equipment items. These instructions may be modified by the operator to meet individual situations, but in general such modifications require the approval of the utility manager.

5.2 TYPES OF LUBRICANTS. Oils, greases, and preservatives for waterworks are listed in Table 7. This list does not contain all the lubricants available under commercial specifications, but it has been developed in an effort to establish good lubrication practice for normal operating conditions with as small a number of good lubricants as is feasible. Following Table 7 and Table 8 (a list of uses for oils and greases) does not relieve the operator from using lubricants that meet the requirements of the equipment manufacturer's recommendations. The information in Table 40 should be familiar to all maintenance and operating personnel. This list is subject to modification at the judgment of maintenance personnel, providing the modification is approved by the utility manager.

5.3 LUBRICANT USES

- Different authorities may make conflicting lube recommendations for essentially the same item; however, general reference material is available to help select the correct lubricant for a specific application.

- Grease is graded on a number scale, or viscosity index, by the National Lubricating Grease Institute. For example, No. 0 is very soft; No. 6 is quite stiff. A typical grease for most treatment plant applications might be a No. 2 lithium or sodium compound grease, which is used for operating temperatures up to 250°F (120°C).

- A list of uses for lubricants that are generally satisfactory when used on equipment operating under normal ranges of temperature, pressure, and corrosion is contained in Table 8. However, in view of the wide variation in characteristics of equipment and conditions of operation, the manufacturer's instructions for lubrication should be checked to make sure that listed lubricants meet the requirements of the manufacturer's recommended lubricants.

Product	Military Specification Number	Symbol	Approximate SAE Grade(a)	National Stock Number(b)	Temperature Range
					Above
Lubricating oil, general purpose	MIL-L-15016A	2075	20W	--	-10°F (-23°C)
		2110(c)	10W-75W	9150-00-223-4137	0°F (-18°C)
		2135	20W-75W	9150-00-231-6664	0°F (-18°C)
		2190	30W	9150-00-231-6639	35°F (2°C)
		2250	40W	--	35°F (2°C)
		3050(c)	20W	9150-00-223-4138	0°F (-18°C)
		3065	30W-80W	--	5°F (-15°C)
		3080	40W-90W	9150-00-223-8890	15°F (-9°C)
		3150	140W	9150-00-240-2258	25°F (4°C)
Lubricating oil, compounded	MIL-L-15019B	4065	40W	9150-00-243-3196	35°F (2°C)
		6135	140W	9150-00-231-6645	60°F (16°C)
		8190	30W	9150-00-231-9033	35°F (2°C)
Lubricating oil, mineral, cylinder	MIL-L-15018B	5190	140W	9150-00-240-2260	60°F (16°C)
Lubricating oil, stream turbine (noncorrosive)	MIL-L-17331B	2190TEP	30W	9150-00-235-9061	60°F (16°C)
Lubricating oil, internal combustion engine, subzero	MIL-L-10295A	OES	--	9150-00-242-7603	-65° to 0°F (-54 to -18°C)
Lubricating oil, instrument jewel-bearing, nonspreading low temperature	MIL-L-3918	OCW	--	9150-00-270-0063	-40°F (-40°C)
Lubricants; chain, exposed-gear and wire rope	VV-L-751A	CW-11B	--	9150-00-246-3276	All
Lubricating oil, internal combustion engine	MIL-L-2104A	OE-10	10W	9150-00-265-9425	-20°F (-29°C)
		OE-30	30W	9150-00-265-9433	0°F (-18°C)
		OE-50	50W	9150-00-265-9440	15°F (-9°C)
Grease, automotive and artillery	MIL-G-10924A	GAA	--	9150-00-190-0907	-65° to 125°F (-54 to 52°C)
Grease, ball and	MIL-G-18709	BR	--	9150-00-249-0908	125° to 200°F

Table 7

Lubricating Oils, Greases, and Preservatives

Product	Military Specification Number	Symbol	Approximate SAE Grade(a)	National Stock Number(b)	Temperature Range
roller bearing40					(52 to 93°C)
Grease, graphite	VV-G-671C	GG-1	--	9150-00-272-7652	125°F max. (52°C)
Lubricating oil, internal combustion, preservative	MIL-L-21260	PE-1	--	9150-00-111-0208	
Lubricating oil, preservative, medium	--	PL-MED	--	9150-00-231-2356	
Corrosion preventive, petroleum, hot application	MIL-G-11796A	CL-3	--	8030-00-231-2353	
Corrosion preventive, compound, solvent cutback, cold application	MIL-C-16173B	CT-1	--	8030-00-231-2362	

(a) SAE numbers 10W through 50W are for crankcase lubrication. SAE numbers 75W through 140W are for transmission lubrication.
(b) National stock numbers are for 5-gallon containers for lubricating oils and 35-pound containers for grease, except 1/2-ounce can for MIL-L-3918. For other containers see Federal Supply Catalog.
(c) Quenched.

Table 7 (continued)

Lubricating Oils, Greases, and Preservatives

Equipment	Oil or Grease Symbol
Air compressors	
Vertical with splash lubrication	
Gage pressure less than 100 psi	2110, 3050
Gage pressure greater than 100 psi	2135, 2190, 3050
Horizontal	2135, 2190, 3050
External lubrication, sight feed, wick feed, hand oiling.	2135, 2190, 3050
External lubrication, circulating system or splash type crankcase	2110, 2135, 3050
Cylinders:	
Wet conditions	8190
Dry conditions	2190, 2250, 3065
Bearings:	
Ball, all temperatures to 200°F (93°C)	BR
Ball, low-pitch line speed	
Operating temperature below 32°F (0°C)	2075
Operating temperature 32° to 150°F (0 to 66°C)	2190, 2250, 3065
Ball, medium-pitch line speed	
Operating temperature below 32°F (0°C)	2075
Operating temperature 32° to 150°F (0 to 66°C)	2135, 3050
Ball, high-pitch line speed	
Operating temperature below 32°F (0°C)	2075
Operating temperature 32° to 150°F (0 to 66°C)	2110, 3050

Table 8

Lubricating Oil and Grease Uses

Equipment	Oil or Grease Symbol
Ring-oiled, small, miscellaneous	2110
Kingsbury thrust bearing	2190TEP
Thrust (other than Kingsbury, subject to water)	4065
Thrust (other than Kingsbury, not subject to water)	2135, 2190
Bronze guide	GAA
Countershaft	CG 1
Differential (enclosed)	3150, 5190, 6135
Eccentric	3065
Guide	GAA, CG 1
Oilite bronze bushings	OE10, OE30
Pillow block	GAA
Underwater-babbitted	GAA, CG 1
Universal joint, slip splines	BR
Chain Drives	
Roller	3080; GAA, CG1
Roller (enclosed)	Winter, 2075; Summer, 3065
Roller (semi-enclosed)	Winter, 3080; Summer, 6135
Slow-speed	CW-IIB
Medium-speed	5190
Chemical feeders	See manufacturer's instructions

