Commission on Rural Water

O&M Guide for the Support of Rural Water-Wastewater Systems

$10.00

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Commission on Rural Water
Suite 2026
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Preface

This manual is intended primarily as a guide for the manager of a small rural water and wastewater system. He is the "you" referred to in the text. The book is not meant to be a textbook for engineers nor even a sufficient handbook for plant operators. Instead it focuses on the things the manager needs to know if he is to assume the responsibility for system operation. It gives him a look at management and administration, handling of equipment and personnel, estimating costs and budgeting, and supervising the technical side of water-wastewater system operation. This is the gap in the literature of rural water development which we have tried to fill. Nowhere else, we believe, is information on so many different topics pulled together in one place, written for the non-technician, and concentrated on the special problems of rural areas. For those who need more detailed technical information, a selected bibliography is included in the appendix.

A number of people associated with National Demonstration Water Project and the Commission on Rural Water have combined their efforts in producing this guide. Here are the important contributors in both research and writing:

Chapter One (Management) -- Mary E. Morgan of Conset, Inc.

Chapter Two (Water Systems) -- Michael D. Campbell and William Hunt of the National Water Well Association Research Facility.

Chapter Three (Wastewater Systems) -- Steven N. Goldstein and Walter Moberg, Jr., of Conset, Inc.

Chapter Four (Personnel) -- Campbell, Hunt and Moberg.

Chapter Five (Costs) -- Goldstein

Many others contributed their expertise to the guide in the form of comments and suggestions. They include: Jay H. Lehr, executive director, National Water Well Association; Stanley Zimmerman, executive director, National Demonstration Water Project; John E. Foster, P.E., Conset, Inc.; Heinz Russelmann, National Sanitation Foundation; Roscoe Thornbury, president, National Demonstration Water Project; Harry Conard, New Mexico Home Education Livelihood Program; Joseph H. VanDeventer and Wallace

MISCELLANEOUS DATA

Degrees C° = 5/9 (F — 32°); Degrees F° = 9/5C° + 32

Circumference of circle	$= 2\pi r = \pi D$; $\pi = 3.1416$; r = radius; D = diameter
Area of circle	$= \frac{\pi D^3}{4} = 0.7854D^2$
Area of sphere	$= \pi D^2$
Volume of sphere	$= \frac{\pi D^3}{6} = 0.5236D^3$
Volume of Cone	= area of base × ⅓ altitude
Volume of pyramid	= area of base × ⅓ altitude
Area of triangle	= ½ altitude × base
Area of trapezoid	= ½ (sum of parallel sides) × altitude
1 acre	= 43,560 ft^2
1 square mile (mi^2)	= 640 acres
1 inch (in.)	= 2.54 centimeters (cm)
1 ppm (in water)	= 1 mg per liter = 8.34 lb per mil gal
1 cubic foot (ft^3)	= 7.48 gal = 62.4 lb
1 U.S. gallon (gal)	= 8.345 lb = 3.785 liters = 231 $in.^3$ = 0.833 British Imperial gallons
1 pound (lb)	= 7000 grains = 0.4536 kg = 16 oz
1 grain per gallon	= 17.1 parts per million
1 pound per square inch (psi)	= 2.31 ft vertical head of water = 2.04 in. of mercury
1 gallon per minute (gpm)	= 1440 gal per day = 0.133 cubic feet per minute
1 cubic foot per second (cfs)	= 0.646 million gallons per day
1 million gallons per day (mgd)	= 1.547 cfs
1 million gallons per day (mgd)	= 1.547 cfs
1 horsepower hour (hp-hr)	= 0.746 kW-hr = 2546 Btu = (33,000 × 60) ft-lb = 0.065 gal of diesel oil (approx.) = 0.110 gal of gasoline (approx.) = 10-20 ft^3 of gas.
1 British thermal unit (Btu)	= quantity of heat required to raise the temperature of one pound of water one degree F
1 Btu per minute	= 17.57 watts
1 Btu	= 778 ft-lb = 0.000393 hp-hr
1 ton of refrigeration	= 228,000 Btu per 24 hr = 2000 lb of ice × 144 Btu; 1 lb of ice absorbs 144.3 Btu of heat in melting
1 pound of water evaporated from 212°F	= 0.284 kW-hr = 970.3 Btu
1 kilowatt-hour (kW-hr)	= 3412 Btu per hour
1 boiler horsepower	= 33,479 Btu per hour

Pump Efficiencies:

Deep-well displacement pumps have an efficiency of 35-40 percent. Small centrifugal pumps (10-40 gpm) have an efficiency of 20-50 percent. Larger centrifugal pumps (50-500 gpm) have an efficiency of 50-80 percent.

Small duplex, triplex, and reciprocating pumps in general have efficiencies of 30-60 percent; but large pumps have efficiencies of 60-80 percent.

METRIC EQUIVALENTS OF COMMONLY USED ENGLISH UNITS OF MEASUREMENTS

English Unit	Conversion Factors *Multiplier*	*Metric Unit*
acre	0.405	ha
acre-ft	1,233.5	m^3
BTU	0.252	kg-cal
BTU/lb	0.555	kg-cal/kg
bu	35.24	l
bu	0.03524	m^3
cfm	0.028	m^3/min
cfs	1.7	m^3/min
cfs/acre	4.2	m^3/min/ha
cfs/mi^2	0.657	m^3/min/sq km
ft^3	0.028	m^3
ft^3	28.32	l
$in.^3$	16.39	cm^3
yd^3	0.75	m^3
°F	0.555 (°F — 32)	°C
fathom	1.8	m
ft	0.3048	m
ft-c	10.764	lumen/m^2
gal	3.785	l
gpd/acre	0.00935	m^3/day/ha
gpd/ft	0.0124	m^3/day/m
gpd/ft^2	0.0408	m^3/day/m^2
gpm	0.0631	l/sec
gpm/ft^2	40.7	l/min/m^2
hp	0.7457	kw
in.	2.54	cm
lb	0.454	kg
lb/day/acre-ft	3.68	g/day/m^3
lb/1,000 ft^3	16.0	g/m^3
lb/acre/day	0.112	g/day/m^2
lb/day/ft^3	16	kg/day/m^3
lb/day/ft^2	4,880	g/day/m^2
lb/mil gal	0.12	g/m^3
mgd	3,785	m^3/day
mgd/acre	9,360	m^3/day/ha
mile	1.61	km
ppb	10^{-3}	mg/l
pcf	16.02	kg/m^3
psf	4.88	kg/m^2
psi	0.0703	kg/cm^2
sq ft	0.0929	m^2
sq ft/ft^3	3.29	m^2/m^3
sq in.	6.452	cm^2
sq miles	2.590	km^2
tons (short)	907	kg
tons (short)	0.907	metric tons

Chapter 2

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OPERATING AND MAINTAINING WATER SYSTEMS

A key test of a general manager is how well he makes use of technicians and experts. If you have hired well-trained operators and are using them wisely, routine preventive and corrective maintenance should present no problems. When really serious malfunctions occur, you will want to call in engineers or other technical experts to advise you.

In either case, you must be able to speak the technicians' language well enough to translate their advice into decisions and policies. A technician who wants a new piece of equipment is not expected to know all the cost implications, but you are. At the same time, you must know the technical considerations so you can weigh them against the cost factors. You must know in general what the technician knows in detail. The technical material in this chapter is discussed in that light. As you read the chapter, imagine yourself as either the water plant operator or as someone looking over his shoulder as he performs his duties.

UNDERSTANDING THE SYSTEM

A "water system" in the physical sense is simply the various structures, pieces of equipment, and supplies which connect households and businesses to a water supply.

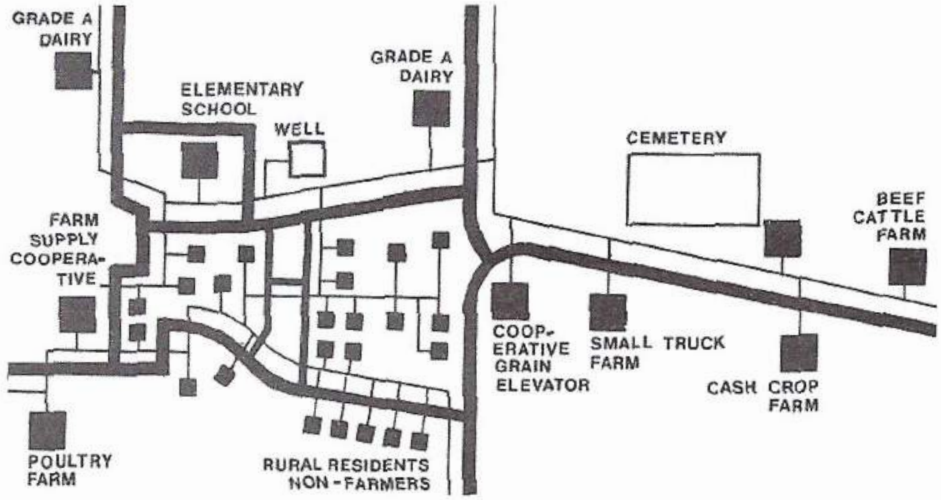
The two chief water supply sources in the United States are surface water (rivers, lakes, creeks) and ground water (undergound water-bearing strata called aquifers). A water company may purchase and redistribute treated water from another system, but this water also comes from a surface or ground source. Most large cities and many small ones are served by surface waters, while ground water predominates in rural areas. The latter accounts for 90 percent of the potential supply of fresh drinking water in the country.

A Typical Water System

This is not the place to discuss in detail the proper methods for designing and constructing water systems. If you feel the need for greater knowledge about this, consult the references in the Appendix.* We will instead

*Particularly Michael D. Campbell and Jay H. Lehr, Rural Water Systems Planning and Engineering Guide (Washington: Commission on Rural Water, 1972).

Figure 3
Typical Rural Water System



limit ourselves here to a brief discussion of a typical system and its major components.

1. System Overview. The most common water system for the small rural community is the single-well, hydro-pneumatic tank combination. Here, a single pump both extracts water from the well and imparts the required pressure for distribution. The pump may be submerged deep in the well casing -- as is most common -- or may be at ground level for shallow installations. If no storage were provided, the pump would be required to run continuously to provide pressure to the distribution system. To avoid this, a hydro-pneumatic tank is usually installed to provide storage capacity which allows the pump to operate on reasonable "on" and "off" cycles.

The hydro-pneumatic (water-air) tank is a long, cylindrical steel pressure tank, usually installed above ground, into which the well pump discharges. The upper part of the tank is filled with air under pressure, called the "air pad." As the well pump fills the lower part of the tank with water, the air is compressed in the upper part. After the pump stops running, the air pad exerts continuous pressure on the water, forcing it into the distribution system under fairly constant pressure. To maintain the proper ratio of air and water in the tank, it is good practice to provide a small motor-driven air compressor which, in combination with an automatic sensor mounted through the tank wall, automatically maintains the air pad at the proper volume and pressure.

In addition to the air pad control, the tank is also provided with an adjustable pressure switch which electrically starts and stops the well pump to maintain water volume and pressure in the tank. This is commonly adjusted to start the pump when the water lowers to one third of the tank volume, and to stop it when it restores water level to the two-thirds volume point. A sight glass is mounted on the end of the tank to provide visual observation of the water-level changes and to aid in setting the controls (or a gauge may be used).

The hydro-pneumatic tank may in some cases be replaced by some type of elevated storage (ground storage tank, elevated tank, or standpipe) somewhere along the distribution system. An unpressurized, elevated tank has the advantage of providing more storage and eliminating the air pad controls. But it also has numerous disadvantages -- higher initial cost, higher maintenance costs, and increased probability of contamination.

Whatever the storage method, it may be necessary to disinfect the water, either because the water is contaminated as it comes from the well or because it becomes contaminated in the distribution system, including the furthest extremities.

In either case, the disinfectant is usually applied at the well house by pumping a liquid solution of disinfectant into the water leaving the well before it enters the storage tank. The disinfectant pump rums simultaneously with the well pump. Two cocks are required so that the water may be sampled before and after treatment. If water softening treatment is required, the well water is pumped through tanks containing the softening chemicals.

If additional treatment is required to remove iron, or to remove or neutralize other chemicals, this will be done in unpressurized, ground-level tanks where the proper chemicals are applied and solids are allowed to settle. This may be followed by filtering to further remove solids. The treated water is then pressurized by a "supply" pump which discharges either into the hydro-pneumatic or elevated tank. In small systems, the entire installation, except tanks, is enclosed in an enlarged well house and is largely automatic.

If the raw water source is a surface supply, the system is only slightly different and most of the preceding discussion still applies. An intake structure is installed at the lake, river, or spring. A pump is installed to pump the water. If the source is at a high elevation, a pump may not be required, and the water may be delivered to the treatment units as needed through a "butterfly" valve which maintains the required flow rate. The treatment required may be somewhat different, since raw surface water is usually higher in bacterial contamination and total dissolved solids, but lower in mineral contamination, than ground water.

2. System Components. A water system may be thought of as a series of interconnected parts or components. To deliver water for residential and commercial purposes, you must:

(a) Tap a water source and bring it to treatment facilities (collection)

(b) Treat the water for impurities as necessary (treatment)

(c) Store it where it is ready for distribution to specific connections (storage and distribution).

Although each phase of operation and maintenance (start-up, steady-state, and troubleshooting) will be discussed here in terms of these three system components, it is important to remember that it is system output that counts in the end, not the performance of particular components.

The purposes of the water system are: (1) to deliver water to users in quantities sufficient for their needs, (2) to deliver water of acceptable quality from the standpoint of taste and purity, and (3) to do both as efficiently as possible in terms of time and money. When any of these objectives is not being realized, there is a system malfunction which must be corrected.

When a malfunction occurs, it can be in any component of the system. The water source may have become contaminated, the pump may be clogged with sand, an electric motor may have blown out, a piece of treatment equipment may not be working, a storage tank may have a faulty valve, pipes may be leaking, or a meter may need replacing. When the trouble is found and corrected, the system returns to steady-state.

Gathering Information

In order to perform either preventive or corrective maintenance, you and your operators need information on how the parts of the system are functioning.

The principal ways of gathering this information are: (1) measuring and recording, (2) sampling and testing, (3) systematic monitoring, and (4) looking and listening.

1. Measuring and Recording. Since a decline in the volume of water being produced can be one of your most serious problems, it should be regularly measured. Watch the water gauge as you watch the gas gauge while driving a car.

With a ground water supply, it is a good idea to keep a record of the well yield, pumping water level and duration of pumping, and static water level. A pressure gauge is most commonly used to determine the static and pumping water levels of a well. But whatever method is used, the measurement should be accurate because water levels, along with discharge rates, are the basis for determining the specific capacity of the system.

All measurements should be recorded over a period of time sufficient to pinpoint any long-run fluctuations in system output. The manager should review these reports regularly and complete records should be kept in the office. Be sure to compare produced-water to billed-water in order to detect any system losses.

2. Sampling and Testing. When the water supply has been developed, a series of samples should be collected to provide background data. Thereafter, assuming it is a ground water source, the raw water should be checked about once a year. If surface water is used, this may be increased to semi-annually or quarterly, depending on the source. The necessary tests should be done by a commercial laboratory or by a state, county, or other agency laboratory. If the water is to be treated, more frequent tests will be necessary, since test results

will determine the kind and amounts of treatment agents to be used.

As for quality control of treated water, the following factors will have to be checked from time to time: disinfectant effectiveness (chlorine residual), presence of bacteria (coliform count), acidity and alkalinity (pH), iron and manganese (when treating for these), and calcium carbonate (when treating for hardness).

3. Systematic Monitoring. In many water plants today, a variety of informational, decision-making, and control functions can be performed by mechanical or electrical devices. These range from turning a pump on and off under pre-set conditions of pressure or water level, to operating a complete system from a distant location. Automation and telemetry (measurement by remote control) can save time and money. However, they are usually impractical for a small water system. At this point, simply keep in mind that there are many things, even in a small system, which need not be done by hand. When you think some automation might help you, ask the manufacturers of control equipment for assistance. The telephone company, which often leases transmission lines for telemetry systems, may also be able to give advice.

4. Looking and Listening. Water system operators should keep their eyes and ears open for signs of malfunction. If water is standing in the well house, something is amiss, whatever the gauges may say. An electric motor may appear to be functioning well, but if it doesn't sound right to the operator, it should be checked. Observation, of course, is only a supplement to the more scientific methods of detection, but if the detection methods themselves misfire, the operator should not be helpless. Keep in mind the old story about the man who settled into his seat for a computerized airplane flight and heard the following announcement: "This is a recording. This flight is completely computerized and not subject to human error. Nothing can go wrong, go wrong, go wrong...."

THE START-UP PHASE

Start-up preparation in a water system is basically a process of checking all facilities to see that they have been properly installed, and all equipment and supplies to insure that they are the proper type and are in good working order. You also will need to do some testing to establish benchmarks for the system, in terms of water quality and quantity. Your examination and tests should cover all parts of the system.

Collection

1. See that the water source is well protected. This is important whether you have a ground or surface source. Your company is well-advised to acquire land ownership to protect the well field or reservoir, and issue rules for incompatible uses. The lands should be posted and policed to insure that no violations of these rules occur.

If you have a ground water source, state regulations will normally require that a concrete pad be constructed around the well casing above ground level to protect the well from contamination by surface waters. This concrete pad is used as a base upon which to build a weather-proof well house, which protects the well and provides an enclosure for the electrical gear and controls.

The hydro-pneumatic tank is usually mounted on concrete piers, with the end containing the controls, sight glass, and pump-connecting piping, protruding into the well house for protection and easy access. The remainder of the tank is, of course, exposed to the elements and must be protected from freezing in severe climates. The roof of the well house would normally include a large removable hatch centered over the well to permit removal of the well pump and drop pipe for servicing or replacement.

To reduce vandalism, the well house should be sturdily constructed and kept locked at all times. There should be no holes in the walls or floor if you want to protect the health as well as the peace of mind of your operators. A cool well house is particularly attractive to snakes.

2. Check for proper construction. If any errors or misjudgments have been made in the design or construction phase, you need to uncover them at the start. Familiarize yourself with the engineering drawings and see if they have been followed. You should conduct a visual inspection of all accessible portions

of the system. The engineer, contractor, your operators, and possibly a manufacturer's representative should accompany you. All operating equipment should be checked for initial maintenance and necessary adjustments.

If a deep well is your water source, obtain and study all well construction data such as well-drilling logs, screen analysis, water quality analysis, and pump and recovery tests. You want to make sure that the well itself does not offer any avenues for contamination. Any break or other opening in the well casing, or between the casing and the pump base, is a potential source of trouble. The area immediately surrounding the casing frequently offers a passage for contaminants if there is an improperly constructed gravel pack. Since the well is in the ground, you will not be able to see all mistakes, but any you find should be promptly corrected. Your intention is not to second-guess the engineers, but only to confirm the fact that the well site selection and well construction were in accordance with sound engineering standards.

3. Verify that your water meets accepted quality standards. The Drinking Water Standards (DWS) issued by the U.S. Public Health Service in 1962 have been widely followed at the state level. The standards have now become the responsibility of the U.S. Environmental Protection Agency which is preparing a revision, partly in anticipation of bills on safe drinking water pending before the U. S. Congress. You should obtain a copy of the most recent standards from EPA headquarters in Washington, or one of its regional offices, as soon as possible because EPA standards will set minimum requirements for state standards.

The present Drinking Water Standards prescribe minimum standards in each of the three areas which determine water quality -- physical quality, bacterial content, and chemical content. However, there are two sets of standards: a list of mandatory limits when use of the water for drinking is considered hazardous if exceeded, and recommended limits where better treatment is suggested. Here is a partial list:

Table 6
Drinking Water Standards:
Recommended

Partial List of Bacteriological, Chemical, and Physical Constituent Concentration Limits Taken from the 1972 U.S. Public lic Health Service Drinking Water Standards

Table 6 (Continued)

RECOMMENDED LIMITS

If the concentration of any of these constituents are exceeded, a more suitable supply of treatment should be sought

Constituent	Limits
Alkyl Benzene Sulfonate (Measured as methylene-blue active substances)	0.5 mg/l
Arsenic	0.01 mg/l*
Boron	1.0 mg/l**
Chloride	250 mg/l
Color	15 Units
Copper	1.0 mg/l
Carbon-Chloroform Extract (CCE)	0.200 mg/l
Cyanide	0.01 mg/l
Fluoride	
Temp. (Ann.Avg.Max.Day, 5 years or more)	
50.0-53.7	1.7 mg/l
53.8-58.3	1.5 mg/l
58.4-63.8	1.3 mg/l
63.9-70.6	1.2 mg/l
70.6-79.2	1.0 mg/l
79.3-90.5	0.8 mg/l
Iron	0.3 mg/l
Manganese	0.05 mg/l
Nitrate	45 mg/l
Radium-226	3 c/l (pCi/l)***
Strontium-90	10 c/l (pCi/l)***
Sulfate	250 mg/l
Total Dissolved Solids (TDS)	500 mg/l
Turbidity	
Untreated	5 Units
Treated by more than disinfection	1 Unit
Zinc	5 mg/l

Table 7
Drinking Water Standards: Mandatory

If the concentration of any of these constituents are exceeded, the further use of this water for drinking and culinary purposes should be evaluated by the appropriate health authority because water of this quality represents a hazard to the health of consumers.

Constituent	Limits
Arsenic	0.05 mg/l
Barium	1.0 mg/l
Boron	5.0 mg/l**
Cadmium	0.01 mg/l
Chromium (hexavalent)	
Coliform organisms (Measured by membrane filter technique)	Fails std. if: a) Arithmetic average of samples collected greater than 1 per 100 ml b) Two or more samples (5% or more if more than 20 examined) contain densities more than 4/100 ml

Table 7 (Continued)

Cyanide	0.2 mg/l
Fluoride	
Temp. (Ann.Avg.Max.Day, 5 years or more)	
50.0-53.7	2.4 mg/l
53.8-58.3	2.2 mg/l
58.4-63.8	2.0 mg/l
63.9-70.6	1.8 mg/l
70.7-79.2	1.6 mg/l
79.3-90.5	1.4 mg/l
Gross Beta activity (in the absence of β or Sr-90)	1.000 c/l (pCi/l)***
Lead	0.05 mg/l
Selenium	0.01 mg/l
Silver	0.05 mg/l

*Although the recommended arsenic concentration is 0.01 mg/l, because of interferences in some waters, the concentration of arsenic was only determined to be less than 0.03 mg/l. For the purposes of this study, these waters were considered not to exceed the recommended standard.
**Proposed for inclusion in the Drinking Water Standards.
***If these limits are exceeded, refer to Section 6.2

It is impractical to have water analyzed for each parameter listed, and the manager should not feel the responsibility for doing so. The decision regarding the analysis will be made by the consulting engineer who designs the system and the state agency having jurisdiction for approval. Perhaps the list will be limited to the most common constituents: alkyl benzene sulfonate, chloride, color, fluoride, iron, manganese, nitrate, sulfate, total dissolved solids, turbidity, and coliform organisms.

The physical quality of the water is its appearance to the consumer. It should be clear and low in color concentration. It should be odorless and free of any substances which may produce odors when chlorine is added or the water is used for cooking. The temperature of the water should not be too high. Ground water temperature ranges from 40 to 55 degrees Fahrenheit and surface waters from 40 to 80.

