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Factors concerning water distribution systems, including an evaluation of materials and a recommendation of materials best suited for service in typical facilities are discussed. Several installations are discussed in an effort to bring out typical features in selected applications. The following system types are included--(1) industrial applications, (2) pharmaceutical processing and research, (3) chemical, and (4) health research. Significant factors include water impurities, distilled water purity, materials and material costs, and system design and operation. (RH)

Laboratory Design Notes

Distributed in the interest of improved research laboratory design

DISTILLED WATER DISTRIBUTION SYSTEMS

by
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U.S. Department of Health, Education, and Welfare – Public Health Service

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DISTILLED WATER DISTRIBUTION SYSTEMS

Introduction

Water, one of our vital natural resources, plays a significant supporting role in fostering progress and establishing new frontiers, not only in the scientific community but also in practical and industrial applications. Chemical companies, food manufacturers, pharmaceutical houses, universities, colleges, research and industrial laboratories, and many other organizations have growing needs for specially processed water. As a matter of fact, numerous laboratory research techniques and manufacturing processes require purified water that is not only free from inorganic contaminants, but also free from pyrogens, bacteria, and organic impurities.

The increased demands for an adequate supply of purified water are readily apparent. One obvious indicator is the many research, industrial, and teaching facilities, presently in the design and construction phases, that incorporate provisions for a centralized source of distilled water. Similar facilities, designed twenty years ago, made no provisions for a central source of purified water. Today, it is no longer necessary for the individual to maintain his own source of pure water; recent advances in water purification and distribution technology have relieved him of this age-old responsibility. Modern stills (or demineralizers) capable of producing hundreds of gallons of purified water per hour, coupled with large-volume storage tanks, will provide an adequate supply of distilled (or deionized) water on tap in the scientist's laboratory, or the manufacturing plant.

While the traditional materials for handling distilled water have been metals, principally tin and aluminum, advances in the field of plastics since World War II have created a number of attractively priced, non-metallic piping materials. In addition, glass piping, particularly the "Pyrex" variety, is now available in mass production quantities at a competitive price.

The purpose of this report is: (a) to evaluate numerous materials for distilled water distribution system usage, and (b) to recommend a material (or materials) best qualified for service in typical facilities. Significant factors included in the discussion are: (1) water impurities, (2) distilled water purity, (3) available materials, (4) material costs (see Table I), (5) typical installations, and (6) system design and operation. These criteria are not considered all-inclusive, nor is their order indicative of their relative importance.

Water Impurities

Purification and water treatment procedures must remove a variety of gaseous, liquid, and solid constituents from water. Analysis shows that surface water from lakes, ponds, rivers, and similar natural sources contains organic wastes, oil, mineral salts, mud, and various other impurities. Ground (well) water may contain similar impurities except that the concentration of mineral salts may be high in proportion to the quantity of organic wastes. Almost any natural water contains impurities. As a matter of fact, water precipitated from the atmosphere far above the earth's surface probably contains impurities. Thus, regardless of its source, until water is purified it may contain a variety of foreign substances.

Purification not only removes impurities but also endows water with an increased affinity for gases, as well as liquids and solids. For example, purified water allowed to stand in an open metal container is capable of absorbing atmospheric gases and dissolving various metallic constituents from the walls of the container. For this reason, the handling and storage of purified water must be done carefully, in order to minimize or avoid re-contamination. Storage tanks must be constructed of an impervious material which does not affect water purity. Furthermore, to control gaseous contamination the tank must be designed to limit atmospheric contact with the water.

In addition to absorbed gases and dissolved solids, it may be necessary to eliminate insoluble solids (suspensions), miscible liquids, emulsions, and colloids. Specific examples of the more common solid impurities to be removed by water purification processes are: sugars, salts, silica, clay, and biologicals (pyrogens, viruses, bacteria, etc.). Frequently encountered liquid contaminants are alcohols, detergents, and oils, while carbon dioxide, ammonia, and nitrogen are the usual gaseous impurities.

To separate impurities from water, a combination of processes performed in individual steps, or successive stages of treatment, is usually required. Many installations include a train of equipment, consisting of filters, demineralizers, and distillation equipment arranged so that water passes through one type of equipment to the next. While one treatment stage may be effective in eliminating one form of (or a specific) impurity, additional stages of treatment may be necessary to separate another type of contamination. For example, ion exchange (demineralization) readily removes dissolved inorganic salts, yet this method is ineffective in eliminating sugars and many other organic compounds. Likewise, filtration will remove insoluble solids, but it is not effective in eliminating dissolved solids. Thus, the need for employing successive stages of treatment is apparent.

Removal of a contaminant by distillation, ion exchange, filtration, or any other effective means depends on impurity characteristics such as: (a) the physical state of the contaminant (e.g., liquid, gas, solid), (b) its ionization, (c) its physical-chemical properties, (d) its miscibility with water, and (e) its solubility in water. Besides these factors, the ultimate water purity, and the residual trace contaminants, are important considerations in selecting proper treatment steps and procedures.

