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DEPARTMENT OF THE ARMY TECHNICAL MANUAL

WATER SUPPLY

WATER SOURCES

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ENGINEERING AND DESIGN

WATER RESOURCES

Army and Air Force

ENGINEERING AND DESIGN

WATER SOURCES

1. PURPOSE. This manual prescribes the procedures to be followed in obtaining and developing sources for potable-water supplies for Army and Air Force installations and for special projects. It describes general investigative procedures to be followed in determining the most feasible means of obtaining the required water supply. It establishes criteria to be followed in the development of underground or surface supplies, degree of treatment required, and types of pumping equipment to be used. List of laboratory furniture, apparatus, and supplies required for water filtration plants is given in the appendix.

2. SCOPE. The manual is applicable to all elements of the Corps of Engineers performing military construction and to those elements of the Air Force planning military construction.

3. REFERENCES.

EM 1110-345-220—Water Supply—General Considerations (AFM 88-10, Chap. 1).
EM 1110-345-222—Water Treatment (AFM 88-10, Chap. 3).
EM 1110-345-223—Water Storage (AFM 88-10, Chap. 4).
EM 1110-345-224—Water-Distribution Systems (AFM 88-10, Chap. 5).
EM 1110-345-228—Water Supply for Fire Protection (AFM 88-10, Chap. 6).
EM 1110-345-229—Water Supply for Special Projects (AFM 88-10, Chap. 7).

4. RESCISSIONS. *a.* Engineering Manual for Military Construction, Part VII, Chapter 2, February 1946.

b. Engineering Manual for Military Construction, Part VII, Appendix B, February 1946 (EM 1110-345-226).

5. GENERAL. The selection of a source of water supply will be based on availability, adequacy, quality, cost of development, and expected life of the project. Generally the supply that can be utilized at the lowest first cost is preferred, especially for projects having a comparatively short life. However, in addition to first cost, the question of annual operating costs, including power, chemicals, and personnel salaries will be investigated and given due consideration in view of the expected life of the project in arriving at the final selection of source. For projects located adjacent to municipalities, the municipal facilities will be investigated to determine whether they are capable of supplying the projects and whether the appropriate officials are favorably inclined toward serving the project at a reasonable cost to the Government. These investigations will take into consideration any increase in the city's requirements by reason of the construction of the Government facility and by reason of the future growth and development of the city.

In cases where a long supply line is required between source of supply and the distribution system, a study will be made of the economic size of main, taking into consideration cost of construction, expected length of use, cost of operation based upon power cost and minimum use of critical materials. If there is an existing water supply under the jurisdiction of the Department of the Army, the Air Force, or other Government agency, investigation will be made to determine its capacity and condition and the possible arrangements that might be made for its use with or without enlargement.

Where existing supplies cannot be utilized economically, the availability, quality, and cost of both well and surface supplies will be investigated.

6. EXISTING SUPPLIES. Investigation of existing sources of supplies will include the following:

Source.
Reliability of supply.
Quantity developed.
Ultimate quantity available.
Excess supply available not already allocated.
Type of treatment.
Rates in gallons per minute at which supply is available.
Cost per 1,000 gallons.
Distance from site to existing supply.
Variation in pressure at point of diversion from existing system.
Ground elevation at point of diversion and at point of use.
Existence of contaminating influences.
Quality of water.

7. WELL SUPPLIES. An investigation to determine the availability, quality, and economy of well supplies will cover the following:

Reports on ground-water resources from State Board of Health, State Geologist, U. S. Geological Survey.
Reports on rainfall (distribution, maximum and minimum intensity).
Reports from operating water companies securing supplies from the formations.
Records of available well logs, draw-down data, total pumpage from area, both seasonal and long term, and variations in elevation of ground-water table.
Records of permeability of the aquifer and velocity of the ground-water flow (laminar or turbulent).
Records of physical, chemical, and bacteriological analyses.
Existence of contaminating influences.
Necessity for treatment, such as iron removal, softening, corrosion control, taste, and odor.
Spacing required between wells to prevent mutual interference.
Legal clearance if required by proximity to well fields of others.

8. SURFACE SUPPLIES. An investigation to determine the availability, quality, and economy of surface supplies will include the following:

Topographic maps showing total tributary drainage areas of stream or reservoir.
Reports on rainfall (distribution, maximum and minimum intensity).
Reports on runoff and stream flow (variations in stream flow).
Survey of contaminating influences including quantity, location, and degree of treatment of sewage entering stream and quantity, location, and nature of industrial wastes entering stream.
Records of physical, chemical, and bacteriological analyses of proposed supply.
Feasibility of obtaining supply without construction of a reservoir.
Location of available reservoir sites and geological data relating to underlying formations that may affect foundation conditions or ability to hold water.
Location and probable cost of reservoir, pumping station, supply line, and treatment plant.
Plans of others to develop reservoirs on the same watershed, and water rights of downstream users.