Table 8 (continued)

Lubricating Oil and Grease Uses

Equipment	Oil or Grease Symbol
Clarifier equipment	Do
Couplings	6135
Drive jaw clutch	OE50
Gear case or gear head	Low temperature, 3080; High temperature, 5190
Gears	
Herringbone	Winter, 2075; Summer, 3065
Helical	Do
Motor reducers	Winter, 3050; Summer, 2135
Open	5190
Planetary	Winter, 2075, 2110; Summer, 2135
Worm and pump transmission	Winter, 3080; Summer, 6135
Instruments	OCW
Motors	See manufacturer's instructions
Packing, sludge pumps	4065, 6135
Pumps	See manufacturer's instructions
Seal packings	GAA
Shafting	

Table 8 (continued)

Lubricating Oil and Grease Uses

Equipment	Oil or Grease Symbol
Large	2190, 3065
Small	2110, 2135, 3050
Shear pins	WB
Sheaves	CG 1, GAA
Solenoid oilers	3050
Valve stems	GAA

Table 8 (continued)
Lubricating Oil and Grease Uses

5.4 LUBRICATING PRECAUTIONS. In order to avoid plant failures due to improper lubrication, take the following precautions:

- Do not over lubricate. Over lubrication causes antifriction bearings to heat and may damage grease seals; it may also cause damage to the windings in electric motors.

- Do not lubricate totally enclosed or insufficiently guarded equipment while the equipment is in motion.

- Lubricate greased bearings as follows:

    - Shut off, lock out, tag and block the unit if moving parts that might be a safety hazard are close to the grease fitting or drain plugs.

    - Remove the drain plug from the bearing housing.

    - Remove the grease fitting protective cap and wipe off the grease fitting. Be sure that you do not force dirt into the bearing housing along with the clean grease.

- Pump in clean grease until the grease coming out of the drain hole is clean. Don't pump grease into a bearing with the drain plug in place. This could easily build up enough pressure to blow out the seals.

- Put the protective cap back on the grease fitting.

- With the drain plug still removed, put the unit back in service. As the bearing warms up, excess grease will be expelled from the drain hole. After the unit has been running for a few hours, the drain plug may be put back in place. Special drain plugs with spring-loaded check valves are recommended because they will protect against further buildup.

- Generally, the time between flushing and repacking for greased bearings should be divided by 2 for every 25°F (14°C) above 150°F (65°C) operating temperature. Also, generally, the time between lubrications should not be allowed to exceed 48 months, since lube component separation and oxidation can become significant after this period of time, regardless of amount of use.

- Another point worth noting is that grease is normally not suitable for moving elements with speeds exceeding 12,000 inches per minute (5 mps). Usually, oil lubricating systems are used for higher speeds. Lighter viscosity oils are recommended for high speeds, and, within the same speed and temperature range, a roller bearing will normally require one grade heavier viscosity than a ball bearing.

- Keep lubricant containers tightly closed, except when in use, to prevent contamination of the lubricant by the entrance of dust, grit, and abrasives. Store lubricants in dust-free areas. Before using lubricant containers, wipe the spouts and lips; before using grease guns, wipe the gun and fitting to ensure the absence of foreign matter.

- A good rule of thumb is to change and flush oil completely at the end of 600 hours of operation or 3 months, whichever occurs first. More specific procedures for flushing and changing lubricants are outlined by most equipment manufacturers.

- Every operator should be aware of the dangers of overfilling with either grease or oil. Overfilling can result in high pressures and temperatures, and ruined seals or other components. It has been observed that more antifriction bearings are ruined by over greasing than by neglect.

- A thermometer can tell a great deal about the condition of a bearing. Ball bearings are generally in trouble above 180°F (82°C). Grease-packed bearings typically run 10 to 50°F (5 to 30°C) above ambient temperature.

- For clarifier drive units, which are almost always located outdoors, condensation presents a dangerous problem for the lubrication system. Most units of current design have a condensate bailing system to remove water from the gear housing by displacement. These units should be checked often for proper operation, particularly during seasons of wide air temperature fluctuation.

- Pumps incorporate many types of seals and gaskets constructed of combinations of elastomers and metals. As for lubricants, conflicting advice can be obtained. A file containing data on general properties of materials used can help in the choice of lubricant.

5.5 GREASE FITTINGS. The same grease gun fitting should be provided on all lubrication points requiring the same grease. This practice reduces the number of grease guns required, keeps the use of improper lubricants to a minimum, and simplifies operation.

5.6 IDENTIFYING LUBRICANT ITEMS. The product symbol and identifying color should be marked on lubricant containers and grease guns, and at or near all oil cups and grease fittings, to assure the choice of the proper lubricant for that location.

6. INTERNAL COMBUSTION ENGINES

Very few water system operators actually repair gasoline- or diesel-powered engines. However, a number of inspections and routine procedures are needed to ensure that these engines are well maintained.

7. CHEMICAL STORAGE AND FEEDERS

7.1 GENERAL. Different chemical feeders work on very different principles. Each water treatment facility will require several chemical feeders to accurately control chemical application to the process. Some general information is provided in this section. Always read and follow the manufacturer's instructions for mechanical equipment.

7.2 LIME SLAKERS

a) Clean the dust-removal and the vapor-removal equipment during every shift. Make sure that dust and moisture do not reach the chemical feeding mechanism and cause caking or corrosion. Remove clinkers or grit not removed by regular operations.

b) While the slaker is out of service each week, clean grit out of each compartment. Wipe off the outside of the slaker with an oily rag. (The thin film of oil prevents the adherence of moisture or lime solution and thus protects paint.) Clean the vapor-removal system and check the mechanism for proper functioning. Clean all appurtenances.

c) Each month, check agitators, stirrers, and heat exchangers; replace any impellers on baffles in front of the heat exchanger that show appreciable wear. Inspect and repair, or replace as necessary, all wiring defects or metal deteriorations. Tighten bolts, eliminate vibration, tighten belts, and paint the equipment where necessary. Every 1,000 to 1,500 hours, lubricate the support bearing-drive with grease (do not use oil).

d) Overhaul lime slakers each year. Drain and clean the slaker and dust-removal system. Check the slaker bottom and sides for wear and repair them as necessary. Paint the exterior and inside top edges of the slaker lids to protect them from corrosion. Check for leaks and scale in the heat exchanger. Clean the thermometers and check their accuracy. Clean and lubricate all bearings. Repair controls, floats, piping, screens, valves, and vapor-removal equipment. Paint all equipment where necessary.