Water Purity

Since purified water fulfills many different needs, satisfactory purity requirements for one application are not necessarily sufficient for another occasion. In some instances users disagree on water quality to the extent that the method of purifying water is a more critical consideration than the actual purity of water. Theoretically, pure water exhibits a specific resistance of 18.3 megohm-cm when measured at 25°C. However, in practice, water of absolute purity is difficult to produce and maintain at this purity level without becoming contaminated by atmospheric gases and dissolved solid materials originating from the storage vessel. Fortunately, few users require water that is absolutely pure, and most users are satisfied with water of much lower quality.

While some users prefer to base their standards of purity on the absence of trace elements, specific resistance is generally used as a basis for comparing water purity. Strictly speaking, specific resistance is expressed in ohm-centimeter units; however, in actual practice purity may be expressed in parts per million (ppm) concentration of an ionized salt (e.g., sodium chloride) as the equivalent of a given specific resistance. The conversion of specific resistance to parts per million is possible provided a known concentration of the specific salt yields a specific resistance value which can be measured. It should be recognized, however, that specific resistance measurements are indicative only of ionized contaminants. Other types of contaminating material must be detected and measured by other means.

Where a number of research disciplines and/or manufacturing processes have need for purified water from a common source, a survey should be conducted to determine the overall and optimum purity requirements, and daily consumption. Such a survey will usually confirm that all users do not demand the same quality or quantity of water. The purity spectrum will usually range from relatively impure up to, and including, absolutely pure water. Since daily consumption varies from user to user and day to day, the total daily water consumption must be estimated from the number of users and a liberal average quantity per user.

To differentiate between requirements, several levels of water purity have been arbitrarily established as follows: (1) absolute purity water, (2) ultrapurity water, (3) high purity water, and (4) low purity water. This type of classification will assist the designer in evaluating the survey data and determining the most effective system layout. For example, if a small group (25%) of users require ultrapurity water in small quantities, then small volume, laboratory-type stills are probably the ideal solution. On the other hand, if a large group (50%) of users collectively demand several hundred gallons of water per day, a central treatment plant and distribution system should be considered as the optimum system design.

The levels of water purity previously mentioned are further described in the following paragraphs.

(1) Absolute purity water (18.3 megohm-cm specific resistance*)

For practical reasons, the production of water that is absolutely pure is limited to small laboratory-scale stills. Units of this type are commonly referred to as 'conductivity' stills wherein the feed water is digested with oxidizing agents to break down organic matter prior to distillation. Water production from such a still is, ordinarily, a few liters per hour. The equipment is complicated, but fortunately, the demand for water of this purity is low.

(2) Ultrapurity water (greater than 1 megohm-cm specific resistance)

For sophisticated research, investigators may insist on extremely pure water, but not necessarily, absolutely pure. Tradition, custom, or even past research experience may make him reluctant to use water from a central distilling system without subsequent treatment. Trace contamination is usually the principal cause for concern. In such instances, house system water may be used as a starting point for one or more subsequent distillations in a laboratory-type still capable of producing only a few gallons of water per hour. If operating properly, such stills will produce water having a specific resistance approaching 1.5 megohm-cm. Since these stills are generally small capacity units, they are usually installed in a laboratory or utility room without an extensive distribution system. Where there is no great concern about the presence of organic contamination, demineralization, a cheaper process than distillation may be satisfactory.

(3) High purity water (1 megohm-cm specific resistance)

Without special pretreatment of raw (city) water, a large volume still (e.g., 100-500 gallons per hour) can be expected to consistently produce water with a purity of about one megohm-cm. Reputable still manufacturers are acutely aware of equipment capabilities and will not normally guarantee routine still operation above this level with special pre-feed water treatment. Furthermore, unless storage tanks and distribution piping are constructed of proper materials, considerable degradation of the distillate quality through physical contact with storage tanks, piping, and even the atmosphere can result. Contamination, even in immeasurable (trace) quantities, can be objectionable to the researcher because cell growth may be inhibited, research results may be obscured, or certain sensitive biological or biochemical processes may be deactivated.

*Measured at 25°C.

(4) Low purity water (less than 1 megohm-cm specific resistance)

In health and biological systems research there are a few investigators whose demands are such that almost any purity of distilled water is sufficiently good. Trace contamination will not affect the research results and there is little concern about the water purity.

PIPING AND STORAGE TANK MATERIALS

The selection of a particular distribution piping and storage tank material is a decision which must be supported by water purity and contamination studies, previous experience, and cost analyses. Generally, the choice will originate from three broad categories of materials, namely: plastics, glass, and metals. Advances in the field of plastics as well as the adaptation of glass to mass-produced pipe are the chief reasons for including these types of materials here, in conjunction with metals. Many materials, however, are quickly eliminated either because contact with water results in excessive contamination, the material is too costly, or tank and/or pipe fabrication difficulties are encountered.