9. ANALYSIS OF SUPPLY. Where new water sources are being developed, physical, chemical, and bacteriological analyses will be made to determine whether treatment is required to make the water safe and potable, or satisfactory for cooling purposes, laundries, and boiler use. The chemical properties of the water must be known in the early stages of the project so that the proper type of water-treating equipment may be selected without delaying completion of the project. The water supply will, in general, meet the Drinking Water Standards of the U. S. Public Health Service. The presence of more than 0.1 part per million of lead, 1.5 p.p.m. of fluorides, 3.0 p.p.m. of copper, or 15 p.p.m. of zinc will constitute grounds for rejection of the supply. Where chlorides or sulfates exceed the 250 p.p.m. recommended, and a more suitable water supply cannot be obtained, consideration will be given to the installation of facilities to reduce the concentrations below 250 p.p.m. However, request for waiver of these requirements or for the installation of treatment facilities will be submitted to HQDA (DAEN-MCE-U) WASH DC 20314. Where a choice is possible between a soft-water supply and a hard-water supply, an economic analysis will be made to determine the proper source to be selected.

10. WATER-SUPPLY WELLS. *a. Test Drilling.* Prior to the construction of permanent water-supply wells, a careful investigation will be made of all wells in the vicinity. If there are no existing wells in the area, the topography and geology of the region will be studied and test wells driven. Prospect holes and observation wells will be not less than 2 inches in diameter, and test wells will be not less than 4 inches in diameter. Rotary test drilling is rapid and economical for extensive explorations in unconsolidated materials. Specifications will be written by persons familiar with local conditions and with established drilling practice in the area. Special consideration will be given to the size of the well so that a suitable well pump may be installed. Except where water requirements are small, the diameter of all deep wells will be not less than 8 inches. For wells more than 500 feet deep, the minimum well diameter will be 10 inches.

b. Well Construction. Well construction will, in general, conform to American Water Works Association Standard Specifications for Deep Wells. Gravel-wall-type wells will be constructed where the nature of the water-bearing formation indicates that this type of construction is desirable or necessary. When requested by State authorities, plans for proposed facilities may be furnished for information, but are not subject to review and approval by State agencies. Where well permits are required by the State in accordance with underground-water-resources conservation policies, full cooperation will be given to the State authorities regarding the withdrawal and use of equitable quantities of the underground water supply.

c. Well Houses. At permanent projects, well houses will be of incombustible construction such as reinforced concrete, concrete or tile block, brick, or other masonry. Incombustible roof and roof scuttle with structural-steel derrick for handling the well pump will be provided. Frame construction with timber derrick may be used for temporary projects except where special fire hazards exist. Where climatic conditions permit, well houses may be dispensed with and weatherproof motors, pumps, and control equipment installed. A fence will be provided around the well and appurtenances in such cases.

d. Well Pumps. Deep-well turbine-type pumps are normally used. Where feasible, submersible pumps will also be considered. Pumps will not be purchased until the capacity and drawdown of wells are known and total head conditions determined. Guide specifications covering turbine-type deep-well pumps have been prepared in the Office of the Chief of Engineers and are available for use in accordance with current instructions.

e. Meters. A direct-reading meter will be installed in the discharge line from each well pump. Velocity-type meters may be used for this service.

f. Number of Wells. Not less than two wells will be provided except in the case of very small camps or when flowing artesian wells or springs are developed. A sufficient number of wells will be developed to yield the required daily demand for water in approximately 16 hours. In case two wells are completed, one of the wells will normally be equipped with a combination electric-motor gasoline-engine-driven pump. In addition to satisfying the above requirements, the aggregate capacity of well pumps equipped with gasoline-engine drive will equal at least 50% of the total required well-pump capacity. In some cases either the installation of gasoline-engine-drive only may be necessary or the installation of dual drive for all well pumps may be justified (see par. 6 of EM 1110-345-223).

g. Well Fields. Where multiple wells are located within the area served by the distribution system, they will discharge directly into the distribution system except where the water requires treatment that can be more economically provided in a central plant. Collection lines in a well field will be carefully designed and sized with full consideration given to the varying hydraulic characteristics that occur when all of the wells are operating and when several are not operating. These varying conditions will also be considered in determining suitable head curve characteristics of the well pump.

h. References. The following references are quoted for information:

AWWA A100—Standard Spectifications for Deep Wells.
American Water Works Association, 521 Fifth Avenue, New York 17, N. Y.
Ground Water, Its Development, Uses and Conservation, by E. W. Bennison,
Published by Edward E. Johnson, Inc., St. Paul 4, Minn.

11. SURFACE-WATER PUMPING STATIONS. *a. Arrangement of Raw-Water Pumping Stations.* The arrangement of intake structures and raw-water pumping stations will depend entirely upon the requirements of the specific situation. In general, a pumping-station arrangement adapted to the utilization of horizontal centrifugal pumps will provide for greater operating economy, although in certain instances, the use of vertical-type pumps taking suction directly from a receiving well may prove to be more economical. The use of automatic priming equipment in installations may effect savings in construction cost.

b. Substructures. Substructures will usually be of reinforced concrete.