7.3 GAS CHLORINATORS. The operator should be familiar with the equipment to be maintained. An instruction book is furnished with every chlorinator; consult it for specific steps to follow in servicing. Should the book be lost, the manufacturer can supply a duplicate (as long as the model and serial numbers are included with the request for replacement). Follow the manufacturer's suggestions for O&M. This paragraph offers general maintenance procedures that apply to all gas chlorinators. A troubleshooting chart for solution-feed, vacuum-operated gas chlorinators is included as Table 9. General maintenance procedures for chlorination equipment are summarized in Table 10.

a) Inspect Chlorinator for Leaks. Examine the chlorinator and all piping for chlorine or water leaks each day. All chlorine leaks are serious because they increase rapidly in size and cause extensive corrosion and damage. Red discoloration at gas header connections means that a leak is corroding the fittings. Use an ammonia-water bottle to locate the chlorine gas leak. Do not pour ammonia water on the suspected leak. Rather, waft the open bottle near the suspected leak. If chlorine vapor is present, a dense white cloud will appear. Use litharge and glycerine cement or Teflon tape in making all metal-threaded pipe connections. Do not use grease or oil.

b) Operate the Chlorine Valves. Open and close all chlorine valves each day to ensure proper and complete operation. Do not use force in closing a valve. Repair or replace any faulty valves at once.

c) Check the Water System. Each month, clean the water strainers and check the pressure reducing valve for proper operation. Clean the injector nozzle and throat once a year. (Insufficient injector vacuum usually indicates that cleaning is required.) Muriatic acid may be used for cleaning mineral deposits from the injector nozzle and throat.

Symptom	Possible Cause
Flowmeter fails to indicate gas flow.	Gas supply valve closed.
	Gas supply cylinder(s) empty.
	Insufficient ejector vacuum.
	Filter in gas-inlet connection block dirty.
	Dirty flowmeter.
	Rate valve closed.
	Rate valve dirty.
	Air leakage in regulator stack.
	Vacuum regulator valve plug stuck in closed position.
Ejector vacuum is insufficient.	Ejector water supply valve closed.
	Solution line valve closed.
	Dirty strainer.
	Dirty ejector.
	Partially or fully blocked solution line.
	Ejector throat not full of water (applies only when ejector is mounted in horizontal position and back pressure is zero or less).
	Insufficient water supply flow rate and

Table 9

Troubleshooting Checklist for Solution-Feed, Vacuum-Operated Gas Chlorinators

Symptom	Possible Cause
	pressure for existing back pressure conditions.
	Drain valve leaking air.
	Insufficient booster pump discharge pressure.
Gas flow rate cannot be controlled.	Condensed gas vapor (liquid chlorine) in chlorinator.
	Dirty vacuum regulator valve.
	Air leakage in regulator stack.
	Insufficient ejector vacuum.
Maximum gas flow rate produces too low a residual in the treated process liquid.	Chlorinator capacity too low. Air leakage caused by dirty sealing surfaces.
Minimum gas flow rate produces too high a residual in the treated process liquid.	Chlorinator capacity range too high.
Flowmeter continues to indicate flow when ejector water supply valve is closed.	Condensed gas vapors (liquid chemicals) in chlorinator. Vacuum regulator valve stuck in the open position. Solution line draining due to a back pressure of zero or less. Ball stuck in flowmeter.
Water leaks from ejector into gas line.	Diaphragm backflow check valve not seating properly.

Table 9 (continued)

Troubleshooting Checklist for Solution-Feed, Vacuum-Operated Gas Chlorinators

Inspection	Action	Frequency (1), (2)
Operation maintenance	Insert a new lead gasket in the chlorine valves or tubes to cylinders or equipment.	V
Condensation on chlorine cylinders	Ventilate.	V
Chlorine leak detection	Use an unstopped bottle of aqua-ammonia to detect leaks; repair immediately.	D
Gas system	Disassemble, clean, and replace faulty parts in piping, meters, valves, and tubing.	D
Chlorine valves	Open and close valves to assure that all are operable; check stuffing boxes and repair or replace faulty valves or packing.	D
Chlorine solution tubes	Look for location of potential leaks, and for iron and manganese deposits; if iron or manganese are present, treat with a solution of hexametaphosphate in makeup water.	A
Chlorine feeder water supply	Clean water strainers and pressure reducing valves; adjust float valves and ejector capacity.	M
Hard-rubber threads, valves and parts	Disassemble or operate; use graphite grease to prevent freezing; hand tighten only—do not use tools.	Q
Vacuum relief	Clean out any obstruction.	D
Cabinet and working parts	Clean all parts where accumulation may interfere with proper operation.	W

Table 10

Maintenance Checklist for Chlorination Equipment

Inspection	Action	Frequency (1), (2)
Overhaul	Disassemble and clean all parts thoroughly; paint cabinet inside and out; examine parts and repair or replace as needed; use care in choice of cleaning agents and lubricants.	A
Direct-feed chlorinators	Use same procedures as for solution-feed machine where they apply.	

(1) D-Daily; W-Weekly; M-Monthly; Q-Quarterly; A-Annually; V-Variable, as conditions may indicate.
(2) The frequencies shown are suggested frequencies that may be modified by local command, as individual installation conditions warrant.

Table 10 (continued)

Maintenance Checklist for Chlorination Equipment

Check the Gas System. Check all piping and parts carrying chlorine gas to verify that they are operating properly. Check flexible connectors at the gas-supply containers. (To maintain a gas-tight seal, use a new lead gasket each time a valve or tube is connected, including each time an empty chlorine cylinder is replaced.) Remove and clean gas filters periodically. Check the heater each day to make sure it is warm. See that metering devices, pressure reducing and shutoff valves, hose lines, etc., work properly. Disassemble and clean when necessary, to determine the cause of the fault. At the first sign of weakening, replace any faulty parts.

- Clean the Cabinet and Critical Working Parts. Thoroughly clean the chlorinator cabinet, glass parts, flowmeter, rate valve, vacuum regulator valve, and other parts in which dirt may interfere with operations or make equipment unsightly. Clean and cover unpainted metal that is subject to corrosion with a proper protective coating.