The bacterial content of water is extremely important because it is so closely related to disease. Drinking water should always be free of harmful or pathogenic bacteria. Instead of expensive testing for specific bacteria, the common practice today is to test for the presence of coliform bacteria as an index of bacterial pollution. Coliform bacteria are commonly found in the intestines of warm-blooded animals (including man), and it is present in abundance when pathogenic organisms or bacteria are found. Therefore, the presence of coliform indicates either the presence, potential presence, or possibility of future presence of harmful organisms in a water supply.

The recommended standards for drinking water delivered to the consumer are roughly equivalent to restricting the coliform concentration to not more than one organism for each 100 milliliters of water (about half a cup). Water at its source, especially a surface source, will nearly always contain coliform, but disinfection should reduce them to the required standard. Coliform is usually not present in drilled wells, unless they are contaminated, but chlorination is still desirable

Most water, especially ground water, will contain some chemicals. Some of them cause illness and, if the water supply includes more than the minimum amount, the water should not be used. Other chemicals are not necessarily poisonous, but they may have some adverse effects on health -- or, at best, give the water a bad taste.

4. Determine the Capacity of the System. The amount of water that can be obtained from any well depends on three main factors: character of the aquifer, well type and construction, and characteristics of the pumping equipment.

A common way to describe well yield is to express its discharge capacity in relation to its drawdown (the distance, in feet, the static water level of the aquifer is lowered from its static level by pumping). This relationship is called specific capacity and is expressed in gallons-per-minute (gpm) per foot of drawdown. The specific capacity may range from less than one gpm per foot of drawdown for a poorly developed well, or one in a tight aquifer, to more than 100 gpm per foot of drawdown for a properly developed well in a highly permeable aquifer.

A pumping test should be made after the well has been developed to determine its yield and drawdown. The pumping test should include the determination of:

(1) The volume of water pumped per minute or hour

(2) The depth to the pumping level as deter-

mined over a period of time at one or more constant rates of pumpage

(3) The recovery of the water level after pumping is stopped

(4) The length of time the well is pumped at each rate during the test procedure.

The pumping test must be accurate because the data you obtain will be used to determine if capacity has declined or increased.

5. Check All Transmission Equipment. Since the water will be transmitted by electrically driven pumps, they must be selected and installed with care. The manager should recheck them during start-up. They are highly specialized pieces of equipment which are designed to accomplish a specific job within very narrow limits. They perform adequately only within these limits. Since there are hundreds of items on the market, the trick is to make sure the ones selected fit your intended purpose.

The key factors in selecting a well pump are size of the casing, limits of total lift required, capacity required and available, system pressure required, and total depth and pumping level.

This information can be used to compute a system head curve for your installation. Pump manufacturers publish a characteristic pump curve for each of their products. By comparing the system head curve with various pump curves, the proper match will occur -- and the correct pump can be chosen. Since pumps are matched to motors by the manufacturer, the selection of the pump according to system requirements will dictate the type, horsepower, and power requirements of the motor.

There is a possibility that more than one pump could fit your purpose. They are basically classified as:

(a) Positive Displacement Pumps -- those that deliver a constant quantity of water, no matter what the total lift, within a set range. This includes piston pumps, rotary pumps, and screw or squeeze pumps.

(b) Variable Displacement Pumps -- the capacity decreases as the lift increases. This includes centrifugal pumps, jet pumps, and air lift pumps.

Your job at this point is simply to recheck the criteria that were used in selecting pumps and motors to insure that your particular system has the right items.

When the power lines from either a commercial source or an appropriate generator are hooked up, operate the system to bring discharge and line pressures up to system requirements. Check the pump for proper rotation. If the system is such that a higher capacity pump than is actually required for the source had to be used, the appropriate throttling device (fluid level control, flow valve, or automatic back pressure regulator) must be put on line prior to the first run and set as quickly as possible to prevent aquifer damage. During this run, such items as static water level, pumping water level, discharge rate, pump settings, etc., should be entered in the operational log.

Treatment

The equipment and supplies necessary for starting up the treatment process will vary with the kind of treatment you need. The most common method of water treatment consists of adding chemicals to the water to kill pathogenic organisms or neutralize other harmful chemicals. A chlorine solution (more about this later) is the usual chemical used, and it is introduced into the water by a mechanical device called a chlorinator or a hypochlorinator. Chemicals are also used to bring non-settleable particles together in larger masses for easier removal (coagulation), to soften water, or to improve water from a dental standpoint (fluoridation). Additional treatment processes include sedimentation and filtration (after coagulation), and these require appropriate basins.

The start-up operations for the treatment part of the system follow the pattern common where any mechanical devices are used. Devices such as chemical feeders should be inspected for possible damage when received and then checked for proper installation and initial maintenance of moving parts.

They should then be adjusted in accordance with the manufacturer's instructions to provide the proper quantities of chemicals. After a check to assure that all electrical or other power hookups have been made, the equipment should be test-run. This is also the time to make certain that the right amounts of chemicals are on hand and properly stored -- protected from heat, cold, and moisture. It is a good idea to remind your operators about the correct methods for reloading and recharging the mechanical feeders as well as the general handling of chemicals. Check your inventory of spare parts, special tools, operating or instruction manuals, and test equipment.

Storage and Distribution

The final step in the start-up phase is to prepare to distribute the water you have treated. The system design should have specified the storage tanks and distribution lines necessary for your system, and these should be in place.

In a few cases, distribution can be accomplished with a gravity-flow system, eliminating or reducing many operating problems and the need for costly pumping facilities. In the great majority of systems, however, the supply of water must be pumped into the distribution system, with the pumps selected on the basis of whether hydropneumatic, ground level, or elevated storage is to be used -- as well as the storage required, the yield of the water source, and the water demand. Treatment plant capacity will also be a factor.

The four principal tasks, prior to beginning distribution, are (1) inspection of equipment, (2) hydrostatic and leakage tests, (3) disinfection of mains, and (4) water meter checks and tests.

1. Inspection of Equipment. The mains and fittings should have been examined prior to burial for any obvious defects or poorly aligned connections. In addition, valves should be checked to make sure that they operate correctly and are in an open position to insure proper pressure throughout the system. You should compare the actual physical facilities to the as-built drawings.

2. Hydrostatic and Leakage Tests. Hydrostatic pressure tests and tests for leakage should be made by the installing contractor under the supervision of the consulting engineer prior to, and as a condition of, accep-

tance of the system. Provisions for leak testing should be written into initial contracts with all parties. To make a leak test under pressure, each valved section of the main should be slowly filled with water, then air should be expelled from the line, through hydrants or taps installed at higher elevations within the system network. The pressure test is usually made by means of a pump and test gauge and at a test pressure of at least 50 percent greater than the working pressure in the line. The test pressure should be maintained for at least one hour and an examination should be made of the line for visible leaks or pipe movement. Any obvious defects should be repaired before the leakage test is made.

The leakage test should be conducted after the pressure test is completed. These tests are conducted by measuring, through a calibrated meter, the amount of water which enters the test section under normal working pressures for a period of at least two hours. The leakage during this test, based on a 24-hour scale, should not exceed an amount computed on the basis of length of pipe one inch and over in diameter and on 10 gallons per mile per diameter inch of pipe. Thus allowable leakage on four miles of 3-inch pipe, three miles of 2-inch pipe, and one mile of 1-inch pipe would be:

10 x 4 x 3 =	120
10 x 3 x 2 =	60
10 x 1 x 1 =	10
Total	190 gallons (per 24 hours)

Calculate allowable leakage on a shorter test by using an appropriate portion of the 24-hour valve.

<u>3. Disinfection of Mains</u>. Although precautions should have been taken during installation to keep the interior of pipes (and tanks) free from debris and contamination, flushing and disinfection of the mains is necessary to insure a safe water supply. Precautions during installation include "swabbing" the pipe before it is laid and using "bulkheads" during non-working hours to prevent animals, insects, or surface drainage from entering the pipe. Nevertheless, a good flushing of the line under

pressure is needed to remove any dirt and debris.

Solutions of calcium (or sodium) hypochlorite, or chlorinated lime, are commonly used to disinfect mains. Calcium hypochlorite is particularly safe and easy to apply, but care should be taken that the chemical does not lose any of its potency through prolonged exposure to the atmosphere. The dry hypochlorite is mixed with water in the proportion necessary to provide a one percent chlorine solution. This is applied at the end of the main where the flow of water can distribute it throughout the length of pipe. The chlorine dose should be sufficient to produce a 10 mg/l (milligrams per liter) residual at the extreme end of the main after standing 24 hours. A 25-mg/l chlorine solution will usually produce this, although more may be required under some conditions. After disinfection has been completed, the treated water should be thoroughly flushed from the line and then tested for coliform. Pipelines may also be disinfected with chlorine gas -- liquid chlorine becoming gaseous when released from the cylinder. But this form of chlorine is dangerous and should be avoided, except when done on a very large system by a skilled contractor. It is an inappropriate method for small rural systems.

4. Water Meter Checks and Tests. The meter is the last part of the system the water touches before reaching the consumer, and it is likely

You should check your meters before you begin operation and periodically thereafter. The main meter -- this one is located in the pump house of a small system in the NDWP Roanoke project -- is especially important since it allows you to track total water usage.

to be the most important part to him since it determines the amount of his bill. Make sure that you have the proper meters and that they are accurate before you begin charging the customer.

The two basic types of water meters used for customer service are positive-displacement meters and current meters. (Proportional and compound meters are variations of these.) Positive-displacement meters measure water use by filling and emptying a chamber, and registering the number of such cycles. The principal advantage of these meters is that they are only slightly affected by water quality, mainly fine sediment content, and will over-register only a small amount. Their accuracy is good unless they are clogged by large amounts of foreign matter.

In current meters, the water strikes a bladed wheel and the amount used is measured by the number of rotations of the wheel. However, current meters are not accurate at low rates of flow since the water must be moving at a certain velocity before the wheel will start to rotate. Moreover, these meters tend to over-register when the blades of the wheel become clogged with sediment or other foreign material, since the smaller wheel openings mean that the water must pass through at a higher velocity.

Meters should be checked for accuracy and head loss, either by consulting reliable manufacturers' data or by tests on the scene. AWWA has developed standards in both these areas. Accuracy should be checked at various rates of flow. For 5/8-inch meters, the flow limits are 1 gpm to 20 gpm. Between these limits, and at various rates of flow, run a known quantity of water through the meter and see if it registers properly. Remember that the customer may be afraid that you have your thumb on the scales, and you should be able to give some assurances (such as by an actual test) beyond the word of the manufacturer.

Meter head loss is the water pressure lost in overcoming friction through the meter. Loss of head may be expressed in feet of water or similar terms, but it is usually clearer to express it in pounds per square inch (psi). In testing for head loss, the meter may be placed on a bench and the gauges connected in such a way that they measure the pressure as the water enters the meter and as it leaves. Head loss in a 5/8-inch displacement meter should not exceed 15 psi at a flow rate of 20 gpm. Finally, keep careful records on all meters -- serial number, location, condition, date installed, date reconditioned, etc.

As in general management, you should treat the early months of operation by the technical side of the system as essentially a shakedown cruise, making adjustments as necessary before you settle into the routine of operation and maintenance. You should be busy in the field during this period watching the plant and equipment perform, and satisfying yourself that the operators are in control of the situation.

THE STEADY-STATE PHASE

It is a familiar adage that all ventures look their best at the beginning, and your water system venture is no exception. The plant and equipment are clean and shiny and everything operates smoothly -- assuming that you did a proper job of start-up. The shine will soon disappear, but it is up to you to see that the smooth operation does not disappear with it! In all parts of the system, routine maintenance will be necessary.

Collection

Surface water can be tapped indefinitely as a source, assuming, of course, that the source which feeds the lake or river itself does not dry up. In arid regions of the country, or in periods of general drought, the water source might indeed become depleted. This is not a support problem, however, because there is no maintenance that can be performed on a receding lake or river, apart from pumping less water to conserve the dwindling supply. Of course, observations and measurement may help you anticipate shortages and be a basis for water use restrictions.

On the other hand, if it is ground water that is being retrieved, routine maintenance does make a difference in this part of the system. A water well has a definite life span and, in a sense, it begins to "die" the moment it is "born." Wells in consolidated formations ("rock wells") should live 50 years or more, while those constructed in sand and gravel last about 25 years. Along with local geology and care in construction, good maintenance may determine how close a well comes to its normal life expectancy. Your biggest problems will be maintaining well yield, fighting corrosion, preventing sand in the pump, and maintaining electric motors.

1. Maintaining Well Yield. There are several reasons why the yield of a well (specific capacity) may decrease as the well is used over a period of time:

(a) The rate of pumping may be reduced by pump wear or by a change in piping which increases the dynamic head (the force driving the water into the well).

(b) Drought may reduce the recharge source, lowering the static water level and thus reducing the available drawdown.

(c) The pumping level for one well may be lowered because of interference from nearby wells.

(d) The water-bearing formation just outside the well -- like the opening in the intake portion of the well, the well screen, or the slotted pipe -- may become clogged. This is usually called incrustation.

(e) Corrosion may cause the screen or casing to fail.

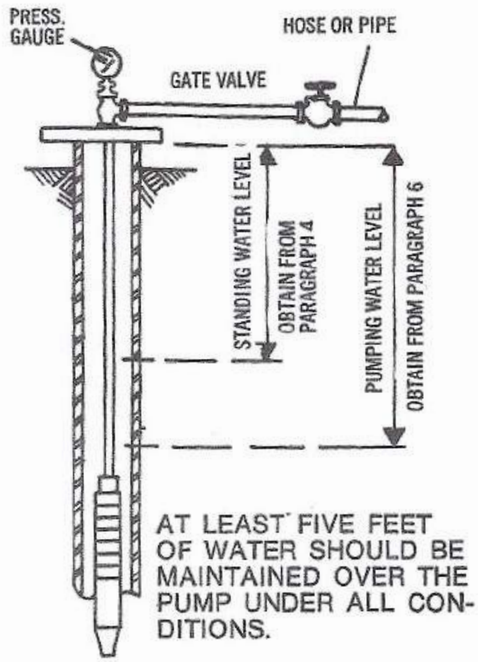
(f) There may be sand infiltration due to excessive pumping.

In addition to regular monitoring and control of the amount of water being pumped, you should conduct periodic pump tests in an effort to detect any changes in specific capacity.

The water level in the well under either static or dynamic (pumping) conditions can be readily determined by standard depth indicators, if they have been installed. In their absence, static and pumping water levels can be tested via a pressure gauge. Remember that the difference between the two is the drawdown, and when this is related to gallons-per-minute, you have the specific capacity.

With a submersible pump, the water level can be determined without the use of a water level tester and it will be accurate within five to eight feet when tested with a new pump. Figure 4 shows the basic arrangement:

Figure 4 Determining Standing and Pumping Water Levels



(1) Start the pump and, with the valve partially open as in installation, gradually develop the well to duty capacity.

(2) When the water is clear and clean, stop operation and allow the well to recover to its static water level.

(3) Restart the pump. As soon as the water starts to flow, close the valve tightly and read the pressure gauge. It normally reads in pounds per square inch (psi).

(4) To convert to feet, multiply the gauge reading in psi by 2.3 and subtract the total from the closed valve shut-off head rating in feet which is shown on the pump curve for that particular unit. This will give the depth in feet to the standing water level below the center of the gauge.

(5) Open the valve and allow the pump to flow until the reduced pressure on the gauge, or pump discharge, is steady. Then close the valve tightly and immediately read the pressure gauge again.

(6) Multiply the reading by 2.3 and subtract the total from the closed valve head rating in feet for the unit. The result will be the pumping water level, in feet below the center of the gauge.

In this test, if the valve is left closed, the pressure reading will increase as the well recovers and the water level in the well rises. At complete recovery, the pressure reading should be obtained to check the standing water level.

2. Fighting Corrosion. Corrosion is the destruction of metals by an acid environment. It occurs because of the chemical or electro-

chemical reaction of the metal with its surroundings -- air, water, soil. Sometimes an action similar to electroplating (called electrolysis) takes place where an electrical current in the soil, either induced or natural, carries particles of metal from one piece to another. Corrosion is characterized by pitting, etching or cracking, or a build-up of scale or rust. It is a constant problem for water systems because most natural waters are acidic and there is metal throughout the system -- well casing, pumping equipment, tanks, and pipes. You should therefore have a regular program for spotting and fighting corrosion.

The program should begin before the facilities are in place because corrosion-resistant materials should be used where possible. For example, most plastic pipe is not only less expensive than cast iron, but is not subject to corrosion. (It cannot be used for the well-casing, however.) If cast iron is used, the pipe should have an exterior coating of coal tar, cement, or appropriate enamel or vinyl-based paints. Likewise well screens should be selected with a view to whether they will be handling water which is corrosive, encrusting, or a combination of the two.

The second step is to check regularly for conditions which may lead to or be evidence of corrosion. Check all pipe during cleaning or repair. Soil condition is also a factor. Run-off from de-icing salts, for example, will increase moisture content and the salinity of the soil, thus making the soil more conductive and increasing corrosion potential. Colored photographic reference standards are available to evaluate the degree of rusting on painted metal surfaces. In general, you should be concerned when rust content exceeds one percent.

Third, take anti-corrosion measures as necessary. These vary depending upon the cause of the corrosion. There are three types:

(1) Reaction of solution on metal. Waters of low pH (acidic) attack metal because carbon dioxide reacts with the water to form carbonic acid. To combat this, do one of the following:

(a) Adjust pH to 8.2 or above, thus increasing the presence of carbon dioxide and increasing the alkalinity of the solution. The hardness of the water should be within the range of 25 to 50 parts per million.

(b) Adjust pH to between 6.9 and 7.4 and add approximately 2.0 parts per million of hexametaphosphate to provide a protective coating.

(2) Galvanic corrosion, or corrosion between dissimilar metals. When two different metals are connected together and put in solution, an electrochemical voltage is created to the extent that an electric current or electron movement will occur (similar to a car battery). The flow of electrons will be from one metal to the other. Note the galvanic series at the left. The metal nearest the top of the series has the highest potential and electrons flow from it -- thus causing it to corrode -- to the metal nearer the bottom of the list. This metal has a lower potential and usually remains free from attack. The metal of higher potential is called an <u>anode</u> and the metal of lower potential a <u>cathode</u>. For example, if iron and brass were connected, the iron (anode) would corrode as electrons flowed to the brass (cathode). Greater electrical potential, or separation in the galvanic series, speeds up corrosion. Thus zinc corrodes much faster when coupled with brass than when coupled with iron.

Different areas on the same metal show the same differences in electrical potential as different metals do. This is due to variations in composition, surface finish, and hardness from point to point. When the surface of, say, a steel pipe is wetted, we have the elements of the galvanic cell. Where the current leaves the pipe (the anode area), the pipe is corroded; where it returns to the pipe (the cathode area), a thin film of hydrogen is deposited on the surface of the pipe and this area is protected. This kind of corrosion is called <u>local action</u>.

Corrosion between dissimilar metals can be prevented by placing an insulator such as hard rubber, plastic, or other non-metal between the two to interrupt the flow of electrons. Galvanic corrosion in the form of local action is attacked using a "sacrificial" anode of magnesium or zinc near, or connected to, the tank or pipe. This anode is destroyed because of its higher electric potential and the other metal is protected. The cathodic protection continues until the supply of sacrificial material has been exhausted. Commercial firms will estimate the cost and amounts of equipment necessary to protect your particular installation.

(3) Stray currents cause corrosion of a pipeline by removing electrons from the pipe. Grounds for electrical circuits can create this problem when tied to water pipes if there is an electrical leakage from some electrical source. Direct current is a much greater source of trouble than alternating current because of the constant direction of electrical flow. Sacrificial anodes are used to protect metals from stray currents.

Table 8 Galvanic Series

Corroded End	Magnesium Magnesium alloys
	•
	Zinc
	•
	Aluminum 25
	•
	Cadmium
	•
	Aluminum 17 ST
	•
	Steel, iron, cast iron
	•
	Chromium-iron (active)
	•
	Ni-Resist
	•
	18-8 stainless steel (active)
	•
	Lead, tin, lead-tin solders
	•
	Nickel, Inconel (active)
	•
	Brass, copper Bronze, Monel
	•
	Silver solder
	•
	Nickel, Inconel (passive)
	•
	Chromium-iron (passive) 18-8 stainless steel (passive)
	•
	Silver
	•
Protected End	Gold, platinum

(As listed by The International Nickel Co., Inc., New York)

3. Preventing Sand in the Pump. Apart from the motor, the pump is a simple device and, if well made, is relatively immune to damage except by vibration and sand-pumping. Submersible pumps are the most susceptible to sand damage and will be discussed here as an example. They are not recommended for use when the water con-

tains more than one part in 100,000 of sand grains up to .010" across or larger.

Sand grains vary in size from about .010" to .002". Smaller particles are called silt, while larger ones sink to the bottom of the well and are no problem. Particles causing damage are mostly those between .008" and .002". The running clearance of submersible pumps are normally .004" and particles of the size mentioned will score the bearing surfaces unless they are soft enough to break up before doing damage.

One way to determine if you have a sand problem is the "milk bottle test." Fill a milk bottle (or a suitable substitute) from the water being pumped and allow the sediment to settle. A proportion of one part in 40,000 is represented by a layer of sand not more than one grain thick which completely covers the bottom of the bottle. If there is more sand than this in the collecting vessel, steps should be taken to reduce the sand content of the water.

Since it is the suction of the pump that brings sand into the water, sand intake can be reduced by reducing the velocity of the pump intake. However, the discharge velocity of the column of water must be high enough (roughly 8 ft./sec.) to keep the sand in suspension all the way to the surface, so this factor must be balanced against the need to reduce intake velocity.

A similar phenomenon occurs when using a suction lift pump. Do not let the pressure at any point in the suction line drop too low. If you do, vapor bubbles will form at the pump intake and burst under the higher pressures inside the pump. The process of formation and collapse of bubbles (cavitation) causes unsteady flow. Sever pitting and excessive vibration result, which will harm the pump.

4. Maintaining Electric Motors. Since the electric motor is more complex than the pump, most of the transmission problems will be found here. Here are the common enemies of electric motors, the damage they do, and the steps to be taken to combat them.

Table 9
Protection for Electric Motors

The Offender	The Damage it Does	How to Combat It
Dirt	Plugs ventilating spaces and prevents cooling; causes wear and harmful sparking in commutator faces and slip ring brushes; causes shorting or grounding of windings; retains moisture	Wipe dirt off with cloth, no waste fibers; blow out with clean, dry air-pressure not to exceed 50 psi to protect insulation; remove with solvents, using petroleum distillates with a flash point of over 100°F and observing safety precautions such as adequate ventilation
Moisture	Harms insulation on windings so they no longer withstand the voltage; absorbs acid or alkali fumes and becomes destructive agent	Install motors in cool, dry place; run standby motors occasionally to guard against condensation; make sure motors not subject to drips from leaks or to splatters; make sure water has not condensed in air line when using air pressure to remove dirt
Overload	Causes excessive amperage and overheating	Reduce water volume by partially closing discharge valve
Friction	Causes wear in all moving parts; may start fires	Follow all instructions of manufacturer when lubricating; do not over-oil or over-grease as this may cause friction itself; do not add new oil while motor is running; if motor lacks sealed, sleeve-type bearing, excess oil will harm the windings, commutator, or collector; on motors with roller or ball bearings, make sure inner race is tight enough on shaft to rotate it but not so tight as to cause frictional distortion
Vibration	Shakes parts loose; breaks electrical connections, may crystallize parts of the metallic structure; causes wear in moving parts	See that motors and impellers are not misaligned due to heavy floor loading, foundation settling, or misaligned drive shafts; see that vibration in powered machinery is not transmitted to motor; check for bent motor shaft, loose bearings, or loose mounting bolts

In addition to the above, there is other maintenance which must be done on particular parts of a motor -- bearings, windings, armature, and electrical circuits and controls.