c. Superstructures. For permanent projects, superstructures will be of incombustible construction, such as reinforced concrete, brick, concrete or tile block, or other masonry. Similar-type construction will be used at temporary projects where special fire hazards exist, and wherever possible for the larger stations where interruption of pumping-station operation may have serious consequences. Frame construction is not generally favored except for minor installations. Pumping-station roofs will preferably be of noncombustible construction such as reinforced concrete slab, precast concrete, or gypsum slab on open steel supports or similar-type construction. Where it is not possible to provide this type of roof construction because of critical material situation, local conditions, and economy, and it becomes necessary to use frame roof construction, the exterior will be covered with roofing material of at least Class C type conforming to the requirements of the Underwriters' Laboratories, Inc. Where important pump houses are of combustible construction, automatic sprinklers will be installed. If special fire hazards exist, roof covering will be of at least Class B material. The interior of the roof, when a flat or sloping joisted roof is used, will be protected by using two layers of gypsum lath, each $\frac{3}{8}$ inch in thickness, applied to the underside of the joists, securely fastened with $1\frac{1}{2}$-inch plasterboard nails spaced not more than 6 inches apart, and covered with two coats of gypsum and sand plaster (1:2) to a thickness of $\frac{1}{2}$ inch. Where a peak roof is used, the preceding type of roof protection will be applied as a ceiling supported on the underside of the trusses or rafters supporting the roof. Proper ventilation will be provided for the space above the ceiling, which will be so arranged

that the entrance of sparks into the concealed spaces will be prevented. Where explosive gases, smoke, or toxic or noxious fumes cannot be adequately removed by gravity, means will be provided with exhaust or supply ventilation for year-round operation capable of handling a minimum of 1 cubic foot of air per minute per square foot of floor area. Where dust results from the handling and transfer of chemicals from containers to feeding equipment, suitable exhaust facilities will be provided.

d. Pumping Equipment. In general, the size of the pumping units in the raw-water pumping station will be fixed by the size of the filter units and the total rated capacity of the filtration plant. A minimum of three motor-driven pumps will be installed with sufficient range of capacity to permit operation of the filtration plant at rated capacity with the largest pumping unit out of service. In addition, a sufficient number of the pumps will be equipped with electric-motor-gasoline-engine power, or standby gasoline-engine-driven pumps will be installed, capable of supplying 50% of the rated capacity of the filtration plant except where a greater capacity is indicated or required.

e. Pumping-Station Control. Supervisory or remote control of motor-driven pumping units from the filtration plant is desirable if such control will eliminate the need of operators at the pumping station.

12. FILTRATION PLANTS. Filtration plants will usually be required for the treatment of domestic-water supplies obtained from surface sources and from ground-water supplies containing excessive quantities of iron and manganese. The principal treatment methods include screening, plain settling, coagulation and sedimentation, filtration, disinfection, softening, and aeration. Treatment plants will be planned and designed not only with first cost in mind; operating costs, ease of operation, and dependability also will be considered. All water supplies will not require every type of treatment mentioned. Existing plants will be enlarged and completely utilized where practicable. Equipment and space for storage, measuring, or feeding chemicals will be arranged as compactly as possible, consistent with accessibility for operation and maintenance. Short solution lines are desirable, and long ones will be avoided where possible. Convenience in handling materials is a prime consideration. The chemical unloading point will be as near as practical to the place of storage, which, in turn, will be reasonably near the feeding equipment. The ready availability of supplies will be considered in determining space requirements for storage of chemicals. Bags will normally be stacked not more than 4 feet high. A 60- to 90-day supply is the usual bag-storage requirement.

a. Degree of Treatment. Partial treatment consisting of coagulation and sedimentation only may be required for process-water supplies. Complete treatment including filtration and sterilization will usually be required for drinking-water supplies taken from surface sources. Softening will usually be provided only for water required for laundry, hospital, and power-plant use and may be accomplished by the installation of industrial-type zeolite softeners at such structures. However, in case an excessively hard surface or underground supply is to be used, softening of the entire supply may be justified (see EM 1110-345-222). Water-treatment plants will, in general, be designed using design factors established in the American Society of Civil Engineers Manual of Engineering Practice No. 19, entitled: "Water Treatment Plant Design," adopted 23 July 1939. Reference will also be made to the Manual of Water Quality and Treatment, published in 1950 by the American Water Works Association. When requested by State authorities, plans for proposed facilities may be furnished for information but are not subject to review and approval by State agencies.

b. Capacity. Filtration plants will have a normal rated capacity, based on 24-hour operation, equal to the required demand when operating at a filter rate of 2 gallons per square foot per minute. No spare filter units will be provided, but plant piping will be designed to handle flow rates 50% in excess of the rated capacity. To secure operating flexibility, the re-

quired filter capacity will be secured by providing at least two filter units. The selection of site and arrangement of sedimentation basins and filter units will be such as to permit expansion at a minimum cost.

c. Type of Filtration-Plant Construction. Reinforced-concrete substructures with incombustible superstructures conforming architecturally to existing construction will be used for permanent posts (see par. 11 above). Departure from these standards for temporary and minor projects may be justified by local conditions.

d. Chemical-Feed Equipment. Machines for the application of chemicals, such as filter alum or other coagulant, lime, activated carbon, fluorides, and chlorine (duplicate machines) will be installed for all filtration plants, as required by method of treatment. Fluoride-feeding machines will be provided only when approved by the Surgeon General of the Service involved. If possible the chlorine-feeding-machine room will have a door opening to the outside air.

e. Chemical Mixing and Coagulation. Mechanical mixing and flocculating equipment is considered justified at permanent plants and for temporary plants having capacities greater than one million gallons per day. If mechanical mixers are not used, adequate means such as baffled chambers will be provided to mix the chemicals thoroughly with the water being treated in accordance with accepted practice.

f. Settling Basins. Settling basins will be designed for flexibility and will be arranged to permit bypassing of any single unit. Mechanical sludge-removal equipment may be justified for permanent projects (especially softening) but will not be used for temporary or short-lived projects. Wood tanks if properly baffled may be used for emergency and similar-type projects. In some cases secondary coagulation, prior to filtration, may be required for the treatment of highly turbid waters; however, in such cases, the conditions will be reported to HQDA (DAEN-MCE-U) WASH DC 20314, and approval for such action obtained prior to construction.

g. Solids Contact Basins. Where the entire water supply is softened, the use of suspended-solids contact basins may be considered.

h. Filters. The number, type, and size of filter units will depend upon individual requirements for economical design and operation. Standard wood-tub filter may be used for temporary projects. Pressure filters are not generally favored unless special conditions warrant their consideration.

i. Filtered-Water Storage. Clear-well capacity in an amount to meet wash-water requirements and to permit satisfactory operation of pumps and filters will be provided.

j. Laboratory. Each plant will be provided with a laboratory properly equipped to make routine control tests appropriate for the size and character of the plant (see app).