7.4 LIQUID CHLORINE EVAPORATORS. The chlorine vessel on the inside of the evaporator and the water bath mechanism are the primary components requiring maintenance. The chlorine vessel is subject to internal corrosion from chlorine and external corrosion from the water bath. The chlorine vessel and the water bath are normally cleaned and inspected every 2 years or after evaporating 250 tons of chlorine, whichever occurs first. The sacrificial anodes in the cathodic protection system in the evaporator should be replaced when the evaporator is taken apart for cleaning and inspection. Follow these steps to clean the evaporator:

- Dismantle and remove the chlorine vessel from the evaporator.

- Flush the chlorine vessel with cold water to remove corrosion products from the inside.

- Visually inspect the interior for pitting. If pitting is severe, replace the chlorine vessel.

- Remove all flushing water and reassemble the evaporator.

- Fill the water bath and heat it to 180°F (82°C). Attach an aspirator so that a vacuum can be exerted on the inside of the chlorine vessel. The vacuum should be about 25 inches (635 mm) of mercury, and should be held for 24 hours with the water bath at 180°F (82°C), to make sure that all moisture is removed from the inside of the chlorine vessel.

7.5 HYPOCHLORITE SOLUTION FEEDERS

- Hypochlorite solutions are highly alkaline. The reaction of this alkaline material with the hardness in the makeup water results in carbonate scale deposits in the pump head and tubing, and in the solution diffuser at the point of application. Dilute (5

percent) hydrochloric (muriatic) acid solution can be pumped through the hypochlorinator to remove this scale. Be sure to flush out the hypochlorite solution with water first.

- The diaphragm continually flexes. Inspect it to make sure it operates properly.

- Check valves and seats for corrosion, hardening, swelling, scale, or foreign material that might prevent proper seating.

7.6 DRY CHEMICAL FEEDERS. Maintenance procedures for dry chemical feeders are summarized in Table 11.

7.7 TEST CALIBRATION. Make monthly calibrations to check the accuracy of feed-rate and control mechanisms. Indicate or record feed rates and amounts. The test procedures in Table 12 apply to various feeders.

7.8 SOLUTION FEEDERS. Maintenance procedures for solution feeders are summarized in Table 13.

Inspection	Action	Frequency (1), (2)
Dry feeders	Remove chemical dust accumulations; check feeder performance; check for loose bolts; clean solution tank of accumulated sediment; lubricate moving parts.	D
Drive mechanisms and moving parts	Service and lubricate.	Q
Calibration	Check feed-rate accuracy and adjust, as necessary	M
Overhaul feeders	Thoroughly clean feeder and feeding mechanism; paint; service and lubricate drive mechanisms and bearings; clean and paint solution tanks.	A
Feeders out of service	Clean; remove all chemicals from hopper and feeder mechanisms.	V
Disc feeders	Clean rotating disc and plow.	V
Oscillating feeders	Check and adjust mechanism and adjustable stroke rod.	M
Rotary gate feeders	Clean pockets of star feeder and scraper.	M
Belt-type feeders	Check vibratory mechanism, tare-balance, feeding gate, belt drive and belt; calibrate delivery.	M
Loss-in-weight feeders	Check feeder scale sensitivity, tare-weight, and null balance.	M
Screw feeders	Clean screw, check ratchet drive or variable speed drive.	M
Dust collectors		
Motors	Lubricate motors	V
Filter bags	Check condition and attachment. Securely attach sound bags; replace damaged or torn bags.	V

(1) D-Daily; M-Monthly; Q-Quarterly; A-Annually; V-Variable, as conditions may indicate.
(2) The frequencies shown are suggested frequencies that may be modified by local command, as individual installation conditions warrant.

Table 11

Maintenance Checklist for Dry Chemical Feeders

Inspection	Action	Frequency (1),(2)
Volumetric dry feeders		
Test calibration and adjust feeder	Perform the test described below for your type of volumetric dry feeder (with or without scale) and repeat several times. Average the data from several tests to compare with the rate setting, rate indicator, and recorder (if one is used). Take particular care in the timing and weighing operations. Make any adjustments necessary to bring the feed rate within ± 5 percent by weight of the rate setting.	W
Feeders not on a scale	Make at least three tests within the normal operating range of the feeder. Use a pan or other container of known weight to catch the discharge of the feeder for a definite period. Weigh the discharged material, calculate the rate of feed per hour, and compare the results with the rate setting, rate indicator, and recorder (if one is used).	W
Feeders on a platform scale	Balance the scale or record initial reading while the feeder is stopped; start the feeder and run for a definite period; rebalance the scale (i.e., record weight loss).	W

Table 12

Calibration Tests for Dry Chemical Feeders

Inspection	Action	Frequency (1),(2)
	From the difference in the two scale readings, calculate the amount fed in the measured time and then calculate the feeding rate in pounds per hour.	
Belt-type gravimetric feeders	Calibrate weekly or whenever the feeder is used for a different chemical.	W or V
Clean belt and feeder	Clean according to manufacturer's instructions	W or V
Set initial balance	Balance the scale and operate the feeder until the feeder scale beam is in full balance and indicates a proper load on the belt. If the feeder is proportionally paced, set the proportioning equipment on "manual control." Set the rate-of-feed at maximum and proceed with the following calibration test.	W or V
	Stop the feeder and make sure the scale moves freely and is in exact balance.	
	Adjust the amount of chemical on the belts by adding or removing chemical at the rear of the belt, until an exact balance is obtained.	
	Zero the belt revolution counter or weight integrator, start the feeder, and run it until a definite weight of chemical has been discharged (about two-thirds of a belt load). Then stop the feeder.	
Determine weight of material discharged	Rebalance the scale precisely. The difference between this scale reading and the one taken during the test is the weight of material discharged.	W or V

Table 12 (continued)

Calibration Tests for Dry Chemical Feeders

Inspection	Action	Frequency (1),(2)
	From the difference in the two scale readings, calculate the amount fed in the measured time and then calculate the feeding rate in pounds per hour.	
Belt-type gravimetric feeders	Calibrate weekly or whenever the feeder is used for a different chemical.	W or V
Clean belt and feeder	Clean according to manufacturer's instructions	W or V
Set initial balance	Balance the scale and operate the feeder until the feeder scale beam is in full balance and indicates a proper load on the belt. If the feeder is proportionally paced, set the proportioning equipment on "manual control." Set the rate-of-feed at maximum and proceed with the following calibration test.	W or V
	Stop the feeder and make sure the scale moves freely and is in exact balance.	
	Adjust the amount of chemical on the belts by adding or removing chemical at the rear of the belt, until an exact balance is obtained.	
	Zero the belt revolution counter or weight integrator, start the feeder, and run it until a definite weight of chemical has been discharged (about two-thirds of a belt load). Then stop the feeder.	
Determine weight of material discharged	Rebalance the scale precisely. The difference between this scale reading and the one taken during the test is the weight of material discharged.	W or V