(a) Bearings. They should be frequently inspected and, if they are the older types of sleeve bearings, supplied with oil. Newer sealed bearings are grease lubricated and do not require such frequent maintenance. The safe temperature rise for a bearing is 40°C (104°F) above the air temperature of the area in which the motor is located. If a bearing becomes too hot to touch, reduce the load if possible. Then feed lubricants carefully, loosening the nuts on the bearing cap. If the machine is belt-connected, slacken the belt. If no relief occurs, shut down the motor in order to prevent the bearing from freezing.

A warm bearing, or "hot box," will probably be caused by one of the following: no oil; excessive belt tension; failure of oil rings to revolve with shaft; rough bearing or journal surface; improper application of motor; improper fitting of journal boxes; bent shaft; misalignment of shaft and bearing; dirty or poor-grade oil; loose bolts in the bearing cap; excessive end-thrust due to misalignment of motor with respect to driven equipment; end-thrust due to magnetic pull; excessive side pull because the rotating part is off center; vibration.

(b) Windings. The windings in electric motors should be snug in their slots and the insulation should be fresh, flexible, and treated with varnish. This condition is best maintained by periodic cleaning. Motor overhaul, which includes varnishing and baking treatments, is usually performed by specialty shops.

One condition which frequently hastens winding failure is movement of the coils due to vibration in operation. As the insulation dries due to age, it loses its flexibility, and vibration may cause short circuits in the coils and possible failures from coil to ground, usually at the point where the coil leaves the slot. Properly-applied varnish and baking treatments will fill all air spaces caused by drying and shrinkage of the insulation, will maintain a solid winding, and will provide an effective seal against moisture. Improper varnishing will have the opposite effect, however. For this reason, it is advisable to have spare motors -- and to have worn motors overhauled by motor specialists.

(c) Armature and Commutation. The armature is the first part of a DC motor to give evidence of distress if over-loaded. The success of the motor depends on good commutation (transmitting electric currents through rotating armature rings). The commutator surface should be smooth, concentric, and properly undercut; the brush-holders should be free of dirt; the brushes which maintain contact with the armature rings should be the proper kind. Here are some suggestions for giving proper maintenance to brushes and collector rings in AC and DC motors: see that brushes are free in the holders; check spring pressure and keep at value recommended by the manufacturer; replace worn brushes; replace worn or broken tension fingers; check collector rings and clean insulation; adjust brushholders to between 1/6" and 1/8" from the face of the commutator (1/32" for fractional horsepower motors); see that brush box is parallel with commutator bar.

(d) Electric Circuits and Controls. Control systems are usually designed so that individual circuits control only one function of a machine. An example would be start-stop of a pump motor by means of pushbuttons or control of solenoid valves by limit switches. The main factor to remember is that a complete circuit can be analyzed as an assembly of basic circuits, each of which is usually associated with a basic machine function.

The control box should be mounted in a vertical position in an area not exposed to direct sun, excessive heat or moisture of any kind. The power supply is brought directly from the main switch to a separately fused disconnect switch near the motor control box. For 115-volt current, a single pole switch can be used since it is necessary to break only the hot line. For 230-volt current, always use a 2-pole switch so that both lines are broken and fused. On three-phase installations, a three-pole disconnect must be used to break all three lines.

Factors such as temperature, humidity, and mishandling may adversely affect the performance of motor controls, and these possibilities should be considered if the motor does not function properly. For example, a noisy, humming armature may be caused by incorrect coil voltage or dirty ground pole faces.

Treatment

The type of treatment you give to the water before you distribute it is governed largely by the quality of the raw water (and, of course, by health department regulations dealing with treatment of public water supplies). This is a function of the source to some extent. After many years of stream pollution, it is difficult to find any surface water which does not require extensive treatment because it typically contains many harmful bacteria and minerals. On the other hand, some ground water is almost pure and may require nothing but disinfection, if that. However, some ground water is polluted, or may be hard, or may contain excessive amounts of iron even if free from bacterial contamination. In addition, water which is pure at the point of collection may become contaminated in the distribution system.

As a result, practically any community water system will include at least minimal treatment.

The objective of treatment is to render water acceptable for human consumption by removing solids, improving color, disinfecting to destroy pathogens, removing hardness, removing or neutralizing harmful minerals, and improving taste and odor.

Treatment may also include some processes designed primarily to control corrosion in the distribution system or to introduce a supplement to the water, such as flouride to control tooth decay. These objectives are accomplished by adding the proper chemicals to the water, as well as using a variety of settling, filtering, and aerating techniques.

A complete description of all treatment processes you may have to employ -- equipment, chemicals, applications and standards, etc. -- is a book-length topic in itself. Many state health departments and other agencies have produced detailed manuals to guide the operators of water treatment plants. Make sure that your operators have the most advanced manuals and that they follow them. As the manager, you will also want to familiarize yourself with these manuals. We will limit ourselves here to discussion of some of the highlights of water treatment operation and maintenance.

1. Chemical Coagulation. The term "coagulation" covers a process for speeding the removal

of suspended and dissolved solids from the water. The process involves several steps: feeding one or more chemicals to the water; mixing the chemicals to distribute them evenly; and gently agitating the water for a period of time (flocculation). In this way, solids are brought together in large lumps (flocs) and then removed by sedimentation.

There are a number of chemical compounds which may be used as coagulants, but aluminum sulfate (alum) is the most common one. To get the best dosage, add known amounts of coagulant to several jars of the water to be treated, stir the mixture gently for a period of time, and observe the quality and settling characteristics of the floc.

Coagulants are usually fed by a machine which can be set to deliver a certain amount during a particular period of time -- so many pounds per 24 hours, for example. Mixing is necessary to disperse the alum in the water. It can be done mechanically or hydraulically in special tanks, parts of other tanks, or in piping sections. Flocculation takes place following mixing, usually in a single tank. The water should be gently agitated for 15 to 45 minutes.

The most common hydraulic method for doing this is the "baffled basin" -- having the water flow in, over, and under baffles. However, the present trend is toward the use of power-driven paddles or agitators which can be carefully controlled for best results. The control of flocculation basins consists mostly of controlling the amount of coagulant added and the degree of agitation. Properly coagulated water should show visible floc in clear water. Excess coagulant chemical in the water is wasteful and affects taste.

2. Sedimentation. This is the process of removing solids by passing the water, usually after coagulation, through a basin at a low velocity. Settleable material thus sinks to the bottom of the tank. The velocity should be less than two feet per minute and the water should be detained for two to four hours, depending on water quality.

A regular sedimentation tank can be cleaned by draining the water and removing the settled material (sludge) with fire hoses and squeegies. (See Chapter Three for discussion of sludge disposal.) However, many tanks are now cleaned by mechanical scrapers which scrape the sludge to one end of the tank, or to the center if the tank is round. In addition to saving water and time, the mechanical method allows the tank to be cleaned more frequently, thus lessening the chance that bacteria in the sludge will affect water taste or cause odors.

Sometimes, part of the settled floc is used to "scrub" the raw water as it passes through a special tank (solids-contact process). These units are not only quicker (one to two hours), but they can, being smaller, be more carefully controlled. Solids-contact units may be used for either water clarification or softening.

3. Filtration. Coagulation and sedimentation are usually followed by a filtering process which removes fine organic and inorganic matter, thus reducing bacterial content and contaminants which cause poor taste and odor. The most common filters for water are sand or anthracite, specially prepared or selected according to grain size. They may be either the pressure or gravity type. Gravity filters are further classified as slow sand or rapid sand. Pressure filters may be either sand or diatomaceous earth (the skeletal remains of a type of algae known as diatoms). Pressure filters are most common in rural systems.

The trend is toward construction of rapid sand plants -- also called mechanical sand filters because they use mechanical control equipment to wash the sand beds. Rapid filters have a filtration rate 40 times greater than slow sand, and they work well as long as operators watch for any build-up of conditions which might cause failures and require costly replacement of sand. Some of these conditions are:

(a) Excessive Floc Penetration. To detect floc in the clear water basin, lower a submersible light bulk into the basin and look for floc in the reflected light.

(b) Negative Head. The term describes the existence of a pressure below atmosphere. If it occurs in the filter, the reduction in pressure allows air dissolved in the water to escape, causing air binding in the filter.

(c) Air Binding. In addition to negative head, increases in water temperature during filtration and release of oxygen by the algae can cause air binding. The operator should work to prevent these occurrences.

(d) Mud Accumulation. Mud balls can be removed with a dipper when washing or by breaking them up with rakes or water jets.

(e) Crack Formation. Cracks and clogging of a filter may occur when a blanket of floc, organic matter and mud forms on the filter. They can be controlled in the same way as mud balls.

4. Disinfection. The minimum treatment required by state laws for public water supplies is usually disinfection to kill bacteria and other disease-producing organisms. This is increasingly true for ground water as well as surface sources. Chlorination is the most generally accepted method of disinfection today. It also inhibits organic growths which cause deposits and dirty water in the distribution system. Important considerations for the manager are (1) type of chlorination, (2) point of application, (3) proper dosage, and (4) chlorine redidual.

(a) Type of Chlorination. A gas at normal pressures and temperatures, chlorine is stored under pressure in steel cylinders as a liquid. The chlorine gas can be fed directly into the distribution system from these cylinders. However, there are many hazards and inconveniences connected with this -- service, delivery of cylinders, corrosion, protective equipment, special housing, ventilation, etc.

The method is not recommended for small rural systems. Instead, the chlorine should be dissolved in water and fed in solution by chemical feeders to the point of application. The simple solution feeders can be easily maintained and serviced by utility personnel, and are cheaper and safer than direct-feed gas chlorinators. Operation merely requires periodic supplementation of the chlorine solution. Whatever type of chlorinator you use, you should keep a duplicate on hand and use the two alternately. A stand-by unit should always be kept in operating condition as a safety measure.

You should make sure that an adequate supply of solution is on hand at all times and that the proper concentration has been verified by assays. Check carefully for any deterioration of stored stock solutions. (In some cases, chlorine compounds called hypochlorites are used for disinfection. These come in liquid or powder form and are mixed with water before application.)

(b) Point of Application. The precise point of chlorination varies from system to system. As a minimum, it should be at a place of moderate pressure with minimum variation in flow rates and with the best facilities for securing rapid and thorough distribution of the chlorine. An additional consideration is accessibility of chlorination equipment for inspection.

(c) Proper Dosage. The state health department will specify the required chlorine dosage, but here are some rules of thumb:

Table 10 "Rule of Thumb" Chlorinator Size Guide

"RULE OF THUMB" CHLORINATOR SIZING GUIDE FOR PLANNERS

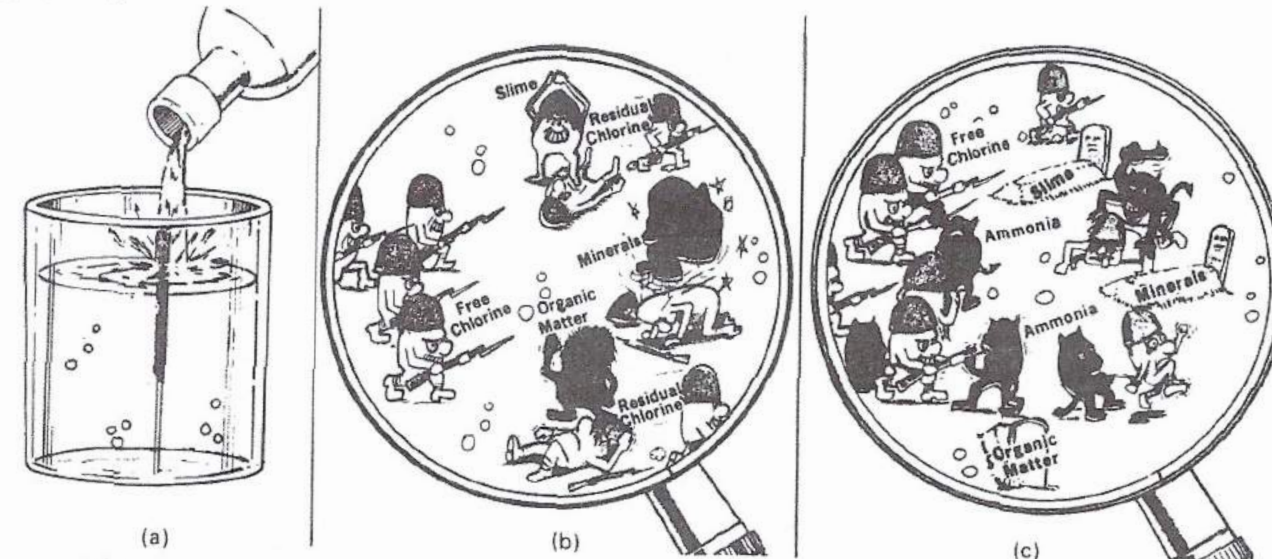
CHLORINATION TREATMENT FOR	TYPICAL DOSAGE RATES IN PARTS PER MILLION (PPM)*
ALGAE	3 - 5
BACTERIA	3 - 5
COLOR (Removal)	Dosage depends upon type and extent of color removal desired. May vary from 1 to 500 PPM dosage rate.
HYDROGEN SULPHIDE—	
Taste and Odor Control	2 times H_2S content
Destruction	8.4 times H_2S content
IRON BACTERIA	1-10, varying with amount of bacteria to control
IRON PRECIPITATION	.64 times F content
MANGANESE PRECIPITATION	1.3 times M content
ODOR	1 - 3
SLIME	3 - 5
SWIMMING POOL	1 - 5
TASTE	1 - 3
WATER	
Cooling	3 - 5
Chilling	20
Washdown	50
Well	1 - 5
Surface	1 - 10 There are many variables that can affect surface water and the treatment required.

*The rates in PPM given above are for average conditions, which may vary from location to location.

(d) Chlorine Residual. The quantity of chlorine necessary to kill bacteria is determined by the "chlorine demands" of the water. Chlorine combines with some organic compounds present in water and is absorbed by others, so enough chlorine must be added to the water to overcome these losses with enough chlorine remaining to act as a disinfectant. The remaining chlorine is called "chlorine residual." The state health department will specify the required chlorine residual and this must be tested regularly at the point of distribution to the consumer. It is the key measure of the effectiveness of disinfection processes.

Some of the chlorine residual may exist as hypochlorous acid or as hypochlorite ions, or both (free available chlorine), while the remainder may be in combination with natural or added ammonia in the water (combined available chlorine). The former works faster and kills more bacteria with the same quantity, but the slower-acting combined available chlorine persists longer in the distribution system and is more effective in controlling organic growths in the mains.

Figure 5 Chlorination Illustrated
(From Henderson)



(a) Dosage is the amount of chlorine added to water. (b) Organic matter and minerals will "use up" some of the chlorine causing it to lose its killing action. Any chlorine that is left over is called "residual chlorine." Residual chlorine may be "free," as shown or (c) if ammonia is present (as in most pond water), some chlorine will combine with it. Combined chlorine is much slower in its killing action than free chlorine because of this handicap.

An <u>orthotolidine</u> kit is commonly used to test chlorine residual. A specified amount of premixed test solution is added to a measured sample of water in a glass tube. A greenish-yellow color will develop. The intensity of the color is an indication of the amount of residual chlorine present when compared against a standard color chart. The color that develops in the first 15 seconds is an indication of the free available chlorine. The combined available chlorine reacts more slowly and requires about five minutes at 70° Fahrenheit for full color development. A chlorine residual of 2 ppm should be measurable at the end of the line.

Some treatment processes include large injections of chlorine to destroy bacteria and control odors (super-chlorination). Thereafter, some excess chlorine may have to be removed by having the water come in contact with materials which absorb the free chlorine (activated carbon, for example) or combine with it (such as sulfur dioxide). The process is called dechlorination.

5. Water Softening. Softening, or hardness removal, can be done by any method which removes calcium and/or magnesium, since these are the two principal hardness-producing minerals. Most large plants use a method called chemical precipitation while smaller communities use ion exchange.

In chemical precipitation, lime, or lime and soda ash, are added to the water with about twice as much being required for magnesium as for calcium removal. Chemical equations are used to determine the amount of softening agent required. A big factor in the amount is whether the water hardness is "carbonate" (calcium and magnesium bicarbonates) or "non-carbonate" (calcium and magnesium salts). The equipment necessary for chemical precipitation is similar to that in a coagulation-sedimentation-filtration plant.

Ion exchange softening means removing calcium and magnesium ions, and replacing them with other ions such as sodium. The sodium is placed on an exchange medium (natural or synthetic zeolites) which must be regenerated when the sodium is used up. This is done by passing a strong salt solution through it so that the sodium replaces the calcium and magnesium.

6. Aeration. In aeration, water is brought into contact with air, gases and volatile substances in the water are changed, and the chemical and physical character of the water is improved. Aeration equipment either exposes water films to the air (cascade type) or introduces air bubbles into the water (diffused-air type). Problems to watch for are freezing of outdoor aerators, lack of ventilation if aeration is done indoors, and corrosion of metals.

7. Iron and Manganese Removal. Ground water in particular is likely to contain iron and manganese as either soluble or insoluble compounds. Water with high iron content tends to be unsuitable for domestic purposes because it turns tea into a black liquid, makes coffee undrinkable, and stains laundry fixtures. Moreover, there may be bacteria which are partial to

iron, metabolize it, and form slimes which clog well screens or collect in water mains. Once they have a foothold, these slimes are difficult to handle. Proper disinfection of a new well and chlorination of the water supply help to control it.

There are four methods for removing or stabilizing iron and manganese -- aeration followed by sedimentation and filtration, lime and lime soda softening, ion exchange, and stabilizing by adding polyphosphates or other agents to prevent corrosion of water mains.

8. Fluoridation. As a manager, you will possibly have to deal with fluoridation before your operator does. Some persons are violently opposed to having it added to water supplies. (Some even think it is a Communist plot to weaken America physically.)

The addition of flouride to drinking water (1.0 or 1.2 milligrams per liter) tends to retard tooth decay in children. Flouride can be obtained

Fluoridation can be particularly helpful to children, but make sure the community wants it before installing the equipment.

in other ways, such as fluoride toothpastes -- but putting it in drinking water is the easiest, most controllable, and lease expensive way to see that children get the proper amount. Some feel that this is "forced medication." They argue that the flouride that may be good for children is bad for adults -- "it makes their bones brittle." Nonetheless, fluoridation has become a fairly-well established public health measure and was used in about 5,000 communities in 1970.

If your community resolves in favor of it, you should have no technical problems, since prepared chemicals are fed into the system by simple chemical feeders similar to chlorine solution feeders or coagulant dry feeders. Daily tests are necessary to see that required doses are not exceeded.

Storage and Distribution

The principal storage facilities requiring routine maintenance are steel reservoirs, tanks, standpipes, and elevated towers. Earth embankment or concrete reservoirs and plastic tanks are also in common use, but they require little maintenance other than inspection for leaks and an occasional draining, cleaning, and perhaps resealing of the interior surfaces.

The principal maintenance requirements in distribution are for pumping stations and mains. Corrosion is a maintenance problem for all iron and steel facilities, however, and additional preventive maintenance is required for hydropneumatic tanks, mains, cross-connection control, and meters.

1. Corrosion. The basic ways of fighting corrosion in the storage and distribution system are painting and cathodic protection. (The latter was discussed earlier, pp. 121-123.) Steel structures should be painted roughly every five years, preferably by a well-qualified contractor who specializes in coating water and industrial storage tanks.

If you undertake the job yourself, make sure you do the following: Prepare surfaces properly. Select suitable paints (consult EPA for suggestions). Use good workmanship in application. Allow adequate drying and aging.

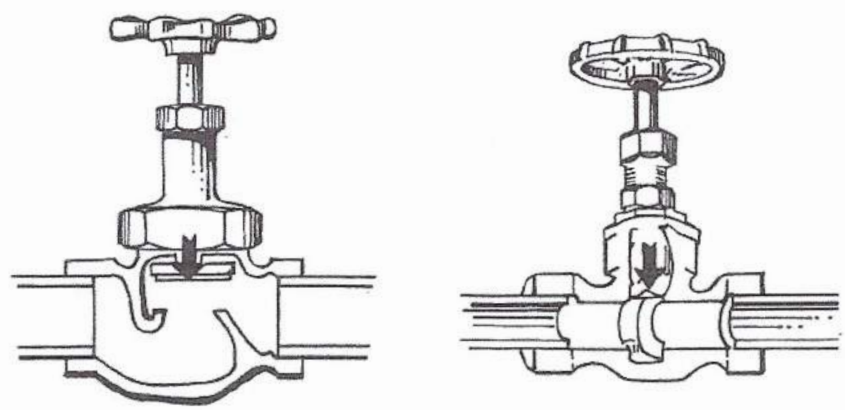
In the intervals between paintings, inspect the structures periodically, removing old paint, and spot-paint where necessary. Since good paint jobs are not always easy to get and interior tank surfaces are difficult to paint in any case, make sure to investigate cathodic protection as an additional safeguard.

The corrosive effect of water can also be combated by the addition of chemicals that react with the corrosion-causing carbon dioxide, depositing a protective film on the inside of water mains. Either line or soda ash may be used, depending on the mineral content of the water. Caustic soda is also economical in some cases, although it must be handled carefully.

2. <u>Hydro-Pneumatic Systems</u>. Since the expansion of pressurized air is used to deliver water through hydropneumatic distribution systems, a pressure tank is also a pressure aerator. Because the air in the tank is in contact under pressure with the water, it is, in effect, treating it with oxygen, thus speeding up corrosion. It may also precipitate iron that may have been originally dissolved in the water, leading to "red water."

Every pressure tank should be drained and cleaned at intervals, particularly in cases where the water is high in iron or turbidity. A drain valve is located at the bottom of the tank to provide an outlet for accumulated dirt and sediment. The drain valve should be a gate-type, which allows free passage when opened. A pipe cap and nipple may be screwed into a discharge opening if there is any concern about its leaking when closed. To reduce friction loss, the shut-off valve should also be gate-type.

Figure 6
Globe and Gate Valves Compared



a. Globe valve has righ resistance to water flow because of narrow passageways and sharp turns.

b. Gate valve provides straight-line water-flow passage with very low resistance.

Draining, flushing, and cleaning a tank involves these steps: (1) Turn off the pump motor, (2) Close the shut-off valve to the distribution system, (3) Open the drain valve and keep it open, allowing the tank to empty completely, (4) Start the pump motor and keep pumping until the water coming out of the drain valve is as clear as the water being pumped, (5) Close the drain valve and allow the pump to operate until it stops automatically by its pressure switch setting, and (6) Open the shut-off valve.