13. HIGH-SERVICE PUMPING. *a. Type of Structure.* The pumps are to be installed in a building conforming in general to the requirements set forth hereinbefore for substructures and superstructures at surface-water pumping stations.

b. Type and Capacity of Pumps. Horizontal centrifugal double-suction constant-speed pumps are usually best suited for high-service pumping. Pumps should be installed with positive suction head; or if this is impossible, pumps will be furnished with automatic vacuum priming system. The priming system will consist of vacuum pump, vacuum tank, solenoid valves, or priming line to each pump and air-release valve on each pump. Unless local conditions require otherwise, a minimum of three motor-driven pumps will be provided with sufficient range in capacity so that, when considered in conjunction with elevated storage, the minimum average and maximum rates can be delivered with the largest pumping unit out of service. (Maximum rate equals one-half the average daily rate plus the fire flow or two-

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and-one-half times the average daily rate, whichever is greater.) Normally, each of two pumps will be of size to deliver the average demand (one pump will be a standby or used alternately), and one pump will be of size to deliver one-half the average daily demand (for nighttime or offpeak periods or for short-time use in conjunction with one of the larger pumps when pumping at 150% of the plant capacity). In addition to the above, a sufficient number of the pumps will be equipped with electric-motor-gasoline-engine power, or standby gasoline-engine-driven pumps will be installed, capable of supplying 50% of the required daily demand except where a greater capacity is indicated or required. The following units will generally provide the desired flexibility in pumping capacity for a plant serving a required demand of 3.0 million gallons per day where adequate elevated storage is provided:

Two 3.0-m.g.d. motor-driven pumps.
One 1.5-m.g.d. motor-driven pumps.
One 1.5-m.g.d. gasoline-engine-driven pump.

Note. Except where gasoline-engine-driven pump is required for fire protection, one 1.5-m.g.d. pump equipped with dual drive may be substituted for the 1.5-m.g.d. motor-driven pump and the 1.5-m.g.d. gasoline-engine-driven pump.

c. Pump Specifications. Guide specifications covering centrifugal pumps have been prepared in the Office of the Chief of Engineers for use in accordance with current instructions.

d. Suction and Discharge Piping. The design of suction and discharge piping for the pumps will provide for the maximum reliability of service. The layout for the discharge piping in particular will provide piping with fittings so connected and valved that the failure of any one pipe, valve, or fitting will not disable more than 50% of the pumping capacity at one time. Where economically feasible, two discharge mains will extend from the pumping station to the underground piping of the distribution system supplying the project, although long parallel mains between the pumping station and the distribution system are not contemplated.

e. Meters. A water meter will be installed in the discharge line from the high-lift pumping station to measure the amount of water delivered to the post. Venturi or fire-service-type meters may be used, the type to be determined by local conditions. If two discharge mains are installed to insure continuity of service and normally only one line will be in use, a meter is required in the latter line only.

14. PRELIMINARY DRAWINGS AND DESIGN ANALYSES. If the supply is secured from an existing source, the design analysis will cover all items outlined in the paragraph EXISTING SUPPLIES hereinbefore. If new well supply is being developed, the design analysis will cover all items contained in the paragraph WELL SUPPLIES hereinbefore. If surface sources are utilized, the design analysis will cover all items referred to in the paragraph SURFACE SUPPLIES hereinbefore. In addition the design analysis will set forth the design population, the basis for the selection of the degree of treatment to be provided, if any, and the basis of design for each unit of the water-supply facilities.

APPENDIX I

LABORATORY FURNITURE, APPARATUS, AND SUPPLIES FOR WATER-FILTRATION PLANTS

1. GENERAL. The following schedule of laboratory furniture, apparatus, and supplies has been prepared for the various types of water-filtration plants as follows:

a. Class A Plants. Filtration plants serving a population of over 10,000 or treating surface water taken from a polluted source where complete control is required for the operation of the plant. The laboratory equipment provided will permit routine chemical and bacteriological analyses as well as microscopic examinations.

b. Class B Plants. Filtration plants taking water from a slightly polluted source or from wells where softening or iron removal is required. The laboratory equipment provided will permit routine chemical-control tests, bacteriological tests for coliform organisms, and total plate counts.

c. Class C Plants. Plants where chlorination only is provided to insure the bacteriological quality of the supply. The laboratory equipment will permit routine residual-chlorine, pH, and alkalinity determinations only. The list of laboratory furniture and apparatus is considered to be the minimum required. The equipment listed is complete in itself with all necessary details and accessories.