Table 12 (continued)

Calibration Tests for Dry Chemical Feeders

Inspection	Action	Frequency (1),(2)
Compare balance and revolution counter; adjust poise if necessary	Check the calculated amount of material discharged against the number of pounds fed as indicated by the revolution counter. If the weight of the chemical delivered differs from that indicated by more than ± 1 percent, adjust the poise on the scale beam and repeat the test. (Moving the poise to a lower value reduces the loading on the belt and vice versa.) Repeat testing and adjustment until a belt loading is found that agrees with the amount fed, as indicated by the totalizer counter. Note: Some belt type gravimetric feeders may be made to discharge into a container of known weight, in which the feed rate may be checked by actually weighing the amount discharged at a definite time.	W or V
Loss-in-weight gravimetric feeder	Test calibration of this feeder is similar to the test calibration method used for the belt-type gravimetric feeder. When the feeder is empty, check the tare weight to make sure that the scale shows 0 weight. All other determinations and adjustments are similar to the belt-type gravitmetric feeder described above.	W or V

(1) W-Weekly; V-Variable, whenever new chemical is used in feeder.

(2) The frequencies shown are suggested frequencies that may be modified by local command, as individual installation conditions warrant.

Table 12 (continued)

Calibration Tests for Dry Chemical Feeders

Inspection	Action	Frequency (1), (2)
Pot feeders		
Flow through pot	Determine amount of chemical fed to ascertain if flow through pot is effective.	D
Sediment trap	Clean trap and check needle valve.	M
Chemical pot	Clean pot and orifice.	SA
Overhaul	Clean and paint pot feeder and appurtenances.	A
Differential solution feeders		
Chemical storage tank	Inspect and clean.	SA
Oil volume	Check and replenish.	SA
Pitot tubes and needle valve	Check and replace as necessary.	A
All equipment	Paint as necessary.	V
Decanter feeders		
Swing-pipe	Check to make sure it does not bind.	M
Motor ratchet, pawl, reducing gears	Check and lubricate.	SA
Overhaul	Inspect, clean, repair, and paint all parts as necessary.	A or V
Rotating dipper feeders		
Motor	Follow manufacturer's instructions	V

Table 13

Maintenance Checklist for Solution Chemical Feeders

Inspection	Action	Frequency (1), (2)
Transmission	Change oil after 100 hours of operation.	Every 100 hours
	Drain and flush, clean interior, and refill.	SA
Shaft bearings	Lubricate.	W
Drive chain	Clean, check alignment; check sprocket teeth; lubricate chain and sprockets.	M
Agitator	If used, clean and lubricate according to manufacturer's instructions.	V
Belt drives	Check alignment, tension, and inner cords of belt drives.	M
Dipper and float valve	Check dipper clearance and adjust float valve setting.	SA
Proportioning pumps		
Operator's inspection	Inspect sight feeders, rate of flow, piping, joints.	D
Feeder	Clean feeder.	W
Solution tank	Clean.	M
Linings	If cracks occur, special linings should be repaired.	A
Overhaul	Disassemble, clean, and overhaul.	A

(1) D-Daily; W-Weekly; M-Monthly; SA-Semiannually; A-Annually; V-Variable, as conditions may indicate.
(2) The frequencies shown are suggested frequencies that may be modified by local command, as individual installation conditions warrant.

Table 13 (continued)

Maintenance Checklist for Solution Chemical Feeders

Inspection	Action	Frequency (1), (2)
Complete inspection	Drain, clean, and examine interior surfaces. Repair as required. Disinfect before returning to service.	Every 3 to 5 years
Foundations, wood	Check for settlement, cracks, spalling, and exposed reinforcing; repair as necessary with 1 part cement to 1 part sand.	SA
Foundations, concrete	Check wood foundations and pads for checked, split, rotted or termite-infested members; also check for direct contact of untreated wood with soil. Repair or eliminate undesirable conditions as necessary.	SA
Concrete tanks (ground-level storage)		
Walls	Check exterior for seepage; mark spots.	SA
	Check exterior and interior for cracks, leaks, spalling, etc.	A (Spring)
	Remove loose, scaly, or crumbly concrete; patch with rich cement grout; paint grout with iron waterproofing compound.	A
	Chip out cracks and repair with cement slurry.	A
	For cracks in prestressed tanks, consult designing and/or erecting company.	A
Expansion joints	Check for leakage; check for missing filler; clean and repair as necessary.	SA

Table 14

Maintenance Checklist for Storage Facilities

Inspection	Action	Frequency (1), (2)
Roofs	Check condition; check hatches; check screens on openings. Clean as necessary.	SA
Earth embankments	Check for erosion, burrowing animals, improper drainage, and leakage through embankment. Repair as necessary. If leakage through the embankment exists, drain tank and look for cracks in tank walls or bottom.	SA
Concrete tanks (underground storage)	Check interior walls, roof, appurtenances and embankment; if leakage is evident, excavate and repair walls.	SA
Concrete tanks (elevated storage)	Check and repair.	SA or A
Steel tanks (ground-level storage)	Check for ice damage in spring; repair as necessary.	A
Walls and bottom	Examine exterior and interior for rust, corrosion products, loose scale, leaky seams, and rivets and for condition of paint.	SA
	Replace rivets or patch leaking areas, as necessary.	V
	Check painted surfaces for deterioration; paint as necessary.	SA
Roofs	Check condition, hatches, screens, manholes and paint; lock hatches; remove spider rods if corroded; repair, replace, or paint, as necessary.	SA

Table 14 (continued)

Maintenance Checklist for Storage Facilities

Inspection	Action	Frequency (1), (2)
Steel tanks (standpipes)	If problem is noted during inspection, arrange for an outside contractor to repair the steel tank.	SA
Steel tanks (underground storage)	Check tank interior, roof, and appurtenances.	SA
Steel tanks (elevated storage)	If problem is noted during inspection, arrange for an outside contractor to repair the steel tank.	SA
Tanks	Use contractor.	SA
Tower structures	Check for corrosion and for loose, missing, bowed, bent, or broken members; loose sway bracing; misalignment of tower legs; or evidence of instability. Repair as necessary.	SA
Roofs	Check obstruction and navigation lights, hoods, shields, receptacle, and fittings for missing or damaged parts or inoperation; also check lightning rods, terminals, cables, and ground connections; repair, replace, or renew; paint as necessary.	SA
Risers and heating systems	Two months before freezing weather, check riser pipe insulation and repair as necessary; also check heating system operation.	A
	One month before freezing weather, operate heating system for 8 hours; repair or adjust defective parts.	A