3. Protection of Mains. In most water distribution systems, it is necessary to clean out sand, sediment, and other substances that settle in the pipes when the velocity of flow is not sufficient to keep them in suspension and moving. A good flushing at high velocity once or twice a year usually removes most of the settled solids. If too much time elapses between flushings, however, other cleaning methods may be necessary.

One way to clear clogged mains is to force a chain-covered, inflated rubber ball through the pipeline by water pressure and induced flow. The rotation of the ball and the scraping of the interior surface of the pipe by the chain agitates the settled material, making it easier to flush out. Another method of stirring up solids for flushing is to use a pipe-cleaning instrument having spring-loaded steel scrapers. The instrument is forced along the pipeline by water pressure and scrapes off the deposited material.

It will be easier to insert and withdraw these cleaning devices if there is a generous supply of wye fittings in every branch of the main. The wyes are often referred to as "cleanouts," and they are one example of how a little extra money spent in construction can save big money in maintenance costs.

Water mains must be cleaned to reduce friction, lower the amount of head (pressure) that is necessary to force water through, and to prevent discoloration and odor. Over the years, pipe interior surfaces become rough and there is a buildup of solids -- scale, slime, iron and manganese deposits, as well as settled solids. Friction tests should be run to determine the need for cleaning if there is any undue loss of pressure.

The section of pipe to be cleaned is first isolated and then the customers' service is shut off. If there are no cleanout wyes, a short section of pipe must be removed from the ends of each section to be cleaned. One cleanout is used to insert the cleaning instrument and the other, at the opposite end, flushes out the scoured materials and removes the cleaner. The insertion cleanout is generally closed by removable couplings, and pressure is applied back of the cleaner to propel it along the line. The discharge end is provided with a bend and section of pipe rising to surface level to dispose of the water and sediment.

After cleaning and closing the open end of the cleanout wyes or rejoining the pipe, it is usually necessary to blow out customer service lines to remove any sediment that has become lodged there.

4. Cross-Connection Control. A cross-connection is any physical connection, direct or indirect, which provides an opportunity for polluted water to enter a pipe or other receptable containing potable water. Any such connection should be sought out, particularly in commercial and industrial premises, and eliminated. For example, if a hose connected to the water supply is running with the open end lying in a puddle of DDT, and a fire hydrant is turned on down the road, the DDT might be sucked into the water supply.

If a cross-connection is absolutely necessary, it should be made only with the approval and supervision of the health authority having jurisdiction. A backflow preventer acceptable to both the utility and the health department should also be installed. Some devices for this purpose are air-relief valves and vacuum breakers, swing connections, air gaps, and reduced-pressure connections.

5. Meter Testing and Repair. Corrosive chemicals in the water may cause meters to deteriorate over time and register the flow inaccurately, thus under-charging or over-charging consumers. (It is usually the former, although it is hard to convince users of this.)

Although you may wish to test more frequently, most state regulatory agencies have adopted standards prescribing maximum periods between tests for most private water utilities and some public ones. The periods vary with meter size. Thus: for 5/8" meters, between five to 10 years; for 3/4" to 3" meters, two to 12 years; for meters 4" and over, one to four years. Meter test equipment is very simple. The test procedure may consist simply of timing the flow through a meter, set in the line, and discharging into a tank on a set of scales for weighing the water. A calibrated orifice may sometimes be used. Where the number of meters to be tested is large, more sophisticated test equipment is commercially available.

The best meter repair procedure is to replace it with a spare new or reconditioned meter, and then return it to the shop or manufacturer for overhaul and testing. This minimizes service interruption and makes return trips by the repairman unnecessary. Most large meter manufacturers offer a meter reconditioning service that includes rebuilding, testing, and certification. They can probably do the job better than a small water utility.

Here are some points to remember in meter maintenance: (1) Clean all meter parts thoroughly, (2) make sure the gear train runs freely, (3) check the action of the disc in the chamber before and after assembly in the maincasing, (4) check for friction as well as slippage, (5) store meters away from heat, (6) use a new meter as a standard of comparison for tolerances and clearances, (7) retest the meter for accuracy after repair, and (8) maintain records on all meter servicing.

TROUBLE-SHOOTING

A water system is like the human body. With good preventive maintenance, it will perform well for a long period of time; with abuse it will decline more rapidly. Even with the best of care, however, the human body sometimes malfunctions and requires corrective maintenance. So do water systems. As a water system manager, then, you can expect to have plenty of trouble-shooting to do. Again it is useful to approach this in terms of the various parts of the system.

Collection

A water well may give good service for a period of time and then begin to deliver water of lesser quantity or poorer quality, or both. The well may even fail completely. These things do not happen by accident, assuming no natural disasters. It is your job to see that the source of the trouble is identified and corrected. We'll discuss some of the problems which arise from abuse of ground water resources and some of the reasons for well failure.

1. Problems of Water Quality. Your water shows an increase in bacterial or chemical con-

tamination. Based on other cases, it may be due to:

(a) Increasing Mineralization. In one case, wells for a municipal water supply were located in the floodplain of a river about 500 feet from a shale and sandstone bluff. After the wells had been pumped for only a few weeks, there was a decline in water quality. Increases in calcium, sulfate, and magnesium content could be attributed to intercepted outflow from the bluff, which bordered the aquifer. However, the concentrations of sodium, chloride, and total dissolved minerals were abnormally high for bedrock waters.

An investigation revealed that these were caused by water-softener waste being discharged into a surface depression near the wells. The wells were relocated 1,000 feet away from the valley walls, and additional lengths of pipe were installed to carry the water-softener waste farther away from the point of ground water retrieval. The final water quality was thus brought within acceptable limits.

(b) Nitrates. The source of excessive harmful nitrates in rural water supplies is usually seepage from feed-lots and septic tank sewage disposal systems, which percolate through the soil or flow overland to nearby wells. In a case in Illinois, a farm which was having this problem did not get a good water supply until the well was moved some 1,500 feet away from the area of contamination.

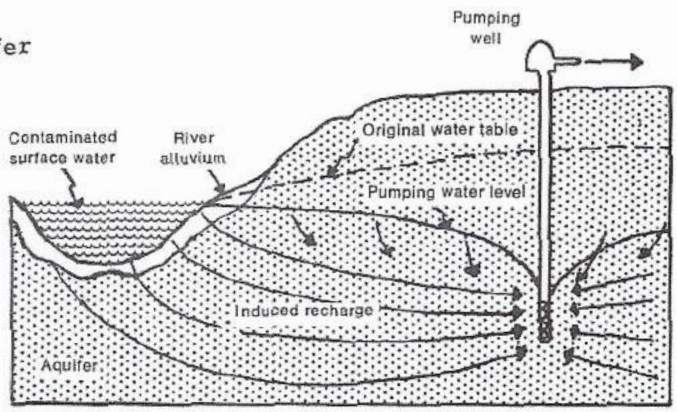
Of course, proper selection of a well site and better construction might have prevented this problem.

(c) Bacterial Contamination. In one case, the source of contamination was found to be waste from a farm located nearly half a mile from the nearest affected well. The contaminated storm run-off from the farm flowed for a quarter of a mile over clayey glacial till to a lowland area, where the impermeable mantle capping the dolomite aquifer had been removed by erosion. The contaminants entered the cracked and creviced dolomite at this point, and from there moved freely through interconnecting solution channels in the dolomite to nearby points of ground water withdrawal.

(d) Turbidity Following Storms. Shallow limestone aquifers, extensively used as water supplies, recharge themselves from precipitation which enters the aquifer on the surface. Wells tapping such limestone may produce turbid water within a few hours after a heavy rainfall, indicating that surface run-off moves from the recharge area with little or no sedimentation or filtration occurring in the aquifer. With this potential for contamination, water from limestone or dolomite wells is suspect at any time, and should always be chlorinated before distribution.

(e) Pollution from Surface Water. Figure 7 represents a major problem for water systems which rely on induced infiltration of surface water from natural sources or from artificial recharge facilities to replenish their aquifers. If a stream that is the source of water for a well field is contaminated by materials that are not purified under underground flow conditions, ground water in the vicinity of the well will probably be of better quality than the raw stream water -- because the percolation through earth materials will have had some effect -- but it will still have to be treated.

Figure 7
Induced Infiltration into Aquifer



Induced infiltration from stream. Stream pollution can result in "groundwater" pollution. Natural purification is limited to those processes requiring no exygen.

(f) Overpumping. This means that, in order to maintain capacity, water must be drawn from an area further and further from the well intake. When this occurs, the result may be that contaminated natural waters are drawn into a shallow fresh-water aquifer, receiving little purification in the aquifer. A continuation of the pumping will mean a persistent increase in the degree of contamination. The migration of poor quality water from deep aquifers may continue for a considerable period of time before it is detected. Therefore, after facilities are installed, there should be periodic monitoring of the sulfates and chlorides to spot any adverse effects of pumping.

(g) Site Problems. Another influence on water quality could be a cracked casing, surface water at the well head, a contaminated pump, or sanitary violations at the site. These should be checked whenever bacterial contamination is discovered.

2. Well Failure. Specific capacity is the best measure of well deterioration, for it decreases as either discharge declines or drawdown increases. As noted earlier, specific capacity should be checked regularly. If it declines as much as 15 percent from the original rate, it is time to look for the cause of the deterioration. This may be:

(a) Mechanical Incrustation. Plugging of a well by silt, clay, and fine sand does not occur often, but it is possible. It is most likely to occur if the well was improperly constructed or where the water-bearing formation contains an unusual amount of these fine materials. The best method of treatment is to use one of the family of chemicals called polyphosphates. They do not dissolve the incrusting materials like acids but act as dispersing and isolating agents, "laundering" the aquifer in the manner of household detergents.

(b) Bacterial Infection. A well infected with bacterial growth can fail rapidly, and production may decline to practically nothing in a matter of weeks. The infection may be due to use of impure "make-up water" from ditches or ponds, failure to sterilize after the original drilling of the well, introduction of growths during repairs, or infiltration of organisms around the pump base or through the discharge pipe.

Iron bacteria and other slime-forming organisms can live in ground water by feeding on iron, organic material, carbonates, or carbon dioxides. Scum and slime suspensions indicating infections can be detected by putting filter bags or strainers over the flow pipe and watching for build-up. Where bacterial growth is plugging the aquifer, chlorine and bactericides provide the best treatment. However, this condition is difficult to cure permanently and treatments will probably have to be repeated regularly.

(c) Chemical Incrustation. The most common cause of plugged wells is the precipitation of calcium and manganese carbonates. The lowered water level in a pumped well results in decreased formation water pressures just outside the well and this, in turn, releases the carbon dioxide which precipitates the carbonates. The most common method of redeveloping wells plugged by chemical precipitation is some sort of acid treatment. This includes introducing liquid hydrochloric acid through a pipe to the intake portion of the well, dropping dry sulfonic acid in granular or pelletized form in the top of the well, or placing dry sulfonic acid in the bottom of the well by some mechanical means, such as a dump bailer. This is normally a job for a contractor.

3. Fine Sand Movement. One of the results of overpumping is likely to be the movement of fine sand into the artificial gravel pack or into the aquifer immediately adjacent to the well screen. This can plug the well and reduce pumpage to a rate less than the proper initial rate. Permanent damage to the well may result. Due to the loss of open area, head losses that occur as a result of plugging should increase at an accelerated rate as time goes on. In the construction of the well, great care should be taken to provide maximum open areas of screen and gravel, and to provide means for the removal of plugging agents when they occur.

4. Pump and Motor Failure. The number of things which may go wrong in the transmission equipment -- the pumps and electric motors -- is virtually endless. The little gremlins which many are convinced haunt these mechanical and electrical devices conspire to see that everything which can go wrong will go wrong. Do not despair, however. Well-trained operators will be able to handle many of the breakdowns, and electricians and motor specialists can be called in for very knotty problems. If equipment is kept clean and dry, lubricated regularly, and checked regularly for trouble-causing conditions, it will reduce your problems.

Table 11 is a compact trouble-shooting guide for a typical pump motor. You may wish to carry this with you when you accompany the operator on his rounds or make solo checks on your own. In any case, familiarize yourself with the common problems because you will probably be hearing about them.

Table 11 Trouble Shooting Guide:
Electric Motors

High Thrust Vertical Motor Trouble-Shooting Guide

SYMPTOM	PROBABLE CAUSE	ANALYSIS
Motor fails to start	Defective power supply	
	Blown or defective primary fuses	Check voltage across all phases above disconnect switch.
	Blown or defective secondary fuses	Check voltage below fuses (all phases) with disconnect closed.
	Open control circuit	
	Overload trips are open	Push reset button.
	Defective holding coil in magnetic switch	Push start button and allow sufficient time for operation of time delay, if used, then check voltage across magnetic holding coil. If correct voltage is measured, coil is defective. If no voltage is measured, control circuit is open.
	Loose or poor connections in control circuit	Make visual inspection of all connections control circuit.
	Magnetic switch closes	Open manual disconnect switch, close magnetic switch by hand and examine contactors and springs.
	Poor switch contact	
	Open circuit in control panel	Check voltage at T1-T2-T3.
	Open circuit in leads to motor	Check voltage at leads in outlet box.
	Leads improperly connected	Check lead numbers and connections.
Motor fails to come up to speed	Low or incorrect voltage	Check voltage at T1-T2-T3 in control panel and at motor leads in outlet box.
	Incorrect connection at motor	Check for proper lead connections at motor, compare with connection diagram on motor.
	Overload Mechanical	Check impeller setting. Check for a locked or tight shaft.
	Overload Hydraulic	Check impeller setting. Check GPM against pump capacity and head.
Motor runs hot	Inadequate ventilation	Assure adequate supply of fresh air. Check air blast through motor by feeling air discharge at bottom of motor.
	Overload	Check load with ammeter.
	Unbalanced supply voltage	Check supply voltage with voltmeter.
Motor vibrates	Headshaft misaligned	Remove top drive coupling and check alignment of motor to pump.
	Worn lineshaft bearings or bent lineshaft	Disconnect motor from pump and run motor only to determine source of vibration.
	Hydraulic disturbance in discharge piping	Check isolation joint in discharge piping near pump head.
Motor noisy	Worn thrust bearing	Remove dust cover, rotate rotor by hand and make visual examination of balls and races. (Brg. noise is usually accompanied by a high frequency vibration.)
	Electrical noise	Most motors are electrically noisy during the starting period. This noise should diminish as motor reaches full speed.

(Courtesy U.S. Motor Co.)

Table 12 Trouble Shooting Guide:
Pumps

FIELD CHECKING CHART
HYDRAULIC

WHAT TO CHECK \ CONDITION	Motor Runs But Delivers No Water	Pump Operates But Flow Is Low	Pump Does Not Stop Running	Pump Starts and Stops Too Often	Service Line Discharges Milky Water
Pump Not in Water Supply	X				
Line Check Valve to Tank Installed Backwards	X				
Pump Air or Gas Locked	X		X		
Check Valve in Pump Stuck	X				
Pump Shaft Broken	X				
Inlet Screen Clogged	X				
Pump Plugged with Deposits from Well	X				
Pump Partly Plugged with Deposits		X			
Water Pumping Level Lowers	X	X	X		
Pump Setting in Sand or Mud	X	X			
Partly Clogged Inlet Screen		X			
Pump Parts Worn		X	X		
Cut-Out Setting of Switch Too High			X		
Water-Logged Tank				X	
Check Valve to Tank Stuck Open				X	
Leak on Discharge Side of Tank			X	X	
Leak in Drop Pipe	X	X	X		X
Pressure Switch Out of Adjustment				X	
Pressure Tank Too Small				X	
Bleed Back Valve Plugged				X	
Pressure Switch Points Welded Together			X		
Incorrectly Selected Pump	X	X	X		
Air Volume Control Faulty					X
Bleed-Back Valve Setting Too Deep					X
Well Water Naturally Gaseous					X
Reverse Rotation, If 3 Phase	X	X	X		
Pressure Switch Not on Tank				X	

FIELD CHECKING CHART
ELECTRICAL

WHAT TO CHECK \ CONDITION	Motor Does Not Start When Fused Switch is Closed	Overload Trips After Short Period	Relay Chatters But Overload Does Not Trip	Fuses Blow But Overload Does Not Trip	Overloading Trips After Pump Has Run for Some Time
Line Fuse is Blown	X				
Overload is Tripped	X				
Pressure Switch Contacts Open or Burned	X				
Wiring Wrong in Control Box	X	X			
Power is Off	X				
Overload Contacts Open or Burned	X				
Broken Wire or Loose Connection	X				
Crooked Well	X	X	X		
Wires to Control Box Too Small		X			
Amperage Too High		X			X
Insufficient Power at Entrance Box		X	X	X	X
Cable Size to Motor Too Small		X	X		X
Motor Winding Faulty	X	X			
Motor or Cable Grounded		X		X	
Wrong Relay in Control Box		X	X		
Capacitor Faulty	X	X		X	
Relay Faulty	X	X			
Pump Running Tight		X	X		X
Locked With Sand	X	X	X	X	X
Low Voltage		X	X	X	X
High Voltage		X			X
Bare Wire Touching Control Box				X	
Worn Bearing		X	X		X
Control Box in Hot Location		X			X
Line Fuses Too Small				X	
Loose Connection in Control Box	X		X	X	
Wrong Control Box	X	X	X	X	X
Control Box Mounted Incorrectly		X			X

(Adapted from Water Systems Council)

Table 12 is a handy field guide for checking both hydraulic and electrical problems. You should also carry this in your pocket or keep it posted in a convenient place at the pumping station.

Sometimes problems are encountered which require detailed investigation with specialized instruments, such as ohmeters (which measure electrical resistance) and amprobes (which measure voltage and amperage). The operators should have the necessary tools and understand their use.

Treatment

Failure of any treatment equipment or supplies should naturally be brought to the attention of the manufacturer for correction or replacement. Or if you think your company can handle the job, his instructions should be consulted. Your biggest trouble-shooting job in the treatment area will consist of spotting potential contamination hazards and correcting them. This procedure, usually called a sanitary survey, must be done by technicians. It includes sampling the water preparatory to laboratory analysis and then taking any action which seems called for by the results. To some extent, this is routine maintenance in the sense that it involves preventive as well as corrective measures.

1. Surveying Procedures. Your sanitary survey should include samples from three locations in the system -- water from the source of supply (raw water), exiting from the treatment plant (treated water), and at customer outlets (distributed water).

Your objective is to determine the bacterial and chemical quality of the water as it comes into the system, the effect of treatment upon it, and the quality actually available to the consumer.

The survey is worthless unless the samples are truly representative. The raw water should be sampled with the water flowing. If the source is a well, the sample should be taken after the well has been pumping for several hours, to make certain the underground stratum is being tested. If you are using a surface water source, do not take the sample too near the bank or too far from the point of water drawoff, or at a different depth than the drawoff depth.

Treated samples should likewise be taken with care. To get representative samples in smaller plants or stations using pulse-type chemical feeders, you may have to collect at points some distance away from the plant where the effects of chemical additives have evened out. However, these points should be ahead of consumer-service connections. Samples from consumer outlets should not be taken from garages, filling stations, kitchens, or other places where grease may collect on the taps. In addition, no samples should be collected from fireplugs or dead-end locations.

Sampling frequency must be determined for each supply and each individual treatment plant. Get help from the local health engineer. Generally, characteristics of water from large storage reservoirs or well supplies fluctuate less than water from small reservoirs or streams. Some well supplies may have to be checked every month. For others, every six months will do. For surface supplies, weekly, and sometimes daily, or even hourly samples may be necessary. For control of chlorination and for bacteriologic reasons, it is probably wise to sample raw and treated water daily.

To control the quality of water in the distribution system -- at the customer outlet -- one sample per month is probably sufficient for systems serving under 2,500 persons. About seven samples a month should serve for those under 10,000. (Consult the Drinking Water Standards.)

2. Sampling Procedures. Water samples for bacterial analysis should be collected only in the special sterilized bottles prepared and provided by the laboratory doing the analysis. If the water to be sampled has a chlorine residual, a specially-prepared bottle with sodium thiosulfate must be used to neutralize the chlorine. No additional material, bacterial or otherwise, should be allowed to enter the collected water. Data identifying the sample should be recorded in detail, usually on the form attached to the bottle. Here are the steps in collecting a sample from a customer outlet:

(a) Let the water run for several minutes to change the water in the service pipe and insure that water enters from the system. Then shut off the water.

(b) Expose the faucet to flame from a portable burner for a minute or two, especially the inner edges. Small, liquid propane or butane torches are sufficient. This sterilizes the faucet and prevents micro-organisms that might have settled on the faucet from contaminating the sample.

(c) Turn the faucet on and let the water run in a small stream about the size of a pencil. Let it run long enough to displace the water in the service and house piping.

(d) Remove the stopper from the sample bottle without removing the paper foil cover and hold the stopper in a manner to prevent contact with other surfaces where casual bacteria may be picked up.

(e) Fill the bottle from the faucet by holding the bottle at an angle to expose as little opening as possible to air. When the bottle is full, take it away without allowing either the the inside of the bottle neck or the stopper to touch the faucet.

(f) Take the sample to the laboratory within two hours, if possible, or as directed by the laboratory. If the sample cannot be delivered within two hours, it should be refrigerated. In no case should you hold the sample over 24 hours. During the holding period, the temperature of the water should be maintained as near that of the source as possible. (An exception is the test for fecal coliform. This sample must be immediately subjected to and maintained at a temperature of 45°C.)

<u>Storage and Distribution</u>

As in water treatment, trouble-shooting in the storage and distribution system is essentially a matter of looking for trouble, preferably in a systematic way, and then making the necessary repairs. The items to be checked include mains, valves, hydrants, leaks, and customer services.

<u>1. Mains</u>. Because water mains are buried and only rarely uncovered or exposed, a systematic routine checking procedure cannot ordinarily be carried out. Nevertheless, by keeping accurate records, you can spot budding failures and correct them in advance.

Keep records of leakage and breakage, and measure the amount of friction in the pipes by pressure and coefficient tests. Distribution and installation crews, as well as meter readers and service men, should be instructed to note and report any unusual conditions discovered in their routine work. When wet connections are made, or valves are inserted in pipelines, the sections cut from the pipe should be observed to note their interior condition. If it seems advisable, the sections should be stored with proper identification for later comparisons.

2. Valves. Periodic valve inspection is essential. In larger systems, this may well be the responsibility of a special crew which works continuously. In smaller systems, however, the distribution crew may have to be assigned for a definite period to this particular work.

Valves are provided in a distribution system principally to isolate small maintenance areas without disrupting service to the entire network. Thus most distribution valves suffer from lack of operation rather than from wear. They should be operated for test purposes from time to time, though there are no set timetables. This should be determined by the corrosiveness of the water, the rate of sediment accumulation, and the sizes and locations of the valves.

As a rule of thumb, valves larger than 12 inches should be operated at least once a year, while smaller ones can be tested every three years. Critical valves should be operated more often. Valve boxes or vaults located in streets subject to frequent maintenance should be checked annually to see that they have not been damaged, filled with earth, or covered over with pavement. (You think it doesn't happen!)