2. LABORATORY FURNITURE. The following list of laboratory furniture includes those items required in Class A and B plants. It is the intention that this equipment will meet the minimum requirements for laboratory furniture. However, discretion will be exercised in selecting furniture that will fit the space requirements in the laboratory and harmonize with other facilities. It is recommended that the several units be purchased readymade, as this type is preferable to built-in furniture. The equipment listed is complete in itself with all necessary details and accessories, and the items listed are standard with at least three manufacturers. The tops of the table and the benches are of materials specially treated to resist the action of the chemicals. The furniture required is as follows:

Item 1. One laboratory table of oak, approximately 6 ft.–0 in. long, 32 in. deep, and 36 in. high. Table shall be fitted with a maple bottle rack with acid-resisting back; rack shall be approximately 60 in. x 8 in. x 18 in. Pegboard over sink, 14 in. x 19½ in., shall be fitted with 16 pegs. Table top shall be fitted with a lead-lined (4 lbs. per square foot) tough, approximately 66 in. x 4 in. x approximately 6 in. at deep end properly pitched to drain. All joints shall be burned with pure lead; soldering will not be permitted. Sink with back at end of table 14 in. x 18 in. x 12 in. mounted on tubular stand shall be of 1¼-in. selected soapstone. Sink shall have 2-in lead p-trap; for connection see PLUMBING. Cabinet-supporting frame shall be mortised and tenoned, glued, and reinforced with bolts. Drawers shall be dovetailed; doors shall be built up and shall have suitable pulls, catches, and hinges. The cabinet shall be equipped with two long drawers at top, four intermediate drawers, and two cupboards. Cupboards shall be fitted with two adjustable removable shelves. Top shall be of shellstone or approved acid-resisting material. Equipment shall have two compression hose bibs over sink for hot and cold water; three straight-way water cocks with hose connection over trough; and ½-in. pipe conduit with two duplex receptacles with T-slots, mounted in cast metal conduit fittings. Connections shall be made to floor outlets. All service lines shall be carried to floor with shutoff for each line. Finish for all exposed steel and service piping shall be acid-

and alkali-resisting enamel. Table shall be type No. 16560 as manufactured by E. H. Sheldon and Company, Muskegon, Mich. or a similar table as manufactured by W. W. Kimball Company, Chicago, Ill., or Hamilton Mfg. Co., Two Rivers, Wis.

Item 2. One balance shelf, 3 ft. long x 2 ft. wide; oak construction, except that top shall be 1⅝-in. thick birch, black carbonized, or impregnated asbestos-cement sheet; equipped with drawer 21 in. wide, 15 in. deep, 3¾ in. high. Shelf shall be equivalent to:

E. H. Sheldon & Company —No. 12520.
W. W. Kimball Company —No. 682.
Hamilton Mfg. Company —No. L-1174.

Item 3. One supply case, 48 in. wide, 15 in. deep, 80 in. high, upper section glazed 44 in. wide, 60 in. high with three adjustable shelves; cupboard shelves; cupboard section 44 in. wide, 12 in. deep, 13 in. high, of oak. Supply case shall be equivalent to those manufactured by the following:

E. H. Sheldon & Company —No. 41040.
W. W. Kimball Company —No. 9562.
Hamilton Mfg. Company —

Item 4. One lower-section cupboard unit 37⅝ in. long x 24 in. wide x 36 in. high containing 1 double cupboard 34 in. wide x 28¼ in. high x 20⅝ in deep, with 1 stone sink 14¼ in. long x 10 in wide x 8 in. deep with 1 set of drain fittings, 1 cold-water pantry cock, and 1 double electric receptacle for 110-v., ac, table top to be scored to drain to sink. The cupboard unit shall be equivalent to those manufactured by the following:

E. H. Sheldon & Company —
W. W. Kimball Company —
Hamilton Mfg. Company —No. L-804.

All furniture shall be oak construction, natural finish throughout, except tabletops, which are to be 1⅝-in thick birch, black carbonized, or impregnated asbestos-cement sheet.

Item 5. In laboratories for Class C plants, the furniture to be provided shall consist of a worktable at least 48 in. long x 36 in. wide and 30 in. high, toegther with a wall cabinet fitted with doors. The cabinet shall be of adequate size to house equipment and chemicals required for a Class C Laboratory. These items need not be of special laboratory construction, as kitchen-type or built-in-place furniture will suffice. A laboratory sink will be provided convenient to the work table.

3. LABORATORY APPARATUS. The following list of laboratory apparatus includes the items required in Class A, B, and C Plants:

Laboratory Apparatus—Water

Quantity				Description	Catalog numbers		
Type of plant			Unit		Central Scientific Co.—J150	E.H. Sargent & Co.—100	Fisher Scientific Co.—111
A	B	C					
1	1		ea.	Balance, analytical, chain type, notched beam w/rubberized cloth cover.	1109 2027	S-2758 S-3965B	1-916 1-990A
1	1	1	ea.	Balance, Harvard trip, agate bearings, 10 gm beam graduated to 0.1 gm.	3470	S-3215	2-035
1	1		set	Balance weights, for chain-type balance, 1 gm to 100 gm, no fractionals, stainless steel, w/case.	8119B	S-3991	2-224-5
1	1	1	set	Balance weights, for Harvard trip balance, metric, 1 gm to 500 gm.	9125C	S-4285	2-301