Table 14 (continued)

Maintenance Checklist for Storage Facilities

Inspection	Action	Frequency (1), (2)
Cathodic protection	Check flow of current; if absent, check fuses, anodes, ground wire connections and immersion of electrodes; adjust or repair as necessary. If current flow or amperage is above desired level, adjust as necessary; make certain that connections to rectifier are not reversed.	V
	Check anode condition; replace as necessary.	V
Wooden tanks		
Towers	Check for loose, missing, twisted, bowed, cracked or split pieces; also check for termite infestation, misalignment of legs, and evidence of loose sway bracing; repair and eliminate undesirable conditions; paint as necessary.	SA
Tanks	Check operating records to make certain tank is kept filled; also check structural condition of tank for soundness, evidence of leakage, and corrosion of steel bands. Check all appurtenances, ladders, roofs, screens, etc.; make any repairs or adjustments necessary.	SA
	Paint metal parts; paint timber only if necessary for appearance.	A
Pneumatic tanks	Inspect air pump and motor; check operating record of time cycle; check for air leaks, if time cycle is too short; check valve operations, particularly pressure relief valves.	Q

Table 14 (continued)

Maintenance Checklist for Storage Facilities

Inspection	Action	Frequency (1), (2)
	Check tank for signs of corrosion; take steps necessary to eliminate corrosion or protect against it.	A
Appurtenances	Check ladders, walkways, guardrails, handrails, stairways, and risers for rust, corrosion, poor anchorage, missing pieces, general deterioration or damage; replace or repair parts as necessary.	SA
Miscellaneous appurtenances	Check all electrical connections and conduits leading to tanks; make any repairs or adjustments necessary.	SA
Grounds	Check for accumulations of debris, trash, and foliage; clean the area.	SA

(1) Q-Quarterly; SA-Semiannually; A-Annually; V-Variable, as conditions may indicate.

(2) The frequencies shown are suggested frequencies that may be modified by local command, as individual installation conditions warrant.

Table 14 (continued)

Maintenance Checklist for Storage Facilities

8. TANKS AND RESERVOIRS. Water storage facilities are maintained according to the procedures listed in Table 14. The following paragraphs cover the activities involved in painting tanks: surface preparation, paint application methods, and paint selection.

8.1 PAINT SYSTEMS FOR STEEL STORAGE TANKS

8.1.1 SURFACE PREPARATION. Good surface preparation is required to ensure adequate bonding of the paint to the metal to be protected.

- If the original surface preparation was poor and the mill scale was not removed when the tank was originally painted, blast cleaning is required before repainting. If the original surface preparation was adequate, but the old paint has completely broken down, blast cleaning of areas with loose or failing paint is usually warranted. If the old paint is still in good condition, only those areas with loose paint need to be removed by wire brushing or sanding.

- All areas that have been cleaned of loose paint down to the bare metal need to be primed before rust has a chance to form. Follow Steel Structures Painting Council specifications.

8.1.2 PAINT APPLICATION METHODS

- Paint may be applied by a number of methods:

    - Brushing
    - Air spraying
    - Airless spraying
    - Roller application
    - Special methods for applying heavy coatings.

- The method best suited for application depends on the type of paint, degree of complexity of the surface being painted, paint viscosity, and other considerations, such as the amount of spray carryover with spray-painting techniques. The paint manufacturer and a professional painting contractor can advise installation personnel of the best application method for the tank being painted.

8.1.3 PAINT SELECTION

a) It is normally recommended that only paints meeting ANSI/NSF Standard 61 be used on surfaces in contact with potable water. Environmental conditions affecting the exterior of the tank and water characteristics within the tank result in varying painting system requirements. A reputable paint manufacturer can provide valuable guidance in paint selection, based on laboratory testing results and experience with painting systems on similar tasks.

b) Paint testing may be required on tanks for which a particular paint system has proven unsatisfactory. Various painting systems can be used on different areas of the tank to determine which system performs the best.

c) The thickness of the dried paint film should be specified and measured after the painting has been completed. Various paints require varying dryfilm thickness for optimum life.

d) In general, it is best to use paints that require similar surface preparation procedures for both the interior and exterior of the tank, since these procedures are usually conducted in a single operation.

e) The standard gives general information on the suitability of the paint systems under varying conditions, as well as information about surface preparation, paint-film thickness,

and procedures for applying paint. Paint systems used for painting tanks on military installations should meet or exceed the requirements established in this standard.

8.2 CATHODIC PROTECTION FOR STEEL TANKS. Design standards and specifications for cathodic and impressed current protection of steel water tanks may be found in the technical literature.

8.2.1 LIMITATIONS. Cathodic protection is limited to structures in contact with an electrolyte, such as soil or water. In steel elevated water storage tanks, only the inside surfaces of the riser and the submerged bowl can be protected. Protect the outside of the tank from atmospheric corrosion by some other means.

9. PIPELINES. Because pipes are normally buried and out of sight, pipeline maintenance is often neglected. Components of a pipeline maintenance program include inspection, leak detection and repair, flushing, pigging, slip-lining, cement mortar lining, wrapping, and cathodic protection.

9.1 PROTECTIVE COATINGS. To supplement the information provided above about corrosion protection for specific equipment, this paragraph offers general information about corrosion-inhibiting coatings.

9.2 GENERAL INFORMATION. The prevention of corrosion and surface deterioration is standard maintenance practice in waterworks. Protect all exposed surfaces, whether external or internal. Protective coatings and linings may be nonmetallic or metallic. The former includes paint, enamel, bitumen, cement, plastic, and rubber. Metallic coatings include zinc, aluminum, and lead. Other corrosion control treatments are used on metal equipment surfaces that cannot be painted. Cathodic protection is used where electrolytic corrosion occurs.

9.3 PAINT PROTECTION. Surface coating with paint is the most general method of corrosion prevention. Try to select paint to meet the existing conditions; the choice depends on whether or not the equipment or structure is indoors or outdoors.