The following procedures should be followed in a proper valve inspection program:

(a) Number the valves consecutively for quick identification and keep a map of the location, type, size, make, and date of installation of each.

(b) Make sure all operators know where all valves are located so that they can be closed in the event of a break in the system.

(c) Operate valves in both directions, fully closed and fully open, and note the number of turns and direction of operation. Take particular care in identifying valves that operate in a direction opposite from the system standard. The use of portable, power-driven "valve operators" is in general, economically feasible for all but very small water systems.

(d) Leave the valves in the open position normally, noting any that had to be closed.

(e) Operate badly corroded valves several times. If necessary, flush out valve seats by opening a hydrant and inducing flow.

(f) Check and record the condition of the valve packing, stem, stem nut, and gearing.

(g) Check, clean, and raise (or lower) valve boxes and vaults as required.

3. *Hydrants*. *Like valves, fire hydrants* have primarily an emergency function and must be checked periodically. They are particularly vulnerable to damage and failure because they are exposed to the elements as well as the somewhat less than tender mercies of road maintenance personnel. All hydrants should be checked at least once a year; in most systems they are operated twice -- in the fall and spring. The correct inspection procedure is:

(a) Sound the hydrant for leaks.

(b) Operate and flush the hydrant, noting the ease or difficulty of operation. Repair any worn or loose parts.

(c) Check the condition of the drain valve, operating nut, nozzles, nozzle caps, chains, packing, and paint.

(d) Check the interior to see if the barrel drains properly.

(e) Note the setting of the hydrant and the distance of the nozzles from the ground and curb lines, making any necessary corrections.

(f) Lubricate the hydrant.

A good point to remember is that frequent hydrant painting has a public relations as well as a maintenance value. They are usually the only part of the distribution system seen by the general public and should look sharp at all times.

4. Leaks. Leak surveys of the distribution system are sometimes desirable, especially if water loss increases without apparent reason. This usually indicates a comprehensive test carried out by sub-dividing the system into districts, then controlling and measuring the flow into such districts for at least 24 hours. The night rate is then compared with the total rate for the 24-hour period. If the night rate indicates high water usage and the usage cannot otherwise be explained, there are probably leaks in the system. By a process of further subdivision, the source can be located.

The amount of unaccounted-for water which may be noted without giving cause for concern varies with the system. 25 percent might be acceptable in one system, while 10 percent loss in another might suggest leakage. Included in these percentages is any water delivered to the system, but not metered or included in an estimate for flat-rate customers. If a system has a high percentage of industrial or commercial use, the unaccounted-for percentage tends to be lower because the total water sold is weighted with larger units. Other factors which affect the percentages are system pressure (higher pressures mean more leaks); length, condition, and age of pipes and service lines; efficiency of meter maintenance (they may be over-registering); soil conditions; unauthorized uses of water; and the attention given to leakage reduction.

Leaks can be detected by geophones or electrical detector equipment. This includes hydrant leaks through defective drain valves, which are common. Soil conditions are a factor in locating leaks because some soils allow water to drain from the surface quickly, thus masking the location of the leak.

5. Customer Services. Checking service lines and meter installations is generally a function best performed by meter readers and service men. Little can be done toward checking the buried portion of the service line, but the condition of the meter or curb box should be inspected. One of the most frequent sources of suits against a utility is injury caused by tripping over a projecting meter or curb box. Such situations should be promptly reported and corrected. Meter readers can also report meters which have stopped operating or which are registering inaccurately, based on past readings.

6. Emergency Repairs. Every water company should be prepared to deal with emergencies, whether they are unpredictable natural disasters such as floods and landslides, man-related emergencies such as fires and explosions, or the more common problem of split pipes, blown joints, broken valves, and malfunctioning hydrants.

Equipment should always be available for emergency repairs, either as a part of the company's stock or on a contract basis with outside sources. Excavating equipment, pavement breakers, pipe cutters, pipe cleaning tools, ditch pumps, chlorinating equipment, flood lights, generators, and welding equipment are some of the items which may be needed. In addition, there should be a stock of spare pipe and fittings, repair clamps, bell joint clamps, sleeves and mechanical couplings, and spare parts for valves and hydrants.

Your own emergency stockpile and equipment should always be well-maintained. Furthermore, you should have a record of equipment that can be obtained from state and federal stockpiles or borrowed from nearby water utilities. Ditto for emergency manpower!

Some emergency repairs may be handled by company maintenance personnel and some by outside specialists on a contract basis. This will depend upon the size of the water system or maintenance area, the difficulty of repair (lines buried to depths of nine feet to prevent freezing are harder to repair than those nearer the surface), and the availability of contract cleaning and repair services.

A small company will probably not be able to handle every emergency. Specialized repair equipment not only costs a lot, but it is also costly to maintain. Some equipment requires special operator training. Thus the over-ambitious company may, in trying to cope with one problem, create others for which it is ill-prepared. When you do use your own people for emergency repairs, make sure they know what they are doing and can respond quickly to emergencies. The speed with which repairs can be made may be an important element in reducing the damage -- and the damage claims.

A final note of warning to the managers of very small companies: You may have a small waterwell system which services only 50 connections, all fairly close together. The water you are pumping may be so pure that you do not even need chlorinators, although the health department may have asked you to install them. Possibly you serve a low-income area and have a flat-rate system with no meters to be read. If that is the case, much of the material discussed here may seem irrelevant to you. You have two barrel-sized storage tanks, no complicated treatment processes, and a small distribution network. So what's to maintain?

The answer is, plenty. You still have a well which can fill up with sand, a pump and a motor which can break down, and pipes which can spring leaks. Your perfect water can begin to pick up contaminants and decline in yield. And customers become no less disgruntled in small systems than in large. You still have plenty of support functions to manage, no matter how small your company. Unfortunately, many small system managers have taken a casual attitude toward operation and maintenance -- and the system has failed, thus helping to bring small water companies into general disrepute. Don't make that mistake!

■

Chapter 4

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TRAINING AND UTILIZING PLANT OPERATORS

In a previous section, we touched briefly on personnel matters, but there we were concerned primarily with office workers. Here we look at the technicians, the plant operators in the field. One big change: You were earlier advised to understaff slightly in the paperwork department. This does not apply to operators. While you certainly will not wish to overstaff, you should have enough people to manage the many complex tasks of system maintenance. If treatment for water or wastewater is provided, state law may require you to have a qualified operator on hand -- or maybe you can qualify yourself! Many of the tasks to be performed are also hazardous, so an operator should have all the help he needs, people as well as equipment.

UNDERSTANDING THE OPERATOR PROBLEM

The public water supply and wastewater industries in the United States serve millions of people with billions of gallons of water every day. Much of it, like the wastewater that results, needs treatment. About a half million men and women work in the water utility field. The Public takes it for granted that they are doing the job in the most professional manner possible, since it is assumed that they are qualified and well-trained. Unhappily, the assumption is not always well-founded.

The Need for Qualified Operators

In 1969, the U.S. Public Health Service surveyed 969 public water supply systems to check their water quality. A substantial number of them (sometimes a majority, depending upon the particular measure used) failed to meet the chemical and bacterial standards which the Public Health Service considered either mandatory or desirable. In an attempt to pinpoint why the systems were performing so poorly, the study covered, among other things, operator training and experience. The results were not encouraging.

Items: (1) Although most of the operators had high school educations, 61 percent had not received any specialized water treatment training. (2) 77 percent were deficient in training for microbiological work, and 46 percent of those who needed chemistry training had none. (3) Many of the operators were low-paid part-time employees. (4) Only 29 percent of the full-time operators were paid more than $7,500 a year. (5) The smaller the system, the greater the difficulty in retaining qualified operators -- and also the poorer the quality of water. Table 23 gives some details of the study.

Table 23
Community Water Supply Study--
Operator Training and
Experience (all numbers are
percent of responses)

	Percent
Education Level - High School or better	84
Water Treatment Training - Short Course or better	39
Number of previous positions - None	58
Training in Sanitary Microbiology	
None	63
On-the-Job	14
Training in Chemistry (systems with more than disinfection)	
At short school or higher level	54
None or on-the-job	46
Full Time Operators	47
Staff adequate (in operator's opinion)	
Number	83
Knowledge	89
Salary	
$7,500/yr or less	84
$2,000/yr or less	37
Operators with more than 20 years experience	43
Operators with less than 2 years experience	15
Operators with less than 2 years experience who are also part-time operators	95

While it is obvious that neither training, experience, nor pay are synonymous with competence, there is certainly some significance in the fact that the poorest water systems had the least trained operators. The water industry has begun to realize that it has been lax in the area of operator training, especially since wastewater treatment problems have become so important. Many individuals and organizations in the field have pressed for improvement in recent years. It is good to report that there has, in fact, been some improvement.

Table 24 indicates the number of certified operators in each state in 1971.* As noted else-

*This and subsequent tables on operator certification are taken from "Operator Certification Programs for Water and Wastewater Personnel," Journal of the Water Pollution Control Federation, XLIV (December 1972), 2218-28, and are used with their permission.

where, more and more states have begun to raise operator standards through certification programs, either providing training courses where certification is voluntary or by making certification mandatory.

Table 24
Number of Certified Operators by State

(January 1971)

	Water Program		Wastewater Program	
	As of January 1971	Certified in 1970	As of January 1971	Certified in 1970
Alabama				
Alaska*				
Arizona	*165*		*142*	
Arkansas	454	84	297	44
California†	*3,000*‡	*341*‡	*1,700*	*150*
Colorado	*515*	*192*	*383*	*197*
Connecticut	21	2	326	42
Delaware		*12*		
District of Columbia				
Florida	2,000		1,500	
Georgia				
Hawaii	‡	‡	*43*	*17*
Idaho	*111*	*22*	*100*	*20*
Illinois	2,349	221	1,300	200
Indiana	370	40	618	166
Iowa	1,366	160	1,022	190
Kansas	*412*	*36*	*248*	*47*
Kentucky	440	119	497	149
Louisiana	1,250	120	1,020	75
Maine			75	60
Maryland	197	76	224	82
Massachusetts				
Michigan	968	128	913	132
Minnesota	587	73	502	117
Mississippi*				
Missouri				
Montana	558	574	470	467
Nebraska	*101*	*15*	*100*	*30*
Nevada	‡	‡	*28*	*9*
New Hampshire				
New Jersey	559	48	892	53
New Mexico	*20*	*18*	*20*	*18*
New York	2,240	128		285
North Carolina	207	96	125	125
North Dakota				
Ohio	1,376	170	1,758	201
Oklahoma	1,407	485	838	321
Oregon	*149*	*30*	*264*	*55*
Pennsylvania				
Rhode Island				
South Carolina	871	195	1,280	978
South Dakota	137	15	80	15
Tennessee	575	100	261	54
Texas	4,486	1,444	2,661	1,002
Utah	*93*	*5*	*53*	*5*
Vermont				
Virginia	303		362	
Washington	*460*	*90*	*477*	*88*
West Virginia	545	108	767	50
Wisconsin	832	218	953	337
Wyoming*				
British Columbia			*48*	*13*
Mandatory programs	24,098	4,604	18,741	5,152
Voluntary Programs	*5,026*	*761*	*3,606*	*649*
Total	29,124	5,365	22,347	5,801

* No program reported.
† California wastewater program is mandatory for plants built with federal or state funds.
‡ Hawaii and Nevada included in California statistics.
Note: *Italics denote voluntary programs;* other states have mandatory programs.

Source: Journal WPCF

A joint committee of the American Water Works Association and the Water Pollution Control Federation studied the matter in 1971. It found that 47 states had some certification program and that it was mandatory in a majority of states (31 for water facilities, 33 for wastewater). The trend toward certification was obvious. Over 60 percent of the mandatory programs were instituted after 1967, and fully three-fourths of them were begun in the last decade. However, there is no common national standard for training. qualifying, and certification.

These figures represent a real challenge for the water system manager. Often faced with a tight budget and customers who resist rate hikes, he must still find a way to get the operators the state says he must have.

The challenge cannot be met unless you can convince your board that it must spend some money for operators. You must have a pay plan that will attract high quality employees. It should be on a level with other utilities, such as electricity and gas; in municipal organizations, it should compete with the starting salaries for policemen and firemen. At present, for example, starting salaries in the average police or fire department, for men with no experience, are at least $20 to $60 higher than for a junior water plant operator. This seems somewhat unfair since no fire department can even function without water! And as concern for pollution increases, it is apparent that the water-wastewater plant operator performs a vital function.

Of course, it is a familiar circular problem. As long as operators are untrained, it is hard to justify higher salaries for them. Without the higher salaries, however, they have little incentive to undergo the necessary training. Do not use this as a dodge. Find some way to get pay up, set high standards, and then see that your employees meet those standards.

Dealing with Employees

You may get better employees with higher pay, but you will not keep them unless you treat them fairly. There are many college courses (even degree programs) and books in the field of "personnel management," and you may wish to partake of these if you are a serious manager who wants to do more than just pay bills. The American Water Works Association offers management training for utility managers at Michigan State University and other locations. MSU also has an EPA sponsored home-study (correspondence) course for middle managers. Government agencies such as the Rural Electrification Administration and EPA also publish a number of booklets which cover personnel and other management topics. If you are really short of time for reading, some of the tips given here, while by no means a Dale Carnegie course, may be helpful.

Rule #1. Deal with people, not personnel. Once you start thinking of your company's employees as "personnel," you are already headed in the wrong direction. It is degrading to people no matter how high or low their status, to know that they are regarded primarily as a name on a form or a Social Security number. You will be asking your employees to do some pretty dirty and dangerous jobs. They deserve respect and personal attention. Besides, talking too much about your "personnel" seems to set you apart as a big shot and isn't good for close working relations

Rule #2. Provide some symbols of position. There is no substitute for good pay, but if your budget can stand it, a few other niceties do tend to make for happy employees. For example, uniforms usually give some status to plant operators or others who do manual labor since they set them apart as "important people." It is a nice gesture if the company pays the cleaning bills, too. (Make sure the rate structure can stand it: Your customers have to pay their own cleaning bills.) One thing which will cost you nothing and usually pays dividends is a title. How much nicer it is to be the "assistant plant operator" or "chief maintenance man" than just another employee! (Some studies have shown, for example, that work output is greater from janitors who bear such titles as "chief custodian" or the like.)

Rule #3. Lay down the rules, but don't harp on them. Until an employee proves otherwise, he should be considered trustworthy and competent. It is insulting to be asked every day if you have made a routine check which you have not missed in years. One of the hardest things for most competent managers to do is delegate responsibility, but you should make a real effort in this direction. You can bog the entire business down by becoming involved in every detail, and employee morale will suffer as well. Make sure your operators know their jobs and then leave them alone to do them. (Ditto for office staff.)

Rule #4. Be careful in handing out instructions. In the first place, your directions should always come across as "instructions" with some reasoning behind them rather than "orders" from on high. Be precise and accurate in stating what you want and make sure the operator understands this. Be fair in your estimate of a job or problem. Adolph Hitler used to decree the impossible and execute people for non-compliance, but he came to a bad end. Expect, and assume, compliance with reasonable instructions. Then do enough checking to know that you are getting it and never let a sloppy job get by.

In general, oral instructions are preferable to a long string of written memoranda. However, this is not always the case, and you should use written instructions when it seems wise.

Here is one way to determine when it is necessary:

+ is the job simple and routine?

+ has the worker done the job before?

+ is the job repetitive?

+ will the job require very little time?

+ can the manager check its progress easily?

+ if there in a mistake, will it be unimportant?

+ is there any emergency?

If the answer to these questions is yes, oral instructions are suitable.

On the other hand, written instructions should be given if the answer to the following questions is yes:

+ does the job involve many details?

+ is the employee unfamiliar with the job?

+ has the employee failed to carry out previous oral instructions?

+ is more than one level of supervision involved?

+ will a mistake be a serious matter?

+ is one person to be held responsible for the job?

Rule #5. Schedule your own time so that employees do not have to wait for you. There is nothing so frustrating as being hung up on a problem because the big man doesn't have the time to give you the answers you need. Some managers are over-worked; more often, they simply use their time poorly and think they are overworked. (Some people even feel more important when they have a desk piled high with unsolved problems and unanswered mail.)

You will have routine and special kinds of decisions to make, and you should devote some time to planning and creative work. There are enough hours in the day if you avoid frittering them away. And employees will love a manager who can answer a simple question in less than a week.

Following these fairly simple rules should help you to get the best out of the talent you have. One final thought -- so obvious these days that we won't call it a rule but a commandment: Prejudice against women and minorities is out. Your personal feelings in such matters are your own business, but discrimination by a manager who wants a good organization is unthinkable. In hiring, paying, promoting, and instructing, treat everyone the same. (Remember the Golden Rule we had you post? It applies here.)

OBTAINING SKILLED OPERATORS

The common assumption is that competence in a certain field is best secured by (1) Specifying what the job requirements are, (2) making available the training necessary to meet those requirements, and (3) instituting a system for certifying that requirements have been met.

Water and wastewater plant operation has followed this pattern. As the manager, you should know what jobs your operators will have to do and what skills they need to do them. If your present operators lack the skills, you must see that they get the necessary training leading to certification. You should probably treat certification as mandatory, even where your state regards it as voluntary. If you are the system superintendent, you may be required to (or wish to) become certified yourself.

Job Requirements

Water and wastewater plant operators are usually classified by letter (A, B, C, D) or number (I, II, III, IV) and the requirements for the positions vary according to the size and complexity of the system. The two top positions sometimes demand at least some college work while the latter two usually require some high school work or completion of grammar school. Experience may sometimes be substituted for part of the educational requirement. Less experience is required for the lower positions. Job requirements for a position of water or wastewater trainee are also sometimes stated.

A sample set of job descriptions of A and D water and wastewater plant operators is given in Table 25. These are as adopted by the South Carolina Board of Certification. Recommended descriptions and specifications in your state may be obtained from the state agency having jurisdiction or from the Association of Board of Certification.

Note that all the positions have some physical qualifications. This is important, especially in wastewater treatment. This industry already has a high accident rate compared to other industries, and the rates go up if employees do not have minimum physical abilities. Experience indicates, for example, that a large majority of the accidents are not due to exotic chemicals or explosions, but from falls and from sprains due to improper lifting. Give all your operators a physical examination before they begin work. If any physical defects show up, ask them to sign waivers and file them with the state Workmen's Compensation Board. Do not arbitrarily rule out women or the slightly handicapped, but make sure they understand the demands of the job before you sign them on.

Table 25
Sample Operator
Job Descriptions

JOB TITLE: Class A Water Operator

JOB SUMMARY: This is general operation and supervision of equipment and facilities of groups I and II water treatment plants.

EXAMPLES OF WORK PERFORMED:

1. Have knowledge and ability to perform all job duties common to class B operators.
2. Manage entire plant operations and personnel.
3. Interview potential employees; hire or recommend to higher authority.
4. Make recommendations regarding plant capacity and needs for new equipment.
5. Responsible for setting up budget for plant.
6. Be skilled in public relations including speaking engagements.

Table 25 (Continued)

7. Instill safety consciousness in all plant personnel.
8. Prepare and maintain standard operating procedure manual.
9. Establish operator training programs.
10. Be responsible for plant inventory.
11. Conduct minor research on improving plant efficiency.
12. Additional duties as directed by supervisor.

JOB SPECIFICATIONS

EDUCATION: Must have the equivalent of a high school education.

EXPERIENCE: Six years' experience in the field of water treatment.

RESPONSIBILITIES: Responsible for entire operation of plant and directing the activities of all plant personnel. Must organize and direct plant in such a way as to produce safe, palatable water and operate plant efficiently within budget. Faulty decisions or errors could result in disease, infection, or death of humans or animals.

SUPERVISION: Responsible for directing the activities of all plant personnel.

WORKING CONDITIONS: Good working conditions, almost entirely inside.

PHYSICAL DEMANDS: Little physical demand necessary.

HAZARDS: Small possibility of being exposed to diseases or infections, or falling into open tanks or manholes.

CONTACT WITH OTHERS: Very frequently deal with officials and supervisor, as well as with general public. Must maintain good public relations with all these people.

JOB TITLE: Class A Wastewater Operator.

JOB SUMMARY: This is general operations and supervision of equipment and facilities of groups I, II, III, IV wastewater treatment plants. Minimum requirements for an operator in charge of a group IV plant is an A certificate, as specified by the S.C. Board of Certification of public water and wastewater plant operators.

EXAMPLES OF WORK PERFORMED:

1. Have knowledge and ability to perform all job duties common to class B operators.
2. Manage entire plant operations and personnel.
3. Interview potential employees; hire or recommend to higher authority.
4. Make recommendations regarding plant capacity, and needs for new equipment.
5. Responsible for setting up budget for plant.

Table 25 (Continued)

6. Be skilled in public relations including speaking engagements.

7. Instill safety consciousness in all plant personnel.

8. Have knowledge of all pollution standards established by state and federal agencies.

9. Prepare and maintain standard operating procedure manual.

10. Establish operator training programs.

11. Be responsible for plant inventory.

12. Conduct basic research on improving plant efficiency.

13. Additional duties as directed by supervising authority.

JOB SPECIFICATIONS

EDUCATION: Must have the equivalent of a high school education.

EXPERIENCE: Six years' experience in the field of wastewater treatment.

RESPONSIBILITIES: Responsible for entire operation of plant(s) and directing the activities of all plant personnel. Must organize, and direct plant(s) in such a way as to prevent violating receiving stream standards and operate plant(s) efficiently within budget. Faulty decisions or errors could result in disease or infection to humans as well as property damage to serviced or neighboring communities.

SUPERVISION: Responsible for directing the activities of all plant personnel.

WORKING CONDITIONS: Good working conditions, almost entirely inside.

PHYSICAL DEMANDS: Little physical demand necessary.

HAZARDS: Small possibility of being exposed to diseases or infections; subject to many of safety hazards existing in plant operation.

CONTACT WITH OTHERS: Very frequently deals with officials and supervisor, as well as with general public. Must maintain good public relations with all these people.

JOB TITLE: Class D Water Operator

JOB SUMMARY: This is general operation and maintenance of equipment and facilities of a water treatment plant. Minimum requirements for an operator in charge of a group II plant is a D certificate as specified by the S.C. Board of Certification of public water and wastewater plant operators.

EXAMPLES OF WORK PERFORMED:

1. Operate plant in an efficient manner as prescribed by supervisor.

Table 25 (Continued)

2. Recognize and identify operational problems within the plant.

3. Notify chief operator or supervisor of any unusual occurrences.

4. Record accurate readings and occurrences in plant log books.

5. Take samples for pH and chlorine. Check temperature, weather data and flow data.

6. Repair or direct trainee in repairing plant equipment as assigned by chief operator or supervisor.

7. Initiate general housekeeping practices.

8. Additional duties as directed by chief operator or supervisor.*

*If D class operator is in charge of a group II plant, additional duties and responsibilities should be included. For example the operator may be responsible for purchasing materials, hiring, and making more decisions than stated above. Refer to descriptions A, B, and C for examples of work operator might perform.

JOB SPECIFICATIONS

EDUCATION: Must have the equivalent of a grammar school education.

EXPERIENCE: Have at least one year's full time experience as an operator in operation of a water treatment plant.