Laboratory Apparatus—Water—Continued

Quantity: Type of plant A	B	C	Unit	Description	Catalog numbers: Central Scientific Co.—J150	E.H. Sargent & Co.—100	Fisher Scientific Co.—111
				Beakers, Griffin, low form, pyrex:			
6	2		ea.	600-ml	14265	S-4675	2-540
4	2		ea.	400-ml	14265	S-4675	2-540
12	6	4	ea.	250-ml	14265	S-4675	2-540
4	2		ea.	150-ml	14265	S-4675	2-540
4	2		ea.	50-ml	14265	S-4675	2-540
				Bottles, dropping, Tk flat stoppers:			
6			ea.	30-ml	10580	S-8785	3-000
6	6	3	ea.	60-ml	10580	S-8785	3-000
2	2		ea.	Bottles, solution, cork stopper, for distilled water, 5-gal:	10310	S-8435	2-880
2	2	2	ea.	Bottles, wash, pyrex, 1000-ml	10710	S-9365	3-395
				Bottles, wide mouth, glass stopper:			
12	12	6	ea.	1000-ml (32 oz)	10450	S-8395	2-910
18	18		ea.	125-ml (4 oz)	10450	S-8395	2-910
2	1		ea.	Brushes, camel's hair, medium, pointed ends.	10938B	S-9725	3-654
2	2	2	ea.	Brushes, flask, for 500-ml flasks	10985	S-9965B	3-570
				Brushes, test tube:			
2	2	2	ea.	¾" to 1" tubes	10966C	S-9985	3-573
2	2	2	ea.	⅜" to ½" tubes	10966A	S-10005	3-576
				Burettes, Geissler, Exax blue lines, 0.1-ml graduations:			
4	4	2	ea.	50-ml	15926C	S-10635	3-699
2	2		ea.	25-ml	15926B	S-10635	3-699
2	2	1	ea.	Burners, Bunsen, Tirrill type, for:			
				(specify) artificial gas	11027A	S-12265	3-960
				natural gas	11027C	S-12285	3-962
				liquified petroleum gas	11028E	S-12285	3-962P
1	1		ea.	Burners, Fisher, high temperature, for:			
				(specify) artificial gas	11105A	S-12195	3-900
				natural gas	11105C	S-12196	3-902
				liquified petroleum gas	----------	----------	3-902P
				Chlorine residual test disc (see pH comparator).			
1	1		ea.	Clamp, burette, double	12116	S-19105	5-781
4	2		ea.	pinch, Mohr, 2¾"	12186	S-19495	5-850
2	2	1	ea.	test tube, Stoddard	12155	S-19555	5-841
1	1	1	ea.	Corks, assorted sizes, regular length and taper.	12404	S-23055	7-785
1	1	1	ea.	Cork borer, brass, sizes 5-mm to 11-mm	12465	S-23175	7-845
12	4	2	ea.	Cover, beaker, 90-mm	15850	S-83605	2-610
2			ea.	Crucibles, filtering, Alundum, medium 25-ml.	10065A	S-24375	8-230
2			ea.	Crucible holder, Walter, for 25-ml crucibles.	18110	S-24475	8-285
				Cylinder, double graduated, Exax blue line:			
2	1		ea.	1000-ml	16125	S-24695	8-554
2	1		ea.	500-ml	16125	S-24695	8-554
4	2	2	ea.	100-ml	16125	S-24695	8-554

Laboratory Apparatus—Water—Continued

Quantity				Description	Catalog numbers		
Type of plant			Unit		Central Scientific Co.—J150	E.H. Sargent & Co.—100	Fisher Scientific Co.—111
A	B	C					
1			ea.	Dessicator, Scheibler, plain, 250-mm w/o plate.	14560	S–25005	8–595
1			ea.	Dessicator plate, small holes, for 250-mm dessicator.	18610	S–25195–5	8–640
				Dishes, evaporating, porcelain, Coors:			
4	2		ea.	90-mm	18575	S–25505	8–690
6	4	2	ea.	75-mm	18575	S–25505	8–690
2	1	1	ea.	Files, triangular, tapered, 6-in.	88325	S–32235	15–228–10
				Filter paper, white, semi-creped:			
4	4	2	pk/100	9.0-cm	13255	S–32915	9–795
2	2	1	pk/100	12.5-cm	13255	S–32915	9–795
1	1		pk/100	quantitative, Munktell's No. 0, 9-cm.	----------	S–32785	9–915
1			ea.	Filter pump, Richards, brass, threaded connections, ¾" inlet pipe.	----------	S–33575A	9–965B
				Flasks, Erlenmeyer, pyrex, narrow mouth:			
2	2		ea.	1000-ml	14905	S–34105	10–040
6	6	4	ea.	500-ml	14905	S–34105	10–040
24	24	6	ea.	250-ml	14905	S–34105	10–040
1			ea.	Flask, filtering, side tube, pyrex, 500-ml	14990	S–34365	10–180
				Flask, volumetric, Exax blue line, w/ ground glass stopper:			
1	1		ea.	1000-ml	16226	S–34845	10–204
2			ea.	500-ml	16226	S–34845	10–204
2	1		ea.	250-ml	16226	S–34845	10–204
2	1		ea.	100-ml	16226	S–34845	10–204
1	1		ea.	50-ml	16226	S–34845	10–204
				Funnels, analytical:			
2	2	2	ea.	long stem, 100-mm diameter	15050	S–35315	10–325
2	2		ea.	short stem, 100-mm diameter	15070	S–35305	10–320
4	2		ea.	short stem, 65-mm diameter	15070	S–35305	10–320
1			ea.	Furnace muffle, electric, Hoskins type FD, size 202, 115-v.	13675A	S–36855	10–511A
1			ea.	Rheostate for furnace, muffle	13678A	S–36875	10–513A
2	2	1	ea.	Gauze, wire, asbestos center, 4" square	19970A	S–35335	15–590
1	1	1	ea.	Hotplate (specify gas or electric) electric, 3-heat, 115-v. 12" x 18" Hoskin type MA 121.	16650	S–41125	11–500
				gas, 2-burner.	16685	S–41475	4–220
				Hydrogen ion comparator (see pH comp.)			
1	1		ea.	Incubator, electric, 37° C., Thelco 2A	----------	S–43505	11–689
2	2	1	ea.	Jars, stoneware, 2-gal, for waste	----------	S–43945	11–845
12	6	2	ea.	Pencils, glass marking, red	14015	S–65775	18–380
1	1	1	ea.	pH Comparator, Hellige, pocket, colorimetric, w/color discs and indicators for pH ranges 4.0–5.6, 5.2–6.8, 6.0–7.6, 6.8–8.4 and 8.0–9.6.	21409	S–41765	11–507–20
1	1	1	ea.	Chlorine residual color disc and orthotolidine reagent for test of 0.0–1.0 ppm residual, for use with Hellige pocket model comparator.	29175	----------	11–507–30