9.4 PAINT APPLICATION. Prepare and apply surface paints according to the procedures detailed.

9.4.1 SURFACE PREPARATION. Before applying the paint, prepare all surfaces. Foreign substances on the surface interfere with the protective action of the coating. Therefore, remove loose scale, rust, dust, oil, or grease completely. For best results, paint only clean surfaces. Sandblast metal surfaces if required. Use sandpaper on a wire brush where required. Wipe off dust and clean greasy or oily surfaces with solvent cleaners. Take special precautions when removing lead-based paints.

9.4.2 PREPARATION OF PAINT. Paint should be mixed properly and screened, if necessary, to remove grit and film. Cover paint containers when not in use. Clean brushes, rollers, and spray applicators before and after use. For damp surfaces, where drying temperatures are less than 40°F (4°C), specially prepared paints are normally used.

9.5 CORROSION-PREVENTIVE COMPOUNDS. Corrosion-preventive compounds are used in pits, pump dry-wells, and damp areas. Paint does not serve this purpose. Two corrosion-preventive compounds commonly used in waterworks are shown in Table 7.

10 CHAIN DRIVES. Chain drives may be designed for slow, medium, or high speeds. Follow these steps to maintain chain drives:

10.1 CHECK OPERATION. Check general operating conditions during regular tours of duty.

10.2 CHECK CHAIN SLACK. The correct amount of slack is essential for proper chain drive operation. Unlike belts, chains should not be tight around the sprocket. When chains are tight, working parts carry a much heavier load than necessary. Too much slack is also harmful. A properly installed chain has a slight sag or looseness on the return run. All drive chains should have a tightener.

10.3 CHECK ALIGNMENT. If sprockets are not in line or if shafts are not parallel, excessive sprocket and chain wear results. To check alignment, remove the chain and place a straight edge against sides of the sprocket where no wear has occurred. Replace sprockets and chain if they are excessively worn.

10.4 LUBRICATE. Lubrication depends on the drive speeds. Refer to the manufacturer's manual.

10.4.1 SLOW-SPEED DRIVES. Because slow-speed drives are not usually enclosed, adequate lubrication is difficult. Heavy oil applied to the outside of the chain seldom reaches the working parts; in addition, the oil catches dirt and grit and becomes abrasive. Soak exposed-type chains in a recommended lubricant to restore lubricating film. Remove excess lubricant by hanging the chains up to drain. Do not lubricate chains on elevators, conveyers, or feeders that handle dirty, gritty material. Dust and grit combine with lubricants to form a cutting compound that reduces chain life. Do not lubricate underwater chains that operate in contact with considerable grit. If the water is clean, lubricate the chain with the recommended lubricant with a brush while the chain is running.

10.4.2 MEDIUM-SPEED DRIVES. Continuously lubricate medium speed drives with a drip- or sight-feed oiler. The lubricant type depends on temperature conditions.

10.4.3 HIGH-SPEED DRIVES. High-speed drives should be completely enclosed in an oil-type case and the oil maintained at proper level. Oil type depends on temperature conditions. Drain the oil and refill the case to the proper level according to the manufacturer's recommendations.

10.5 CLEAN AND INSPECT

- On enclosed types, flush the chain and enclosure with kerosene. On exposed types, remove the chain. Soak and wash it in kerosene. Clean the sprockets, install the chain, and adjust the tension.

- Note and correct abnormal conditions before serious damage results. Do not put a new chain on old sprockets. Always replace old sprockets when replacing a chain. Old, out-of-pitch sprockets cause as much chain wear in a few hours as years of normal operation.

- f) Troubleshooting. A troubleshooting checklist for chain drives is included as Table 15.

Symptom	Cause of Trouble	Remedy
Broken pins or rollers.	Shock leads or chain speed too high for pitch.	If speed-pitch relation is cause, use chain of shorter pitch.
Chain climbs sprockets.	Poor fit or severe overload.	If sprockets fit poorly, renew; make sure tightener is installed in drive chain.
Chain clings to sprockets.	Possibly incorrect or worn sprockets or heavy tacky lubricants.	Renew or reverse sprockets, or change to proper lubricant.
Chain gets stiff.	Poor alignment or excessive overload.	Correct alignment and eliminate overload.
Chain whips.	Too long centers; or high pulsating loads.	Correct either condition.
Noise.	Misalignment; improper slack, loose bolts.	Correct alignment; adjust slack; tighten bolts; reverse or renew worn chain.
Wear on chain side walls or sides of teeth.	Misalignment.	Remove chain and correct alignment.

Table 15

Troubleshooting Checklist for Chain Drives

11. TOOLS AND EQUIPMENT

11.1 TOOL INVENTORY. Effective maintenance requires that the tools needed to service the facility properly be readily available. Table 49 provides a list of suggested tools to keep at the facility for general maintenance use. Specific tools may be required for specialized equipment. Special test equipment may also be needed. Consult the manufacturer's instructions for such equipment needs.

11.1.1 TOOL CARE AND USAGE. Tools have specific uses and in general should not be used for other purposes. When the proper tool is not available, try to obtain it.

11.1.2 TOOL STORAGE. For easy retrieval, keep tools on a tool board or in a toolbox. Keep the board or box clean and, if appropriate, paint it once a year. In general, tools not in their proper places should be in use; if not, find them and return them to their proper places.

11.1.3 TOOL INSPECTION. It is a good practice to inspect tools every month. Damaged or worn tools can be replaced and edged tools (chisels, planes) kept sharp if they are regularly checked. Clean and lubricate tools before returning them to storage.

11.1.4 CAUTION AND USAGE. Do not use a screwdriver as a chisel, pliers as a wrench, or a wrench as a hammer. Do not use toothed-jaw (stillson-type) wrenches on hard rubber pipe, bolts, or nuts.

11.2 EQUIPMENT AND SUPPLIES. In addition to proper tools, a water treatment plant should be adequately supplied with the equipment, implements, and supplies that are essential to proper maintenance. Good housekeeping is a part of maintaining buildings and grounds and a part of operating equipment. Thus, in-house equipment and materials usually include housekeeping and gardening tools, equipment, and supplies. Table 17 lists the suggested implements. Table 18 lists materials and supplies to keep at the facility.