RESPONSIBILITIES: Makes decisions within predetermined framework, as determined by supervisor. Responsible for efficient operation of plant and quality of effluent. Faulty operation or errors could possibly result in diseases, infection or death to humans or animals.

SUPERVISION: May be responsible for directing the activities of trainees.

PHYSICAL DEMANDS: Occasionally opens or closes heavy valves and lifts heavy tools or equipment. Occasionally works in strained quarters when repairing or cleaning equipment. Considerable walking in checking plant operations.

WORKING CONDITIONS: Works both inside and outside (mostly outside); exposed to oil, grease, water and cleaning and hazardous oper. chemicals.

HAZARDS: Exposed to diseases or infections; possible injury due to gases. Danger of falls into open tanks or manholes.

CONTACT WITH OTHERS: Occasionally must deal with public and municipal officials (mostly by phone).

JOB TITLE: Class D Wastewater Operator

JOB SUMMARY: This is general operation and maintenance of equipment and facilities of a wastewater treatment plant. Minimum requirements for an operator in charge of a group I plant is a D certificate as specified by the S.C. Board of Certification of public water and wastewater plant operators.

Table 25 (Continued)

EXAMPLES OF WORK PERFORMED:

1. Operate plant in an efficient manner as prescribed by supervisor.
2. Recognize and identify operational problems within the plant.
3. Notify chief operator or supervisor of any unusual occurrence.
4. Record accurate readings and occurrences in plant log books.
5. Take samples for pH, chlorine, and settleable solids. Check temperature, weather data, and flow data.
6. Repair or direct trainee in repairing plant equipment as assigned by chief operator or supervisor.
7. Carry out schedule for removal of sludge (supervise work of helper).
8. Initiate general housekeeping practices.
9. Additional duties as directed by chief operator or supervisor.*
10. Must show progress toward C certificate.

*If D class operator is in charge of a group I plant, additional duties and responsibilities should be included. For example the operator may be responsible for puchasing materials, hiring, and making more decisions than stated above. Refer to descriptions A, B, and C for examples of work operator might perform.

JOB SPECIFICATIONS

EDUCATION: Must have the equivalent of a grammar school education.

EXPERIENCE: Have at least one year's full time experience as an operator in operation of a wastewater treatment plant.

RESPONSIBILITIES: Makes decisions within predetermined framework (STDS), as determined by supervisor. Responsible for efficient operation of plant and quality of effluent. Faulty operation or errors could possibly result in disease or infection to humans as well as property damage to serviced or neighboring communities.

SUPERVISION: May be responsible for directing the activities of trainee.

PHYSICAL DEMANDS: Occasionally opens or closes heavy valves and lifts heavy tools or equipment. Occasionally works in strained quarters when repairing or cleaning equipment. Considerable walking in checking plant operations.

WORKING CONDITIONS: Works both inside and outside (mostly outside) and is exposed to wastewater, oil, grease, sludge, water and cleaning chemicals.

HAZARDS: Exposed to diseases or infections; possible injury due to gases. Danger of falls into open tanks or manholes.

CONTACT WITH OTHERS: Occasionally must deal with public, and municipal officials (mostly by phone).

The Training Program

With job requirements decided, either by your company or a state agency, you should see that all operators get the appropriate training, either before they are hired or while working. Some courses may be taken by correspondence in the employee's off-duty time, while others might require travel. You will have to work out with the employees and your board such matters as when the training can be fitted into the work program and who is to pay for dues, tuition, travel, etc. There is also the matter of incentive for operators who have already been hired. Will the training enable them to keep their jobs? Mean an increase in pay? Result in a higher operator classification? Or all three? The employees should understand clearly what is involved for them.

1. Training Courses. The kind of training courses which are appropriate will be determined partially by the size of the company and the way the work is structured. Courses may partially overlap employee classifications. In some small utilities, one course may suffice for all employees. In any case, the course or courses should cover at least these areas:

(a) The field crews. This phase of training should be developed in close cooperation with the field superintendent or foreman, if you have these positions. Training should cover, but not be restricted to: installation of water mains, valve installation and maintenance, meter installation, making emergency repairs, and use of liquid chlorine gas and HTH for disinfection.

(b) The meter shop. This instruction may be included with the field crew course in small companies. It should include policy on installation of new meters; removal, replacement, and repair of dead meters; and recalibration of older meters.

(c) Treatment plant. The state board of health will always be happy to cooperate in preparing a training course for water and wastewater treatment plant operators. Operators should be trained to perform the regular water and wastewater tests, chemical and bacteriological, and should be familiarized with board of health requirements in these areas.

2. Types of Training Available. A variety of opportunities exist at present for training

treatment plant operators. The majority of these are short courses held periodically, and they are usually conducted by regulatory agencies in cooperation with college and university extension services. Many larger utilities conduct in-plant training for their employees, and operators from other systems are sometimes admitted. In some instances, courses are conducted by professional societies, such as the American Water Works Association, The Water Pollution Control Federation, and the National Water Well Association. The establishment of the Water and Wastewater Technical School at Neosho, Missouri, in 1959 was an encouraging step forward and one that has proven very successful.

Some AWWA sections conduct schools for training filter plant operators -- usually under the supervision of the state health department and the guidance of a local university. The Robert A. Taft Sanitary Engineering Center in Cincinnati also conducts courses of this nature. Most meter manufacturers have courses on meter maintenance, and any employees engaged in watershed work gain a lot from attending local forestry meetings or meetings of manufacturers of chemicals used in watershed work.

In general, you and your operators should get whatever training is appropriate to certification. The number of regular courses, seminars, correspondence courses, and schools available today is too numerous to list, even in an appendix, but your state health department or environmental protection agency should be able to give you the proper names and addresses. Or write the National Water Well Association, American Water Works Association, or Water Pollution Control Federation.

3. Certification. Certification is a legal process whereby those who pursue particular occupations must have some sort of document (a certificate, usually) attesting to their competence in that occupation. It is not exactly the same as a permit because many businesses must obtain permits before they can operate, without having to show they are competent in anything. Certification is commonly used where a substantial public interest is involved -- medicine, law, education, engineering, or accounting. It is a mechanism for imparting information, providing avenues of communication, and measuring manpower needs.

As in many other fields, the recent trend in water and wastewater operation is toward an upgrading of the profession by means of formal certification. The impetus for this has come both from the industry itself, which would like to improve its image and provide better service, and from government agencies concerned about public health and pollution. The belief is that certification of operators, in the long run, will improve water and wastewater system performance. In the short-run, certification is held to be a means of increasing the operator's incentive to add to his own qualifications. This, in turn, will increase the competence of the operator profession as a whole because the incompetents will be weeded out and those who remain will be better qualified than before. Enrollment in training courses has increased wherever certification has been introduced.

Certification has its detractors, however. In the first place, it is difficult to say exactly what the appropriate standard of competence should be for operators. Do we take the average competence that now exists in the field and use that as the standard -- or do we try to raise standards by requiring higher qualifications than we now have on the average? The usual approach has been to include both factors in certification requirements, setting standards perhaps a bit higher than the average, but still keeping them within reach of the average person. For example, it is not common to require more than a high school education, even for the higher-ranking operators; the Community Water Supply Study mentioned earlier showed that most operators already had this.

As always when standards are raised, fears have been expressed that certification would become a device for improperly restricting entry into the profession, and for denying jobs to persons who were perfectly capable of doing the job but were unable to meet paper requirements. It is fair to say that this has indeed happened in other fields. The medical profession, for example, has such severe standards that, in most places, even simple tasks such as taking blood pressure must be done by a fully-qualified doctor. Such practices are justified on the grounds of protecting the public interest through high standards, but they also have the effect of increasing the pay and prerequisites of the profession itself.

It would be unfortunate if certification of water and wastewater operators did work to erect obstacles to employment by persons without high intellectual skills. Too often in recent years, college degrees have been required for jobs which could be done by those with a high school education. There is no evidence that this is happening in the water and wastewater field.

On balance, it seems desirable for you to help your field operators become certified. They will be in a better position to advance in their occupation and the community will probably get better service.

Certification is usually administered by a state agency concerned with public health or water pollution control. In most cases, the authority for the certification department or board is state law, although simple agency regulations sometimes suffice. Tables 26 and 27 give a state-by-state breakdown of certification administrators, both for voluntary and mandatory water and wastewater programs.

Table 26
State Certification
Administrators -- Voluntary

	Water Program	Wastewater Program
Alaska	No program	No program
Arizona	AWWA section	WPCF association
California*	AWWA section	WPCF association
Colorado	Interagency co-op.	Interagency co-op.
Delaware	AWWA section	See Table I
District of Columbia	AWWA section	No program
Hawaii	AWWA section	WPCF association
Idaho	Certification board	Certification board
Kansas	AWWA section	WPCF association
Mississippi	No program	No program
Missouri	AWWA section	WPCF association
Nebraska	*AWWA section*	*WPCF association*
Nevada	AWWA section	WPCF association
New Hampshire	No program	See Table I
New Mexico	Certification board	Certification board
Oregon	State health dept.	State health dept.
Rhode Island	No program	State health dept.
Utah	Special commission	Special commission
Washington	AWWA section	WPCF association
Wyoming	No program	No program
British Columbia	No program	WPCF association

*California wastewater program mandatory for plants built with state or federal grants.
Source: WPCF Journal

Since certification is becoming so important, you will want to be familiar with the requirements if your state has a program. Tables 28-33 give this information on a state-by-state basis as of 1971. Check for updates in your state.

WORKLOAD PLANNING

Over the past few decades, a number of techniques have been developed that enable managers to better control the operation of water and wastewater systems. Among these techniques, workload planning has had considerable success. Its purpose is to standardize certain maintenance tasks, the time needed to perform these tasks, the frequency of performance, and the level of skill needed.

You should begin workload planning by defining the minimum requirements of routine and non-routine operation and maintenance, including the maintenance of equipment. All equipment on hand should be surveyed and its condition should be evaluated before you get underway. If the facility is already in operation, it is even more crucial to make sure that there is adequate first-line and stand-by equipment in good working condition. If not, you probably will not be able to meet the work goals you have set.

The next step is to examine each of the system components and attempt to estimate the frequency, skill, level, and time required for the various tasks involved. This will result in a performance matrix which will serve as an initial guideline in deciding how many people of what skill level you will need to operate and maintain the facility efficiently.

Table 27
State Certification
Administrators -- Mandatory

	Water Programs					Wastewater Programs				
	Certification Board	Health Agency	Other	Law Passed	Program Effective	Certification Board	Health Agency	Other	Law Passed	Program Effective
Alabama		X		1971	1971		X		1971	1971
Arkansas		X		1957	1957			X	1971	1971
Connecticut		X		1967	1967		X		1969	1969
Delaware	No mandatory water program							X	1968	
Florida		X		1971	1970*			X	1971	1970*
Georgia	X			1969	1972	X		X	1969	1972
Illinois			X	1963	1965			X	1966	1966
Indiana		X		1971	1972		X			1960
Iowa		X		1965	1966		X		1965	1966
Kentucky		X		1966	1967		X		1966	1967
Louisiana		X		1972	1972		X		1972	1972
Maine	X			1969	1971			X	1969	1970
Maryland	X			1967	1971	X			1967	1971
Massachusetts	X			1971	1972	X				1972
Michigan		X		1941	1942		X		1949	1949
Minnesota	X			1971	1972	X			1971	1972
Montana	X			1967	1967	X			1967	1967
New Hampshire	No mandatory water program							X	1971	1972
New Jersey			X	1919	1919			X	1919	1919
New York		X		1970†	1937			X	1970†	1930
North Carolina	X			1969	1971	X			1969	1971
North Dakota		X		1971	1972		X		1971	1972
Ohio		X		1937	1938		X		1937	1938
Oklahoma		X		1959	1959		X		1959	1959
Pennsylvania	X			1968	1971	X			1968	1971
South Carolina	X			1966	1968	X			1969	1971
South Dakota	X			1970	1970	X			1970	1970
Tennessee	X			1971	1971	X			1971	1971
Texas		X		1945	1945		X		1945	1945
Vermont		X		1971	1972			X	1970	1972
Virginia	X			1970	1973	X			1970	1973
West Virginia		X		1933	1933		X		1966	1966
Wisconsin			X	1969				X	1969	
Total	12	16	3			11	12	10		

*Under then existing powers of the department of health.
†Law revised.

Table 28
Certification Requirements for Water Facilities (1971)

Programs	Certificate Requirements					Education Qualifications									Experience Qualification (yr)	
						Highest Class				Lowest Class						
	Written Application	Written Exam	Oral Exam	Either Oral or Written Exam	Interview	College Degree	High School	High School Equivalent	None	High School	High School Equivalent	8th Grade	Other	None	Highest Class	Lowest Class
Mandatory programs																
Alabama																
Arkansas	X	X														
Connecticut			X													
Florida	X	X							X					X	4	1
Georgia	X	X					X							X	2	1
Illinois	X			X				X						X	8	1
Indiana	X	X														
Iowa	X	X						X						X	6	
Kentucky	X	X				X					X				5	1
Louisiana	X	X						X					X		2	1
Maine	X	X	X		X				X					X		
Maryland	X			X	X	X*						X			5	1
Massachusetts																
Michigan	X	X				X						X			5	0.08
Minnesota	X	X					X					X			7	2
Montana	X	X							X					X		
New Jersey	X	X					X			X					3	1
New York	X					X					X				1	0.08
North Carolina	X	X						X			X				3	1
North Dakota																
Ohio	X	X						X			X				5	1
Oklahoma	X	X							X					X	8	
Pennsylvania	X	X							X					X	3	0.5
South Carolina	X	X					X					X			6	1
South Dakota	X	X					X						X			1
Tennessee																
Texas	X	X					X			X					8	1
Vermont		X					X					X			4	0.08
Virginia	X	X				X				X						
West Virginia	X	X					X					X			8	0.25
Wisconsin				X			X							X	1	
Total	24	27	2	3	2	5	9	5	5	3	4	6	2	9		
Voluntary programs																
Arizona	X	X				X					X				6	0.5
California	X	X	X						X					X	5	2
Colorado	X	X							X					X		
Delaware	X			X			X					X			6	1
District of Columbia	X			X			X					X			6	1
Hawaii	X	X	X												5	2
Idaho	X	X	X			X							X		6	1
Kansas	X	X														
Missouri	X	X	X						X					X	4	1
Nebraska		X				X					X				3	1
Nevada	X	X	X												5	2
New Mexico	X	X							X					X	8	1
Oregon	X	X							X					X	5	2
Utah	X	X					X					X			9	1
Washington	X	X				X						X			5	1
Total	14	13	5	2		4	3		5		2	4	1	5		

*Only 2-yr college required.

*For this and information previously cited, we are indebted to "Operator Certification Programs for Water and Wastewater Personnel," *Journal of the Water Pollution Control* Federation, XLIV (Dec. 1972), 2218.28.

Table 29
Certification Programs for Water Facilities (1971)

	Facilities Requiring Certified Operators					Personnel Who Must Be Certified				
	Political and Investor Owned	Industrial	Treatment Plant	Distribution System	Not Covered Below	Superintendent	Principal Operator	Assistant Operator	Laboratory Personnel	Maintenance Personnel
Alabama	R		R	R		R	R			
Arizona	V	V	V	V		V	V	V	V	V
Arkansas	R	R	R	R		R	R	R	V	V
California	V	V	V	V		V	V	V	V	V
Colorado	V	V	V	V		V	V	V	V	V
Connecticut	R		R				R			
Delaware	V	V	V			V	V	V		
Florida	R	R	R							
Georgia	R	R	R	R	100	R	R	R		
Hawaii	V	V	V	V		V	V	V	V	V
Idaho	V	V	V	V		V	V	V	V	V
Illinois	R		V	V		V	V	V		V
Indiana	R		R	R	100	R	V	V	V	V
Iowa	R	V	R	R		V	R	V	V	V
Kansas	V	V	V	V		V	V	V	V	V
Kentucky	R	R	R	R						
Louisiana	R	R	R	R			R			
Maine	R		R	R		R				
Maryland	R	R	R	R		R	R			
Massachusetts	R									
Michigan	R	V	R	V		V	R	V	V	V
Minnesota	R		R	R		R	R	R	R	R
Missouri	V	V	V	V		V	V	V	V	V
Montana	R	R	R	R	10	R	R	V	V	V
Nebraska	V	V	V	V		V	V	V	V	V
Nevada	V	V	V	V		V	V	V	V	V
New Jersey	R		R	R		R	V	V		
New York	R	R	R	R			R	R		
North Carolina	R	V	R				R			
North Dakota	R		R	R	500	R	V	V	V	V
Ohio	R	R	R	R		R	V	V	V	V
Oklahoma	R	V	R	R	50	R	R	R	R	R
Oregon	V		V	V	10	V	V	V	V	V
Pennsylvania	R	R	R	R		V*	V*	V	V	V
South Carolina	R	R	R				R	R	R	R
South Dakota	R	R	R	R	500	V	R	V	V	V
Tennessee	R		R	R		V	R	V	V	V
Texas	R		R	R			R			
Utah	V	V	V			V	V	V		
Vermont			R			R	R	R		
Virginia	R	R	R	R			R			
Washington	V	V	V	V		V	V	V	V	V
West Virginia	R	R	R	R		R	R	R	R	
Wisconsin	R	R	R				R			
Totals for mandatory programs	30 R	15 R 4 V	29 R 1 V	22 R 2 V		14 R 6 V	21 R 6 V	8 R 11 V	4 R 10 V	3 R 11 V
Totals for voluntary programs	14 V	13 V	14 V	11 V		14 V	14 V	14 V	11 V	11 V
Totals for all programs	30 R 14 V	15 R 17 V	29 R 15 V	22 R 13 V		15 R 20 V	20 R 20 V	8 R 25 V	4 R 21 V	3 R 33 V

*Law requires "responsible operator" to be certified.

Note: *Italics denote voluntary programs;* all others are mandatory.

Table 30
Description of Certificates for Water Programs (1971)

Programs	Grade Classifications: Municipal Treatment	Distribution Systems	Industrial Plants	Certificate Duration: Permanent	Renewable (yr)	Can Be Revoked
Mandatory programs						
Albama	IV-I				5	X
Arkansas	C-A	C-A	C-A		2	X
Connecticut				X		X
Florida	C-A				1	X
Georgia	IV-I	IV-I	IV-I		1	X
Illinois					3	X
Indiana					2	X
Iowa	IV-I	I-III			1	X
Kentucky	IV-I	I-IV	I-IV		1	
Louisiana	C-A	C-A			1	X
Maine	I-IV				1	
Maryland	D-A	D-C	I-IV		3	X
Massachusetts					1	X
Michigan	I-III	I-II		X		
Minnesota	A-D	A-D			3	X
Montana	V-I	V-I	V-1		1	X
New Jersey	III-I	III-I			1	X
New York				X		
North Carolina	C-A				1	
Ohio	I-IV	I-II		X		
Oklahoma	D-A	D-A			1	X
Pennsylvania	WC3-WA1				2	X
South Carolina	D-A		D-A		1	X
South Dakota	I-III	I-II			1	X
Texas	D-A	D-A		X*		X
Vermont	I-IV			X		
Virginia					1	
West Virginia	III-I	III-I	III-I	X		X
Wisconsin	IV-I				2	X
Total	5 I-IV 4 C-A 13 others	3 I-II 2 D-A 2 C-A 15 others	2 I-IV 5 others	7		21
Voluntary programs						
Arizona	D-A	D-A	D-A		1	X
California	IV-I				3	X
Colorado	D-A				5	
Delaware	IV-I				2	
Hawaii	IV-I				3	X
Idaho	IV-1	IV-I	IV-I		1	X
Kansas	D-A	D-A	D-A		5	X
Missouri	D-A				2	
Nebraska	IV-I	IV-I	IV-I	X		
Nevada	IV-I				3	X
New Mexico	D-A				2.5	
Oregon	III-I			X		
Utah	VI-I				5	X
Washington	II-I	III-I			1	X
Total	7 IV-I 5 D-A 3 others	2 D-A 2 IV-I 2 III-I	2 D-A 2 IV-I	2		8

*Only highest grade is permanent.

Table 31
Certification Requirements for Wastewater Facilities (1971)

Programs	Certificate Requirements: Written Application	Certificate Requirements: Written Exam	Certificate Requirements: Oral Exam	Certificate Requirements: Either Oral or Written Exam	Certificate Requirements: Interview	Education Qualifications, Highest Class: College Degree	Education Qualifications, Highest Class: High School	Education Qualifications, Highest Class: High School Equivalent	Education Qualifications, Highest Class: None	Education Qualifications, Lowest Class: High School	Education Qualifications, Lowest Class: High School Equivalent	Education Qualifications, Lowest Class: 8th Grade	Education Qualifications, Lowest Class: Other	Education Qualifications, Lowest Class: None	Experience Qualification (yr): Highest Class	Experience Qualification (yr): Lowest Class
Mandatory programs																
Alabama																
Arkansas	X			X				X			X				2	1
Connecticut	X			X	X	X							X		14	1
Delaware	X			X					X					X		
Florida	X	X							X					X	4	1
Georgia	X	X					X							X	2	1
Illinois	X	X				X						X			6	1
Indiana	X	X				X					X				3	1
Iowa	X	X						X						X	6	
Kentucky	X	X				X					X				5	1
Louisiana	X	X						X						X	2	1
Maine	X	X					X						X		12	2
Maryland	X			X	X	X*						X			5	1
Massachusetts	X	X	X			X								X	12	1
Michigan	X	X				X					X					1
Minnesota	X	X					X					X			7	1
Montana	X	X							X					X		
New Hampshire	X	X	X			X					X				12	2
New Jersey	X	X						X		X					3	1
New York	X	X				X					X					
North Carolina	X	X				X						X				
North Dakota																
Ohio	X	X						X			X				5	1
Oklahoma	X	X							X					X	8	
Pennsylvania	X	X							X					X	3	0.5
South Carolina	X	X					X					X			6	1
South Dakota	X	X					X									
Tennessee																
Texas	X	X					X			X					8	1
Vermont	X	X						X							10	2
Virginia	X	X				X				X						
West Virginia	X	X					X					X			7	1
Wisconsin		X					X							X	1	0.5
Total	29	26	2	4	4	11	8	6	5	3	7	6	3	10		
Voluntary programs																
Arizona	X	X				X					X				6	0.5
California	X	X	X			X					X				12	0.5
Colorado	X	X							X					X		
Hawaii	X	X						X		X					8	2
Idaho	X	X	X			X							X		6	1
Kansas	X	X											X			
Missouri	X	X	X						X					X	4	1
Nebraska	X	X				X							X		6	1
Nevada	X	X	X			X*					X				5	1
New Mexico	X	X							X					X	6	1
Oregon	X	X							X					X	5	1
Rhode Island																
Utah	X	X					X					X			5	
Washington	X	X				X						X			6	0.5
British Columbia	X	X					X						X		5	1
Total	14	14	4			6	2	1	4		4	2	4	4		

*Only 2-yr college required.