Laboratory Apparatus—Water—Continued

Quantity			Unit	Description	Catalog numbers		
Type of plant					Central Scientific Co.—J150	E.H. Sargent & Co.—100	Fisher Scientific Co.—111
A	B	C					
				Pipettes, volumetric, transfer, Exax blue line:			
3	2	1	ea.	50-ml	16355	S-69515	13-649
3	2	1	ea.	25-ml	16355	S-69515	13-649
4	4		ea.	10-ml	16355	S-69515	13-649
4	4		ea.	5-ml	16355	S-69515	13-649
4	4	1	ea.	1-ml	16355	S-69515	13-649
1	1		ea.	Refrigerator, electric, 8 cf (requisition from Quartermaster).			
				Rings, iron, w/clamp:			
1	1	1	ea.	5-in.	18005	S-73045	14-050
1	1	1	ea.	4-in.	18005	S-73045	14-050
1	1	1	ea.	3-in.	18005	S-73045	14-050
1	1		lb.	Rod, stirring, glass, 6mm	14050	S-40080	11-375
1	1		ea.	Spatula, stainless steel, 4-in. blade	18755	S-75425	14-365
1			ea.	Spoon, horn, 150-mm	18780	S-75175	14-425
1	1		ea.	Stand, Nessler tube, for 100ml high, 50 ml low tubes.	29070B	S-21075	7-065
1	1		ea.	Stand, pipette, hardwood, revolving	19120	S-78905	14-745
1	1		ea.	Sterilizer, oven (specify gas or electric)			
				electric, 115v.	48210A	S-76265	14-490
				gas	48242A	S-76285	14-493
1	1		ea.	Sterilizer, pressure, 11" x 24" (Specify gas or electric):			
				electric, 115volt	44122	S-76005A	1-801-1A
				gas	44120	S-76025A	1-797-1
1	1		ea.	Still, 1gph (specify gas or electric):			
				electric, 115v.	12750	S-27415	9-018
				gas.	12760	S-27465	9-022
				Stoppers, cork (see Corks).			
1	1	1	lb.	Rubber, solid, assorted sizes Nos. 1-6	18153	S-73305	14-130
				Supports:			
1	1		ea.	Burette, 20" rod, tripod base	19080	S-78335	14-675
1	1	1	ea.	Funnel, hardwood, 4-place w/clamp	19085	S-78815	14-740
1	1	1	ea.	Ring, iron, 24" rod, 6" x 9" base	19070	S-78305	14-670
1	1	1	ea.	Thermometer, —10°C. to 260°C.	19240	S-30005	14-985
2	2	1	ea.	Tongs, crucible, 9", double bent, brass or cadmium plated steel.	19600	S-82115	15-200
2	2	1	ea.	Triangles, wire, 2½"	19735	S-82415	15-280
2	2		ea.	Tripod, w/concentric rings, 6" diameter	19775B	S-82515B	15-305
2	2	2	ea.	Tubes, drying, 100-mm.	14755A	S-28815	9-215
12	12		ea.	Nessler, APHA, 100ml, graduated 50-100	29060C	S-21035	7-057
3	1		lb.	Tubing, glass, assorted, 5-mm—10-mm	14076	S-40140	11-350
				Tubing, rubber:			
12			ft.	¼" bore, 3/16" wall, vacuum or pressure	18204-3	S-73535	14-173
24	24	12	ft.	¼" bore, ⅛" wall.	18202C	S-73525	14-150
12	12	6	ft.	⅛" bore, 1/16" wall	18200-1	S-73505	14-158
1	1		pr.	Watch glasses, counterpoised, 2½ in.	2250	3785	2-195
1	1		ea.	Turbidimeter, Jackson	29105	83705	15-380