Axes, spare ax handles	"C" clamps, assorted
Awls	Cotter pin puller
Bars	Countersink, assorted for wood or metal
Crow	Cutters, wire
Wrecking	Cutters, 1/2-inch (10-mm) bolt
Bit brace and assortment of bits for wood and metal	Dies, assorted for bolt and pipe threading stocks
Blacksmith's anvil, tools, forge, and hand blower	Drills, assorted
Bolt stock and dies	1/2-inch (13-mm) electric, portable with drill press stand mount
Breast drill and assortment of drills	3/8-inch (10-mm) electric, cordless, 12-voltDrills, assorted (continued)
Calipers	1/4-inch hand drill, heavy duty
Inside and outside	1/4-inch hand drill, heavy duty
Micrometer	Drill bits
Caulking tools, water main type (assorted sizes and types)	Twist drills, high speed fractional set 1/16-inch to 1/2-inch x 64ths
Chisels	Twist drills, high speed metric set 1.0-mm to 13 mm x 0.5 mm
Assorted	Spade bits 1/4-inch to 1-1/2-inch by 1/8ths (6-mm to 40-mm)
Bull point	Masonry bits, carbide tip, for rotary drills 1/4-inch x 4-inch, 5/16-inch x 4-inch, 3/8-inch x 4-inch, 1/2-inch x 6-inch (6-mm x 100-mm, 8-mm x 100-mm, 10-mm x 100-mm, 13-mm x 150-mm)
Cape	
Cold	
Diamond point	
Round nose	
Assorted, wood	
Assorted, for air hammer	

Table 49

Suggested Tools for Water Treatment Plants

Packing hooks	Saws, rip, crosscut, compass and keyhole
Packing tools, assorted	Screwdrivers, various sizes
Pipe Cutter	Saw set
Pipe Cutter, wheels (spare)	Saw vise
Pipe taps	Scale platform
Pipe thread taps (combination), 1/4- to 2-inch (6- to 50-mm)	Screw pitch gage
Pipe threading stock with assorted dies	Scribers
Pipe tripod	Sharpening stone
Plane, smooth, bench, 7-inch (180-mm)	Shovels
Pliers	Square point, long and short handle
Assorted sizes	Round point, long and short handle
Diagonal cutting	Snake, 25-foot (8-m) spiral
Gas	Soldering iron and appurtenances
Combination slip joint	Specific tools for specialized equipment
Needlenose	Square, steel, large and small
Wrench	Stamping tools, steel, letters and numerals
Plumb bob	Straight edge, steel
Puller, gear set	Tampers
Punches, assorted sizes, center, drift	Tape, 50-foot (15-m) steel
Putty knives	Tar pot
Reamers, hand, taper, pipe expansion	Torch, blow and gasoline
Rules, 6-foot folding	

Table 49 (continued)

Suggested Tools for Water Treatment Plants

Trowels Floats, steel, and cork assorted Pointing Valve resetting tool Vises, bench and pipe, portable chain vise and stand Voltage tester Wall scrapers Washer or gasket cutter for making own washers Welding outfit with appurtenances, goggles and gloves Wire stripper	Wrenches Adjustable, various sizes Allen set screw Box wrench set Hydrant Monkey Open end, various sizes Ratchet, socket set Socket, set of various sizes Spanner Stillson, various sizes Torque Valve

Table 49 (continued)

Suggested Tools for Water Treatment Plants

Equipment	
Alemite or zerk grease guns for plant equipment	Paint sprayer
Block and tackle for 1/2-inch and 3/4-inch rope (10- to 20-mm)	Pick
Boots, rubber	Rope, 1/2-inch, 3/4-inch, 1-inch, 10-,20-, 25-mm) and sash cord.
Brooms, street, ordinary, industrial	Safety equipment: Barricades
Brushes, flue, paint and whitewash, scrubbing, wire	Electric blankets
Caulking gun for windows	First aid equipment
Chain hoist, 1-ton (1,000-kg) capacity	Gas detector
Electric drop light, explosion-proof with 200-foot (60-m) extension cord	Gas mask (chlorine)
Electric torch light, 1-1/2 or 3-volt	Harness (safety belt) with 25 feet (8 m) x of 3/4-inch (20-mm) rope
Flashlights, hand	Respirator for paint spraying, dust, etc.
Gloves, rubber and canvas work	Warning signals
Hydrometers, battery and alcohol	Squeegees, floor and window
Ladders, step, extension (20-foot)	Torches, bomb-type
Lanterns, red and white globe	Two-wheel hand trucks
Leak detectors	Vacuum cleaner
Manhole lifter	Valve key
Mop and handle	Waste cans
	Wheel barrow, rubber-tired
	Wringer buckets

Table 17

Suggested Equipment for Water Treatment Plants

Garden Implements	
Brush hooks	Lawn mower (hand or motor)
Garden trowel	Pruning shears
Hedge clippers	Rakes, wood, steel
Hoe	Scythe
Hose: Garden type (300-foot)	Sickle
Nozzle (Shut-off type)	Spade
Insect sprayer	Sprinklers
Lawn roller	

Table 17 (continued)

Suggested Equipment for Water Treatment Plants

Materials	
Alcohol or antifreeze	Chain, assorted sizes and lengths
Assortment of bolts, nuts, washers, screws, cotterpins, rivets, lock washers, cap screws, stud bolt, etc., stored in jars or cans	Chamois skins
Bricks, common	Cleaning powders, assorted
Calcium chloride (for icy pavements)	Cleaning solvents (kerosene, dry-cleaning solvent, wood alcohol)
Caulking compound	Cups, drinking
Caulking compounds, Durolite or equal, for glass house windows	Cutter wheels, spare
Caulking yarn	Disinfectants
Cement	Emery cloth, assorted grades
Cement, asbestos	Fittings, brass or iron, assorted sizes
	Flashlight batteries
	Fuses, assorted Glass

Table 51

Suggested Materials and Supplies for Water Treatment Plants

Graphite	Polish, brass
Grease, for lubrication	Putty
Hose, nipples, and clamps for garden hose, extra	Rags, clean and sterilized
Iron and boiler cement	Sand, stone or gravel
Kerosene	Sandpaper, assorted grades
Lead and lead wool	Soap
Light bulbs	Solder
Measures, oil, 1-quart and 1-pint	Soldering paste
Mops	Spare handles for hammers, hatchets and axes
Nails, assorted sizes	Spare parts for all machines and apparatus
Oakum	Sponges
Oil for lubrication	Steel wool
Oil, rust removing, penetrating	Tape, friction and electrician's
Packing for pumps	Thermometers, assorted
Paint remover	Toilet paper
Painter's drop cloths	Towels
Paints, turpentine, linseed oil, thinners, etc.	Valve grinding compound
Pipe joint compound	Waste, wiping
Pipe stock, depending on system	Wicks, for torches and lanterns
Plugs, rubber expansion	Wire, annealed No. 10 and No. 16

Table 51 (continued)

Suggested Materials and Supplies for Water Treatment Plants