Table 32
Certification Programs for
Wastewater Facilities (1971)

	Facilities Requiring Certified Operators					Personnel Who Must Be Certified				
	Political and Investor Owned	Industrial	Treatment Plant	Distribution System	Not Covered Below	Superintendent	Principal Operator	Assistant Operator	Laboratory Personnel	Maintenance Personnel
Alabama	R		R			R	R			
Arizona	V	V	V	V		V	V	V	V	V
Arkansas			R			V	R	R	V	V
California	V	V	V			V	V	V	V	V
Colorado	V	V	V	V		V	V	V	V	V
Connecticut	R	R	R			R	R	V	V	V
Delaware	R	R	R				R			
Florida	R	R	R							
Georgia	R	R	R	R	5,000	R	R	R		
Hawaii		V	V			V	V	V		
Idaho	V	V	V	V		V	V	V	V	V
Illinois	R	R	R		15	V	R	V	V	V
Indiana	R	R	R			R	V	V	V	V
Iowa	R	V	R			V	R	V	V	V
Kansas	V	V	V	V		V	V	V	V	V
Kentucky	R	R	R			R				
Louisiana	R	R	R	R			R			
Maine	R	V	R			V	R	V	V	V
Maryland	R	R	R	R		R	R			
Massachusetts	R	R	R			R	R	V	V	V
Michigan	R	R	R			R	V	V	V	V
Minnesota	R		R			R	R	R	V	V
Missouri	V	V	V	V		V	V	V	V	V
Montana	R	R	R	R		R	R	V	V	V
Nebraska	V	V	V			V	V	V	V	V
Nevada	V	V	V			V	V	V	V	
New Hampshire	R	V	R			R	R	V	V	V
New Jersey	R	R	R			R	V	V		
New York	R	R	R				R	R		
North Carolina	R	R	R				R			
North Dakota	R		R	R	500	R	V	V	V	V
Ohio	R	V	R			R	V	V	V	V
Oklahoma	R	V	R	R		R	R	R	R	R
Oregon	V	V	V			V	V	V	V	V
Pennsylvania	R	R	R			V	R	R	V	V
Rhode Island				V		V	V		V	
South Carolina	R	R	R				R	R	R	R
South Dakota	R	R	R	R	500	V	R	V	V	V
Tennessee	R		R			V	R	V	V	V
Texas	R		R	R			R			
Utah	V	V	V			V	V	V		
Vermont	R	R	R			V	R	R	V	
Virginia	R	R	R	R			R			
Washington	V	V	V			V	V	V	V	
West Virginia	R	R	R	R	500	R	R	R	R	
Wisconsin	R	R				R				
British Columbia	V	V	V			V	V	V		
Totals for mandatory programs	32 R	22 R 5 V	32 R	10 R		16 R 8 V	25 R 5 V	7 R 14 V	3 R 17 V	2 R 16 V
Totals for voluntary programs	12 V	13 V	13 V	6 V		14 V	14 V	13 V	11 V	8 V
Totals for all programs	32 R 12 V	22 R 18 V	32 R 13 V	10 R 6 V		16 R 22 V	25 R 19 V	9 R 28 V	3 R 28 V	2 R 24 V

Note: *Italics denote voluntary programs;* all others are mandatory.

Tables 34 and 35 are two preliminary performance matrices, the first for a water system and the second for an extended aeration-activated sludge plant. You will need to develop a matrix for your own facility, of course; the matrices here are intended only as suggestions.

Table 33
Description of Certificates for Wastewater Programs (1971)

Programs	Grade Classifications			Certificate Duration		
	Municipal Treatment	Collection Systems	Industrial Plants	Permanent	Renewable (yr)	Can Be Revoked
Mandatory programs						
Albama	I-IV				5	X
Arkansas	I-IV				1	
Connecticut				X		X
Delaware	I-IV		I-IV	X		
Florida	C-A				1	X
Georgia	IV-I	IV-I	IV-I		1	X
Illinois	I-IV			X		X
Indiana	I-IV		A-D		2	X
Iowa	I-IV				1	X
Kentucky	I-IV		I-IV		1	
Louisiana	C-A	C-A			1	X
Maine	I-IV				1	
Maryland	D-A	D-C	I-IV		3	X
Massachusetts	I-VII		I-VII			X
Michigan	D-A			X		X
Minnesota	A-D				3	X
Montana	V-I	V-I	V-I		1	X
New Hampshire	I-VI				1	X
New Jersey	III-I				1	X
New York				X		X
North Carolina	I-V		I-IV	X		
Ohio	I-IV			X		
Oklahoma	D-A	D-A			1	X
Pennsylvania	SC3-SA1				2	X
South Carolina	D-A		D-A		1	X
South Dakota	I-III	I-II			1	X
Texas	D-A	D-A		X*		X*
Vermont	I-V				2	X
Virginia					1	
West Virginia	I-IV	I-IV	I-IV	X		X
Wisconsin					2	X
Total	10 I-IV 5 D-A 12 others	2 D-A 6 others	5 I-IV 5 others	9		24
Voluntary programs						
Arizona	D-A	D-A	D-A		1	X
California					2	
Colorado	D-A				5	
Hawaii	I-IV				2	X
Idaho	V-I	V-I	V-I		1	X
Kansas	C-A	C-A	C-A			
Missouri	D-A				2	
Nebraska	IV-I	IV-I	IV-I		2	
Nevada	I-V		I-V		2	X
New Mexico	D-A				2	
Oregon	V-I			X		
Utah	V-I				1	X
Washington	V-I				1	X
British Columbia	I-V				1	
Total	4 D-A 3 V-I 6 others	4	5	1		6

*Only highest grade is permanent.

Table 34
Performance Matrix for
Water Systems

System Component Analysis	Frequency (Normal Operation)	Time Required (Minimum)	Skill Level (Minimum)
I. Well			
1. Water level	*weekly	8 - 10 hrs.	B
2. Aquifer performance	annual	24 - 72 hrs.	A
3. Incrustation & Corrosion (casing)	annual	10 min.	A
4. Water Analysis	*weekly	4 hrs.	B
5. Depth to bottom (casing)	annual	10 min.	C
II. Pump (Submersible)	annual	2 - 3 hrs.	A
1. Output Capacity	*weekly	30 min.	B
2. Amperage	*weekly	30 min.	B
3. Resistance	*weekly	30 min.	B
4. Pressure buildup to shut-off (time involved)	*weekly	30 min.	B
5. Average time for a cycle (compared with original time)	*weekly	30 min.	B
6. Check pipe for leaks, cracks, etc.	annual	30 min.	C
7. Check Electrical components	*weekly	30 min.	B
III. Pump (Jet)			
1. Output Capacity	annual	30 min.-3 hrs.	B
2. Time/pressure build-up to cut-off	*weekly	30 min.	B
3. Sounds (bearing, air, etc.)	*weekly	30 min.	B
4. Check jets for corrosion or incrustation	annual	30 min.	B
5. Check pump (corrosion or incrustation)	annual	30 min.	B
6. Check drop pipe (for leaks, cracks, etc.)	annual	30 min.	B

Note: *Denotes critical failure item

Source: NWWA Research Facility

A -- Skilled
B -- Semi-skilled
C -- Unskilled

Table 34 (Continued)

System Component Analysis	Frequency (Normal Operation)	Time Required (Minimum)	Skill Level (Minimum)
7. Average time for a cycle (compared with original data)	*weekly	30 min.	B
8. Check disconnect switch and/or...	*weekly	30 min.	B
9. Other electrical equipment for malfunctions			
10. Potentials or malfunctions			
IV. Pump (Turbine)			
1. Output Capacity	annual	30 min-3 hrs.	B
2. Time/pressure build-up till cut-off	*weekly	30 min.	C
3. Sounds	*weekly	30 min.	B
4. Check bowls	annual	2 hrs.	A
5. Check drop pipe and bowl shaft	annual	1 1/2 hr.	B
6. Check oil level	*weekly	2 min.	C
7. Check amperage	*weekly	30 min.	B
8. Check resistance	*weekly	30 min.	B
9. Check electric controls	*weekly	30 min.	B
V. Plumbing to Tanks			
1. Check for leaks	*weekly	30 min.	C
2. Check for corrosion or incrustation	*weekly	30 min.	C
3. Check all gauges and valves, etc.	*weekly	30 min.	B
4. Check pitless adapters (if present)	annual	30 min.	B
5. Check ratio of air to water	*weekly	10 min.	C
6. Check inside corrosion or incrustation	annual	1 hr.	B
IV. Softeners			
1. Check amount of salt	*weekly	10 min.	C
2. Check regeneration & backwash (time)	monthly	4 - 5 hrs.	A

Table 34 (Continued)

System Component Analysis	Frequency (Normal Operation)	Time Required (Minimum)	Skill Level (Minimum)
3. Listen to valves and equipment for unusual sounds	*weekly	30 min.	B
4. Check performance of water softeners	*weekly	30 min.	A
5. Check for leaks, corrosion and incrustation	*weekly	30 min.	C
VII. Carbon Filters			
1. Check water analysis (checking media or cartridge performance)	*weekly	30 min.	A
2. Check for leaks, corrosion and incrustation	*weekly	30 min.	C
3. Sounds	*weekly	30 min.	C
4. Check regeneration of backwash (time)	monthly	4 - 5 hrs.	A
5. Replace media or cartridge	biannually	1 hr.	A
6. Check electrical devices	*weekly	30 min.	C
7. Check flow rate	*weekly	30 min.	B
VIII. Fe, S, Mn Filters			
1. Check water analysis Fe, S, Mn	*weekly	30 min. x 3	A
2. Check flow rate	*weekly	10 min.	B
3. Check leaks, corrosion and incrustation	*weekly	30 min.	C
4. Sounds	*weekly	30 min.	C
5. Replace media or cartridge	biannual (maximum)	1 hr.	A
6. Check electrical devices	*weekly	30 min.	B
7. Check regeneration and bachwash (time)	monthly	4 - 5 hrs.	A
IX. Sand Filters			
1. Check water analysis	*weekly	30 min.	A
2. Check flow rate	*weekly	10 min.	B
3. Check leaks, corrosion and incrustation	*weekly	30 min.	C

Table 34 (Continued)

System Component Analysis	Frequency (Normal Operation)	Time Required (Minimum)	Skill Level (Minimum)
4. Sounds	*weekly	30 min.	C
5. Replace media or cartridge	biannual (maximum)	1 hr.	A
6. Check electrical devices	*weekly	30 min.	B
7. Check regeneration and backwash (time)	monthly	4 - 5 hrs.	A
X. Neutralizing Filters			
1. Check water analysis	*weekly	30 min.	A
2. Check flow rate	*weekly	10 min.	B
3. Check for leaks, corrosion and incrustation	*weekly	30 min.	C
4. Sounds	*weekly	30 min.	C
5. Replace media or cartridge	biannual	1 hr.	A
6. Check electrical devices	*weekly	30 min.	B
7. Check regeneration and backwash (time)	monthly	4 - 5 hrs.	A
XI. Chlorination			
1. Check % of Cl_2 to gal/min outflow	*daily	20 min.	A
2. Check for leaks, gas, liquid	*daily	30 min.	A
3. Check for fire or explosive potential	*daily	30 min.	A
4. Check for corrosion and incrustation	*daily	30 min.	A
XII. Auxilliary Pumps			
1. Output vs. Input	*weekly	30 min.	B
2. Sounds	*weekly	30 min.	C
3. Check for corrosion or incrustation	*weekly	30 min.	B
4. Check for worn parts, leaks, etc.	*weekly	30 min.	B
5. Check electrical fixtures	*weekly	30 min.	B

Table 34 (Continued)

System Component Analysis	Frequency (Normal Operation)	Time Required (Minimum)	Skill Level (Minimum)
XIII. Large Water Tanks, Elevated, etc.			
1. Check for corrosion	*monthly	3 hrs.	B
2. Check for cracks, bad weld, etc.	*monthly	3 hrs.	B
3. Check for paint chipping and pealing	*monthly	3 hrs.	B
4. Structural weakness	*monthly	3 hrs.	B
5. Replace paint inside and out	5 years	2 1/2 days	C

Table 35
Performance Matrix for
Wastewater Systems

Task	Skill	Time (hrs.)	Wkly. Avg. (hrs.)
Initial Overall Inspection			
a. Quick visual inspection	Operator II (most skilled)	0.08/day	0.56
b. Check maintenance schedule	Operator II	0.08/2 da.	0.30
c. Record maintenance jobs	Operator I (intermediate skill)	0.25/wk.	0.25
Check and Maintain Equipment and Tanks			
a. Maintain inlet area			
Hand cleaning of screens	Helper (least skilled)	0.75/wk.	0.75
Removal/Disposal of Debris	Helper	0.50/wk.	0.50
Comminutor cleaning	Operator I	0.50/wk.	0.50
Comminutor Maintenance	Operator II	1.00/wk.	0.12
Clean inlet area	Helper	0.02	0.56
b. Maintain blower equipment			
Check blower and equipment	Opeartor I	0.04/day	0.28
Clean filter	Operator I	0.50/4 wk.	0.12
Blower & pump maintenance (oil change)	Operator II	0.50/8 wk.	0.06
c. Clean areation tank			
Check, scrape & hose down areation tank	Helper	0.30/wk.	0.50

Table 35 (Continued)

Task	Skill	Time (hrs.)	Wkly. Avg. (hrs.)
d. Maintain air and return equipment			
Inspect equipment	Operator II	0.08/day	0.56
Clean air diffusers	Helper	0.50/2 wk.	0.25
Operate foam equipment	Operator I	0.25/2 wk.	0.13
Clean foam equipment	Helper	0.50/4 wk.	0.12
Adjust sludge return	Operator II	0.16/3 da.	0.38
Clean sludge return	Helper	2.00/4 wk.	0.50
Operate skimmer return	Operator I	0.16/wk.	0.16
Clean skimmer return	Helper	0.50/4 wk.	0.12
e. Clean clarifier			
Clean sidewalls, weirs, and still box	Helper	0.25/da.	1.75
Scrape clarifier hopper	Helper	0.16/da.	1.12
f. Sludge removal			
Sludge wasting	Operator II	1.00/wk.	1.00
Disposal of sludge	Operator I	2.00/wk.	2.00
Clean sludge system	Helper	0.50/wk.	0.50
g. Chlorinator maintenance			
Inspect and adjust chlorinator	Operator II	0.08/da.	0.56
Clean chlorinator and feed line	Operator I	0.50/2 wk.	0.25
Refill chlorinator system	Operator I	0.50/2 wk.	0.25
h. Other			
Clean decks, weirs and troughs	Helper	0.50/da.	3.50
Clean & store maintenance equipment	Helper	0.50/da.	3.50
<u>Perform Tests and Maintain Operational Log</u>			
a. Influent characteristics	Operator I	0.02/da.	0.14
b. Aeration characteristics	Operator II	0.08/da.	0.56
c. Clarifier characteristics	Operator II	0.02/da.	0.14
d. Effluent characteristics	Operator I	0.02/da.	0.14
e. 30 minute settleability test	Operator II	0.16/da.	1.12

Table 35 (Continued)

Task	Skill	Time (hrs.)	Wkly. Avg. (hrs.)
f. DO test	Operator II	0.16/da.	1.12
g. pH test	Operator I	0.08/da.	0.56
h. Chlorine residual test	Operator I	0.08/da.	0.56
i. BOD_5 test	Operator II	0.40/wk	0.40
j. Suspended solids test	Operator II	1.00/wk.	1.00
k. Daily flow	Operator I	0.08/da.	0.56
l. Other recordings	Operator I	0.16/da.	1.12
m. Maintain books and test site (room), other test preparation	Operator II	0.50/da.	3.50
Make Operational Adjustments			
a. Remedial measures - other	Operator II	1.00/wk.	1.00
Final and Periodic Operation			
a. Maintain control system	Operator II	1.00/mo.	0.25
b. Clean up plant site	Helper	4.00/wk.	4.00
c. Outside contacts and other maintenance	Operator II	0.16/da.	1.12
		Total	38.43 hrs/wk

Helper - 17.67 hr/wk

Operator I - 7.01 hr/wk

Operator II - 13.75 hr/wk

Let us remind you again that the times suggested for task performance represent an ideal. With experience, you may find there are many short-cuts which may be taken to save time without sacrificing quality. For example, in wastewater testing, you can chop the projected 10 hours to three hours by testing only once a week. As you try to save on manpower, however, bear in mind that hazardous tasks may require that a second person be present even though he or she has only a safety function.

After making up the water system matrix, convert all the work time to an annual figure -- multiply daily tasks by 365, weekly by 52, monthly by 12, and leave the annual tasks as they are.

Add all these together and you have the total number of man-hours needed annually. Divide this figure by 1,500 and round to the nearest half-man to determine the number of full-time people you will need to operate and maintain the facility. 1,500 hours per year assumes a five-day work week; an average of 29 days for holidays, vacations, and sick leave; and 6 1/2 hours per day of productive work. If conditions at your plant are significantly different, you may want to develop a different figure.

MAINTENANCE REPORTING AND RECORDING

At this point, you should have a fair idea of the total staff required for your particular facility, at least on a preliminary basis, and the job of work scheduling can begin. This is the process of fitting the right man to the right job at the right time, and it begins with an adequate system of reporting and recording.

Functions of a Record System

Every item of operating equipment in a plant requires frequent attention. It is virtually impossible for anyone to remember the service requirements of every piece of equipment in a plant, as well as when these requirements should be met. Even if you were lucky enough to have someone with a photographic memory on the premises, remember that he would go on vacation occasionally. You need a good record system. An adequate maintenance record system, conscientiously maintained, enables the manager to perform the following functions:

(1) Schedule work in advance.
(2) Indicate when work is due.
(3) Evaluate equipment performance and need for replacement.
(4) Keep track of equipment and supplies.
(5) Substantiate manpower requirements and budgetary requests.
(6) Assign maintenance people to jobs effectively.
(7) Assure continuity of maintenance during personnel changes.

Organizing Maintenance Records

One of the most versatile and effective methods for organizing maintenance records is the edge-punched record card system. It was developed by the U.S. Army during World War II for use in water plants and has been successfully applied under a variety of conditions, thereby receiving the approval of many rural water and wastewater system operators.

The system is based on a file of 5x7-in. cards, one for each item of plant property requiring maintenance. Punch-coded into the edge of each card is an identification number and the dates on which maintenance is required. Simply by inserting a stylus (or thin rod) through the appropriate holes or notches in the card file, the plant operator can obtain the maintenance schedule for any given day.

Plants using this system vary in size from a design capacity of two to 20 mgd. The method can be adapted to water distribution systems, sewage collection systems, and wastewater treatment plants. It is a kind of manual substitute for a computer, which can be programmed to do the same job, but which will probably be too expensive for a small plant. Here is the procedure for setting up the system:

(1) Classify the Equipment. Each structure and piece of equipment is first assigned a file number. Table 36 is a sample portion of the index of file numbers for a particular water treatment plant. The plant has been divided into nine areas corresponding roughly to the stages of treatment. Each area has been assigned a block of 1,000 numbers, and each item in the area requiring maintenance has been assigned an individual number in its block. Enough numbers are left open to provide for any additional equipment which may be acquired in the future. The assigned numbers serve to identify each item of equipment in all the plant records described below, and they may also be used in storing and requisitioning spare parts.

(2) Make Maintenance Requirement Sheets. After the file number index has been prepared, a maintenance requirement sheet should be filled out for each item of plant property that requires periodic attention or maintenance. Listed on the sheet are all the items of maintenance, including frequency, number of men required, and estimated time of performance. These sheets are filed numerically and maintained as a reference. All additions, deletions, or corrections to the maintenance work schedule should be entered promptly on the appropriate sheets.

(3) Make Equipment Data Cards. The numerical file of equipment data cards consists of one card for each item of equipment, as in Figure 12.

It contains complete nameplate data, operating characteristics, and the address of the local service representative. These cards may also be used to show type of lubricant required and any special maintenance requirements not contained elsewhere in the record system.

Table 36
Maintenance File Numbers

<u>1000 Roads and grounds</u>

- 1100 Landscaping
- 1200 Drainage
- 1300 Sewage disposal
- 1400 Alum Tank No. 1
  - 1410 Alum Tank No. 2
- 1500 Paving

<u>2000 Sedimentation basin area</u>

- 2100 Flash Mixing Tank No. 1.
  - 2101 Flash Mixer No. 1
- 2200 Flocculation Tank No. 1
  - 2201 Flocculator No. 1
  - 2210 Flocculation Tank No. 2
    - 2211 Flocculator No. 2
  - 2220 Flocculation Tank No. 3
    - 2221 Flocculator No. 3
  - 2230 Flocculation Tank No. 4
    - 2231 Flocculator No. 4
- 2300 Sedimentation Basin No. 1
  - 2301 Vertical diffuers, Basin No. 1
  - 2302 Effluent collectors, Basin No. 2

<u>3000 Filters</u>

<u>4000 Operations Building, ground floor</u>

<u>5000 Operations Building, basement</u>

<u>6000 Storage tanks</u>

<u>7000 Pumping equipment</u>

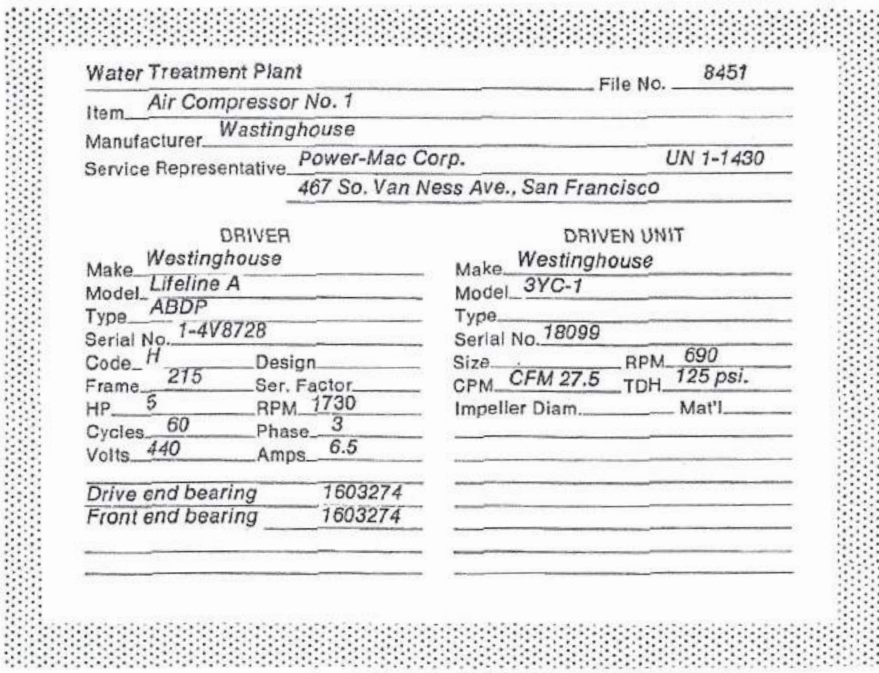
<u>8000 Open</u>

<u>9000 Open</u>

(4) <u>Make a Maintenance Instruction File.</u> This is a numerical file of all data on the installation, operation, and maintenance of each item of equipment. It should contain all manuals furnished by the equipment manufacturers, lists of spare parts, equipment dimension drawings, and other informative literature.