Laboratory Apparatus—Water—Continued

Quantity			Unit	Description	Catalog numbers		
Type of plant					Central Scientific Co.—J150	E.H. Sargent & Co.—100	Fisher Scientific Co.—111
A	B	C					
1	1	1	ea.	Water Test Comparator, Hellige Aqua Tester, with Fluoride Color Disc or equal Comparator.	29170	----------	----------
				BACTERIOLOGICAL			
1	1		ea.	Boiler, double, 1½ qt.	----------	8225	2–750
1	1		ea.	Counter, bacteria, Quebec model, 115-v.	44316	28350	7–908
1	1		ea.	Counter, hand, tally	73320	28285	7–905
1			ounce	Coverglasses, microscope slide, 18-mm	66510B	58715	12–524
30	30		ea.	Dishes, culture, Petri, pyrex, 100 x 15 mm, w/covers.	44370–4	25925B	8–747
1			ea.	Forceps, cover glass	66600	35195	10–295
2	2		ea.	Holders, culture dish, for 100-mm dishes	44398	26055	3–460
1			ea.	Holders, inoculating needle, for No. 24 B & S gage wires.	46220	62765	13–093
1			box	Lens paper, optical	12290	44825	11–996
1			ea.	Microscope, Bausch & Lamb, model FPR–8	61053X	52080	12–310
1			pk/10	Needles, inoculating, 24 B & S gage, chromel, 4-in.	46210B	62755	13–095
				Pipettes:			
24	24		ea.	1.1-ml capacity, calibrated at 1.0 and 1.1-ml.	24115–2	60025	13–669B
24	24		ea.	11.0 ml capacity, calibrated every 1.0 ml.	24115–8	60045	13–669J
2	2		ea.	Pipette boxes, sterilizing, 16-inch	46670	69815	3–465
1			ea.	Reading glass, 4-in.	60410D	44505	12–070
1			gross	Slides, microscope, glass, 3" x 1"	66310	58785	12–550
				Test tubes, bacteriological, w/o lip:			
1	1		gross	175 x 22-mm; 7" x ⅞"	44500–11	79525	14–925
1	1		gross	150 x 19-mm; 6" x ¾"	44500–10	79525	14–925
1	1		gross	100 x 13-mm; 4" x ½"	44500–5	79525	14–925
1	1		gross	75 x 10-mm; 3" x ⅜"	44500–3	79525	14–925
4	4		ea.	Test tube basket, wire 6" x 6" x 6" app.	48515B	79925	14–971
2	2		ea.	Test tube support, 13 hole	19200A	79005	14–770
1	1		ea.	Thermometer, enclosed scale, —20°C. to 110°C.	19255	80305	15–005
				MICROSCOPICAL			
1			ea.	Counting cell, APHA, w/three cover glasses.	29038	84045	15–425
12			ea.	Counting cell cover glasses, 25- x 60-mm.	29039	84055	15–430
1			ea.	Filtering funnel, Sedgewick-Rafter, APHA	29030	84015	15–400
24			ea.	Filtering funel discs, bolting cloth, APHA	29034	84025	15–415
1			ea.	Micrometer disc, eyepiece, Whipple, APHA for use with Microscope, B & L model FPR–8	29037	84065	15–435

Laboratory Books

Quantity			Unit	Description
Type of plant				
A	B	C		
1	1	1	ea.	Standard Methods for the Examination of Water, Sewage, and Industrial Wastes. Latest Edition, American Public Health Association and American Water Works Association.
1	1	1	ea.	Laboratory Manual for Chemical and Bacteriological Analysis of Water and Sewage—Eldridge, Theroux, and Mallman, Latest Edition, McGraw Hill Co.

STANDARD SOLUTION FOR WATER ANALYSIS ACCORDING TO AMERICAN PUBLIC HEALTH ASSOCIATION STANDARD METHODS OF WATER ANALYSIS

Platinum-Cobalt Standard, Color 500	200 ml.
Standard Calcium Chloride Solution	500 ml.
Standard Soap Solution	1000 ml.
Standard Ferric Iron Solution	500 ml.
Standard Silver Nitrate	500 ml.
Soda Reagent	1000 ml.
Acid Sulphuric, N/50 Solution	1000 ml.
Sodium Hydroxide, N/50 Solution	500 ml.
Sodium Hydroxide, N/44 Solution	500 ml.
Potassium Thiocyanate	500 ml.
Acid Hydrochloric Dilute, Approximately 3 N.	500 ml.
Potassium Permanganate, Approximately N/5	500 ml.
Acid Nitric, 6N Solution	500 ml.
Methyl Orange Indicator	500 ml.
Phenolphthalein Indicator	500 ml.
Erythrosine Indicator	500 ml.
Potassium Chromate Indicator	100 ml.
Orthotolidine Indicator	500 ml.
Sodium-meta-arsenite 0.5% Solution	500 ml.

CULTURE MEDIA FORMULAE OF "STANDARD METHODS OF WATER ANALYSIS"

Bacto-Nutrient Agar, Dehydrated	1 lb.
Bacto-Lactose Broth, Dehydrated	1 lb.
Levine's-Eosin Methylene Blue Agar, Difco	¼ lb.

BACTERIOLOGICAL STAINING SOLUTIONS ACCORDING TO "STANDARD METHODS OF WATER ANALYSIS"

Bismark Brown	¼ lb.
Carbol Fuchsin	¼ lb.
Carbol Gentian Violet	¼ lb.
Gram's Iodine Stain	¼ lb.
Methylene Blue, Koch's	¼ lb.
Safranin Stain	¼ lb.
Potassium Iodine	½ lb.

NOTE: For Class A plants chemicals should be bought in bulk and standard solutions and reagents prepared by the Plant Chemist. In many instances the same instructions may apply to Class B Plants.

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