(5) Schedule the Work. After the records described above have been prepared, the actual work of scheduling maintenance duties on the edge-punched cards can begin. From the information contained on the maintenance requirement sheets, prepare a schedule for all maintenance work. Many items will fall logically into certain time periods. For example, work items requiring more than one man for performance should be scheduled for the days and shifts when the largest work force is available. Items which require taking water treatment units out of service for extended periods might be scheduled for the winter months.

Figure 12
Typical Equipment Data Card


Water Treatment Plant File No. 8451
Item Air Compressor No. 1
Manufacturer Wastinghouse
Service Representative Power-Mac Corp. UN 1-1430
467 So. Van Ness Ave., San Francisco

DRIVER		DRIVEN UNIT	
Make Westinghouse		Make Westinghouse	
Model Lifeline A		Model 3YC-1	
Type ABDP		Type	
Serial No. 1-4V8728		Serial No. 18099	
Code H	Design	Size	RPM 690
Frame 215	Ser. Factor	CPM CFM 27.5	TDH 125 psi.
HP 5	RPM 1730	Impeller Diam.	Mat'l
Cycles 60	Phase 3		
Volts 440	Amps 6.5		
Drive end bearing	1603274		
Front end bearing	1603274		

(6) Punch-Code the Maintenance Record Card. The information is punch-coded (holes and notches) on the edge of the cards, as shown in Figure 13. The face of the card contains a list of all work to be done as well as all information on assignment and scheduling. On the back of the card is space for recording work performed and the date of performance. Opposite each numbered work item on the face of the card are three columns headed Reference, Frequency, and Time. The Reference column contains the operation and maintenance instruction file number of the manual which describes the method of performing that particular item of maintenance.

Certain items, such as stand-by equipment, may have two criteria governing maintenance frequency. An emergency generator, for example, may require an oil change after every 50 hours of use or quarterly, whichever comes first. In this case, the card would be coded for the shorter period, and engine running time would be checked twice weekly to determine whether an oil change was due. In the Time column, the specific day for performance is listed. On the card in Figure 13, all work is scheduled for Wednesday. Thus each Wednesday, the weekly items will be performed and, on the fourth Wednesday in July, all the items listed are scheduled for performance.

With the appropriate holes on the top of the card punched out, the months and days of the week when maintenance is due are indicated -- as well as scheduled frequencies and, if appropriate, shift assignments. On the right side of the card, the holes are punched out for those weekdays of the month when maintenance is due. With this information entered, the operator can obtain in seconds the list of work scheduled for any day in the year.

Figure 13
Typical Maintenance Record Card

DAYS OF WEEK FREQUENCY MONTH SHIFT

INSPECTION AND SERVICE RECORD

Equipment Air Compressor No. 1 File No. 8451

Item	Work To Be Done	Ref.	Freq.	Time
1	Check oil level in compressor.		W	Wed.
2	Run compressors through complete cycle.		2 W	2nd & 4th
	Check controls in Auto and Hand.			Wed.
3	Check safety valve.		M	4th Wed.
4	Check V-belt tension.		M	4th Wed.
5	Change oil.		O	1, 4, 7, 10
6	Clean air strainer in solvent.	8450-3	O	1, 4, 7, 10
7	Clean inlet and discharge valves and overload	8450-3	S	1, 7
	check valve.			
8	Clean interior of crankcase and oil strainer.	8450-3	S	1, 7
9	Clean all surfaces and retouch paint.		A	7

Weekday of Month Assignment

SPECIAL

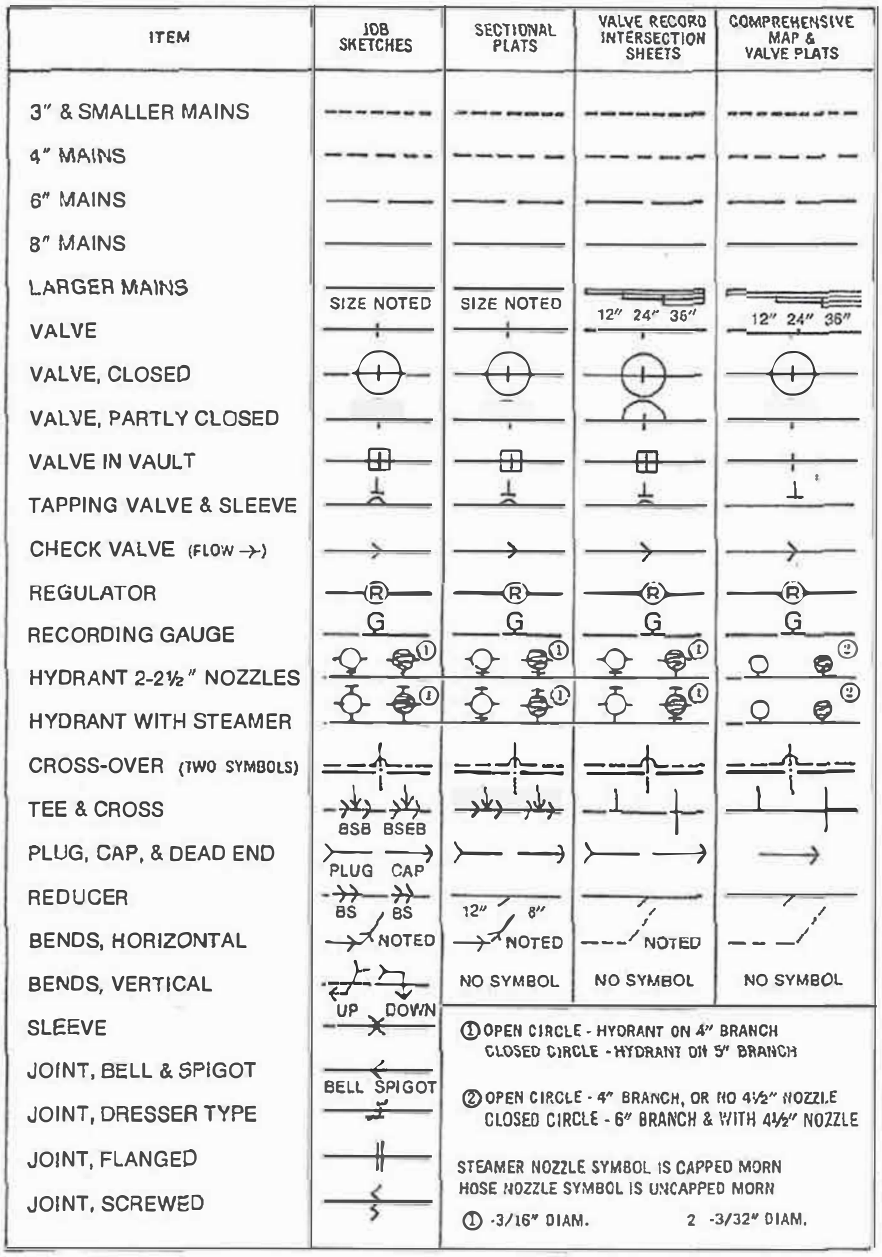
FILE NUMBER

(7) <u>Test the System</u>. Suppose it is the fourth Wednesday in July. The operator arranges all the cards on edge before him with the beveled corners in the upper left. He inserts the stylus (some people use a knitting needle) first through the punched-out hole (notch) corresponding to July, fans the cards to loosen them up, and lifts the stylus. All cards with work scheduled for July will drop down and those remaining (which is

those whose holes have not been punched out) are returned to the storage box. On the remaining cards, the stylus is inserted through the hole corresponding to Wednesday, those cards drop down when the stylus is raised, and the others return to the box. Finally, the remaining cards are turned on end and the operation is repeated for the fourth Wednesday in July. The cards which drop out contain all the maintenance work scheduled for that particular day.

(8) Make Work Assignments. For a plant served by two or three operators, no further

Figure 14
Leak Map-Symbols



breakdown in the work schedule is normally required. For the larger plants where certain of the operators have special skills, the manager may match the tasks to the abilities of the maintenance force by using the assignment section. For example, janitorial duties might be Assignment 1; servicing of mechanical equipment, Assignment 2; maintenance of electrical equipment, Assignment 3; and so on.

(9) Maintain Permanent Records. As noted, the back of the record card is used for recording the performance of all maintenance work, scheduled and unscheduled. When the back of the card has been completely filled, a new card should be prepared and the old card placed in a separate numerical file to become a part of the permanent plant record of equipment maintenance.

Figure 15
Report of Leaks

REPORT OF LEAK BY REPAIR CREW

EXACT LOCATION OF LEAK *California Ave.*
40' East of Texas Ave.

SIZE AND MATERIAL OF PIPE *6" C.I.*

DESCRIPTION OF RUPTURE OR BREAK *Transverse Crack*

PROBABLE CAUSE OF RUPTURE OR BREAK *Pipe resting on large boulder*

QUANTITY OF WATER ESCAPING (ESTIMATED G.P.M.) *300 G.P.M.*

EXACT TIME CREW REACHED SITE OF LEAK *10:05 P.M. Fri. Sept. 29, 1939*

" " FLOW OF WATER WAS STOPPED *10:20 P.M. Fri. Sept. 29, 1939*

" " WATER ON AFTER REPAIRS *2:30 A.M. Sat. Sept. 30, 1939*

WHERE DID WATER ESCAPE TO *Went to sewer. except about 50 G.P.M. which ran into basement of store—7290 California.*

DESCRIPE DAMAGE CAUSED BY ESCAPING WATER *Wet about 24 Boxes of Shoes*

DESCRIBE ACTION OF EMPLOYEES TO MINIMIZE DAMAGE *Moved boxes off wet floor.*

NAMES OF EMPLOYEES AT LEAK:	NAMES AND ADDRESSES OF OTHER WITNESSES:	
A. White	*C. Jamison*	*7290 A California*
C. Gray	*R. Swan*	*7306 Nebraska*
F. Black	*C. Jacobs*	*7220 Michigan*

REMARKS *Small Gasoline Pump #2 did not operate satisfactorily. Trouble in gas feed.*

(USE OTHER SIDE FOR ADDITIONAL REMARKS) REPORT BY *Geo. Brown*

These records will prove valuable for purposes such as determining the cause of breakdowns and evaluating the relative merits of different types of equipment.

Leak Records

The performance matrix given earlier did not include leak surveys because the time required for these depend entirely on the size and complexity of the system. However, you will have to allot some time to this task, since leak records are of vital importance to the long-term operation of a distribution system. These records allow the manager to know whether he is using the proper materials in the system, whether some mains have deteriorated to a point where replacement is called for, and whether the causes of the breaks are corrosion, faulty materials, poor installation, outside forces, increased pressure, or other factors.

Your job will be easier, of course, if the distribution system was not installed with built-in leaks -- and we will hope for the umpteenth time that you were watchful during construction. (In one northern city, a construction company was caught pouring oatmeal into sewers during installation. The oatmeal swelled and plugged leaks for several weeks. By the time it washed out and the leaks became apparent, the contractor was long gone. Don't fall for the oatmeal trick!)

1. Mapping the Distribution System. Use a map mounted on wall board to provide a visual record of leaks in the distribution system. The symbols used on the map should be coordinated with those used in maintenance reporting. However, do not use too many symbols, and try, insofar as possible, to make the ones you use bear some obvious resemblance to the features they represent. Figure 14 has some examples, chosen for their simplicity, clarity, and acceptance in present practice.

2. Reporting Maintenance. In addition to maps, you will also need complete records of leaks reported by others or discovered by your operators. Since lawsuits for damages against the company as the result of leaks may not be filed until months after the leak has occurred, the information is essential to properly defend the utility. The necessary documents include specific leak reports as well as reports of routine inspection and maintenance of valves and fire hy-

drants. Figures 15-17 are samples of these documents.

Figure 16
Routine Valve Reports

REPORT OF LEAK

XYZ WATER WORKS NO. *231-1939*

LOCATION *California—East of Texas*

TIME REPORTED *9:10 P.M.* (HOUR) *Fri.* (DAY) *Sept.* (MONTH) *29* (DAY) *1939* (YEAR) BY (TELEPHONE (CALL AT OFFICE (LETTER

REPORTED BY *C. Jamison* ADDRESS *7290 California*

REPORT RECEIVED BY *Addison Sims*

DISPOSITION OF REPORT *Called Geo. Brown to gather crew and go to leak*

— OFFICE RECORD —

REPAIR CREW REPORT RECEIVED AND FOUND SATISFACTORY *Yes*
INJURY OR DAMAGE INSPECTED BY *A. Scott* DATE *9-30-39*
ESTIMATE OF EXTENT OF DAMAGE *$75.00*
IS SUPPLEMENTARY REPORT NECESSARY? *Yes* SUPP. REPORT ATTACHED? *Yes*
SHOULD REPORT OF THIS LEAK GO TO LEGAL DEPT.? *Yes*
HAS REPORT BEEN MADE TO LEGAL DEPT.? *Yes*

— REMARKS —

(REPORT OF REPAIR CREW ON REVERSE SIDE)

(8½" x 11" SHEET)

ROUTINE VALVE INSPECTION REPORT

VALVE PLAT	VALVE NO	1ST OPERATION DIR	TURNS	OPENED OR CLOSED	2ND OPERATION DIR	TURNS	OPENED OR CLOSED	PACKING	BOX	MEASUREMENTS	REMARKS	OFFICE CHECK
24-I	[illegible]	R	22	closed	L	23	opened	O K	O K	O K		✓ CM
–	24	R	16	closed	L	23	opened	O K	closed 3"	O K	Valve was partly closed	✓ CM
–	25	R	23	closed	L	23	opened	O K	O K	Bad	New measurements taked	✓ CM
–	26	R	20	closed	L	20	opened	O K	O K	O K		✓ CM
–	27	L	20	opened	R	20	closed	O K	O K	O K	Valve left closed	✓ CM
	28	R	50 r	?				O K	O K	O K	Stem found broken	✓ CM
–	29	R	13	closed	L	13	opened	O K	O K	O K		✓ CM
	30	R	13	closed	L	13½	opened	Tightened	O K	O K		✓ CM
–	[illegible]	R	12	closed	L	12	opened	O K	O K	O K		✓ RZ
26-R	[illegible]	L	19	closed	R	19½	opened	O K	Lid Missing	Bad	Lid Replaced New measurements taken	✓ RZ
–	[illegible]	R	23	closed	L	23	opened	Bad	O K	O K	Works hard—Stem Bent should be replaced	✓ RZ
	[illegible]	R	27	opened	Left this valve open			O K	O K	O K	Corrigan valve opens wrong way change valve record	✓ RZ

XYZ WATER WOR DATE 9-30-39 BY Jim Jones

VALVE MAINTENANCE REPORT

(5" x 8" SHEET)

XYZ WATER WORKS — VALVE NO. *24-I-47*

LOCATION *CANADA W. OF TEXAS*

MEASUREMENTS: CHECKED O.K. *√* MEASURED AS FOLLOWS:

___ FT. ___ OF ___ P.L. OF ___

___ FT. ___ OF ___ P.L. OF ___

VALVE TURNS *LEFT* TO OPEN. NO. OF TURNS *19*

FOUND *PARTLY CLOSED* OR *7* TURNS CLOSED ___

PACKING: O.K. *—* TIGHTENED *—* REPLACED *YES*

STEM: O.K. *√* BENT OR BROKEN *—* REPLACED *—*

NUT: O.K. *—* MISSING *YES* REPLACED *YES*

GEARS: CONDITION *NONE* GREASED *—*

BOX *√* OR VAULT ___ O.K. ___ REPLACED ___

BURIED ___ IN. PROTRUDING ___ IN. ___

TOO CLOSE TO STEM *YES* RESET *YES*

COVER: MISSING *YES* BROKEN ___ REPLACED ___

WEDGED IN ___ TARRED OR GROUTED IN *YES*

ANY OTHER DEFECTS *NONE*

INSPECTED *9-27-39* BY *J. JONES*

DEFECTS CORRECTED *9-27-39* BY *J. JONES*

XYZ WATERWORKS — REPORT EVERY OPERATION — 3" x 5" SHEET

VALVE OPERATION REPORT

VALVE PLAT *24-I* VALVE NO. *15* DATE *8-26-39*

PRINCIPAL ST. *NEW YORK* *12* FT. *S.* OF *N.L.*

INTERSECT. ST. *FLORIDA* *19* FT. *W.* OF *W. Curb*

SIZE *6"* MAKE *XXXX* OPENS *L.* TURNS *19½"* DEPTH *32"*

VALVE RECORD: INCORRECT / CORRECT REMARKS: *BOX WAS OFF CENTER*

Realigned—Now O.K.

OFFICE CHECK *8-29-39. cm.* OPER. BY *John Smith*

Figure 17
Routine Hydrant Reports

(5" x 8" SHEET)

HYDRANT MAINTENANCE REPORT

XYZ WATER WORKS ______ HYDRANT NO. 191

LOCATION NEW YORK W. OF FLORIDA

CAPS: MISSING 1-2½" REPLACED YES GREASED YES

CHAINS: MISSING 1-2½" REPLACED YES FREED OTHERS

PAINT: O.K. NO REPAINTED CLASS A COLORS

OPER. NUT: O.K. ✓ GREASED YES REPLACED —

NOZZLES: O.K. ______ CAULKED 1-2½" REPLACED —

VALVE & SEAT: O.K. ✓ REPLACED —

PACKING: O.K. — TIGHTENED YES REPLACED —

DRAINAGE: O.K. NO CORRECTED BLEW OUT WITH PRESSURE

FLUSHED 25 MINUTES 1-2½" NOZZLE OPEN

PRESSURE: STATIC 69# RESIDUAL 36# FLOW 1010 G.P.M.

BRANCH VALVE: CONDITION O.K. BOX COVERED
RAISED 3"

ANY OTHER DEFECTS: STEM APPEARS BENT

STEM REPLACED

INSPECTED 9-8-39 BY Geo. Smith

DEFECTS CORRECTED 9-11-39 BY Jim Jones

(8½" x 15" SHEET)

FIRE HYDRANT INSPECTION REPORT

XYZ WATER WORKS

HYD NO	LOCATION	MAKE	CLASS	PRESSURES: NOZZLE	PRESSURES: INITIAL	PRESSURES: RESID.	PRESSURES: PITOT	FLOW G.P.M.	MINUTES FLUSHED	WATER USED GALS	PAINTED	DRAIN	BRANCH VALVE	REMARKS OR REPAIRS
191	CANADA & TEXAS	XXX	A	4½	80	5		1250	8	9,700	Yes	OK	OK	
307	NEBRASKA & TEXAS	XXX	A	4½	80	76		2100	4	8,720	"	OK	OK	
88	CALIFORNIA & TEXAS	XX	B	4½	83	—	4	1000	9	9,810	"	OK	OK	ORDERED REPAINTED CLASS B COLORS — CM
547	CALIFORNIA & TEXAS	XXX	B	4½	77	—	3	840	15	14,100	"		OK	
[illegible]	CANADA E. OF TEXAS	X	B	4½	80	3		940	22	20,700	"		OK	
118	MICHIGAN E. OF FLORIDA	XX	A	2½	64	31		430	40	17,200	"		?	MEASUREMENT WRONG COULD NOT FIND VALVE
882	OHIO S. OF GEORGIA	XXX	C	2½	60	0		500	18	9,000	"		OK	NEEDS NEW OPERATING NUT
										100,700 gals				

FLUSH HYDRANTS IN ORDER LISTED. REPORT REPAIRS ON HYDRANT MAINT. TICKET
PAINT TOPS & NOZZLE CAPS CLASS A—GREEN CLASS B—ORANGE CLASS C—RED

DATE 7-27-38 BY Richard Roe

Other Records

There are a number of other records which will be useful in your maintenance work. These include as-built drawings, system maps, and an inventory of equipment and supplies.

1. System Maps. If you are managing a rather small system, in addition to your leak map, you should have a detailed map of the entire system. If the system is larger, the maps will show sections of the complete layout.

If it is a water system only, the map should be made at 100-foot scale and, if possible, on a single sheet of tracing cloth (not linen). If the system is more than 4,000 feet wide, two or three sheets of 42-inch wide cloth may be necessary. If the system is very small, or if you wish to show a sewer network, the scale should be 50 feet to the inch.

The map should include the information shown on the sectional plat record and the reference measurements to all valves, with the reference points being property and curb lines. Prints of this record will furnish all the operating information necessary for a small system.

The 100-foot (or 50-foot) scale will allow ample room for inserting all the necessary information without requiring ultra-fine drafting work. The record should be brought up to date each time an addition or correction is required. At the end of each year, transfer the changes from the prints to the cloth tracing and make new prints (black line on white background).

2. As-built Drawings. You should keep a complete set of the engineering drawings used in constructing the system. All changes to plant piping, equipment connections, and electrical circuitry should be entered promptly on this master set. Having a good set of as-built drawings on hand will save the operators time. It will also save the company money when it decides to enlarge the plant.

3. Inventory of Supplies. For efficient operation and maintenance, an adequate stockpile of commonly-used materials, supplies, and replacement parts is essential. Since the stock-pile is of little use if items cannot be found when needed, a good stock inventory, with separate cataloguing of new and salvaged materials and equipment, should be kept.

The essential information to be included in the inventory is:

+ description of items.

+ continuous record of the quantity of each item in stock.

+ identification of each item as to the quantity ordered, date ordered, and purchase order number.

+ record of receipt into stock by quantity, date and source.

+ record of disbursements from stock by quantity, date and purpose.

+ record of the unit costs of items.

+ record of the location of items in stock.

A physical inventory of stock should be made periodically, probably once or twice a year. Significant discrepancies from the running inventory should be investigated.

Although you will want to keep enough items in stock to avoid delays when parts and supplies are needed, considerations of storage space and cost will limit your inventory. A small plant will not have the many detailed problems with stocks that large plants do, but it is just as important that the inventory be maintained with care. Parts and equipment are less likely to be interchangeable in a small plant.

Certain items such as grease, oil, and paints may require special handling. Manufacturers' bulletins and instructions usually include certain definite recommendations regarding lubrication, and it is wise to follow these suggestions. However, equipment in a water or wastewater plant may be furnished by a number of different manufacturers, with each of them recommending a different specific brand of lubricant and possibly two or three grades of each. It is usually impractical to stock all the different brands recommended.

If you are faced with this problem, the best solution may be to call in a competent lubrication engineer. Most suppliers of recognized brands of grease and oil make a consultant available at nominal cost. He will be able to make a comprehensive survey of your needs and to recommend a simplified lubrication program. In one instance, in a large plant, it was possible to reduce inventories from 56 greases and oils to two greases and four oils. Grease stocks were reduced by converting to lithium-based grease. One type was used for ball-bearings and the other for everything else. Oil stocks were cut by converting to an oil which is graded on the basis of adaptability to use rather than the older designation of 10, 20, 30, and 600 "W." No failures have been detected which could be traced to poor lubrication. One of the most spectacular improvements was a reduction of the number of grease guns in the plant from 16 (which sometimes had to be washed for special jobs) to two!

Another item which may be a problem is paint. There are so many kinds of paints and protective coatings, and so many conflicting claims made for them, that a constant program of testing may have to be instituted to decide what types to use.

The smoothest-running plants are those which have enough qualified operators, enough of the proper equipment and supplies, and enough reports and records to keep the men and machines meshing. Few plants could claim perfection in all these areas, but this should be your objective.

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