Where water purity or trace contaminants are concerned, material choices are limited largely by the contaminants which can be tolerated. In health research, for example, water containing heavy metals such as lead, chromium, iron, and copper, even in trace quantities, is toxic to cells. Similarly, in transistor or similar electronics part manufacturing the solid state material must be refined to an extremely pure condition for the element to function as intended. Trace contamination in the water used to refine the material may be detrimental or ultimately poison the part. On the other hand, in pharmaceutical manufacturing the presence of sodium, boron, silica, or certain other constituents leached out from glass tanks (or piping) is probably not objectionable, if the pharmaceutical products are stored (or marketed) in glass bottles.

Quite naturally, previous experience is an invaluable aid which an architect-engineer should explore before selecting a piping material. In many cases, the repeated usage of a material can be attributed to prior knowledge and experience. For example, at the new National Bureau of Standards facility, Gaithersburg, Maryland, experience with tin-lined brass pipe in the old facility eliminated the need to consider other materials for the new facility.

Mechanical, physical and chemical properties, as well as other pertinent information regarding specific materials, is presented in the discussion which follows. Cost data for many of these materials are cited in Table I.

Plastics

In the field of plastics, the more prominent formulations are: Teflon, nylon, polyvinylchloride, polyethylene, and two recent additions, polypropylene and polycarbonate.

Plastics, in general, lack mechanical strength, especially at elevated temperatures, and water contamination from organic constituents such as plasticizers or residual molding products may be excessive. In addition, "environmental or thermal stress cracking" and "cold flow" are phenomena which affect the long term stability of some thermo-plastics. Specific drawbacks to the above mentioned materials are as follows: (1) Teflon, although it does not contaminate water to a measurable degree, is so expensive that its use is limited to lined pipe applications; (2) Nylon, although available in pipe and fittings at considerable cost, is inferior to Teflon from a contamination viewpoint; (3) the objections to polyvinylchloride are its lack of mechanical strength at elevated temperature and its excessive water contamination; (4) while polyethylene is widely used in laboratories as bottles and containers, the low molecular weight material, in popular demand, is subject to distortion at elevated temperature and sheds organic contaminants to the water; and (5) polypropylene, polycarbonates, and high molecular weight polyethylene have temperature operating limits which are adequate, but the water contamination characteristics have not been thoroughly substantiated by experience.

In addition to the above comments, it should be mentioned that plastics are susceptible to attack by rodents. For this reason, the use of plastics in any utility application, particularly in a structure housing rodents, should be given careful consideration.

Glass

As a piping material, glass is relatively new to the market. One of the unexpected deficiencies of this material is the leaching out of certain constituents over extended periods of time, especially during the first six to twelve months of usage. Elements such as boron, lead, arsenic, potassium, and sodium, as well as silica, which are present in the glass, may be expected to appear in the water in varying quantities during the leaching out period. Another objection to glass pipe is its susceptibility to breakage.

Metals

Probably the most widely used materials for storage tanks and transmission piping are tin, aluminum, and stainless steel. In addition, an alloy consisting of a small amount of silver in tin, is being investigated to determine its applicability.

1. Tin -- Because of its high purity and nobility, "block"* tin is probably one of the best materials for a distilled water distribution system. In the fields of research and specialized manufacturing, there have been few, if any, objections to distilled water which has been in contact with tin only. As a matter of fact, in critical applications, although expensive, tin is the material of choice. Tin has been used not only as a liner for storage tanks and piping but also as a liner for distillation units. Lack of mechanical strength, one of the principal drawbacks to tin tubing, has been largely circumvented by using tin lined brass pipe. Tinned threads on the pipe as well as in the fittings provide a continuous inner lining of block tin in an envelope with adequate mechanical strength. Pipe and fittings assemble readily through use of Teflon tape acting as a thread lubricant. Heretofore, tubular tin required continuous support because of its fragility.

2. Aluminum -- Many distribution systems today use aluminum alloy. In fact, the Clinical Center at the National Institutes of Health, a combined hospital and health research facility, employs an extensive distribution system consisting of aluminum alloy tanks and piping. Samples of water from this aluminum system and a similar tin-lined system were analyzed to determine the comparative amounts and types of impurities imparted to the water by each system. Water analysis indicated no marked difference in the contamination. As a matter of fact measurements indicated that: (1) neither system significantly reduced the specific resistance of water and (2) the concentration of aluminum or copper contamination in the water from either system was less than two parts per billion. In no instance did the level of specific resistance fall below one megohm-cm.

Aluminum is a relatively non-toxic, and inexpensive metal which readily forms an inert surface layer of aluminum oxide upon exposure to the atmosphere. This layer apparently inhibits water contamination, especially after long-term exposure, or usage of the aluminum. However, difficulty in threading pipe as well as the assembly of threaded parts cannot be overcome satisfactorily unless the proper type of aluminum alloy is selected. Type 3003, while its purity is not as high as type 1060, or type 1100, does overcome galling, and, for this reason, is recommended by Aluminum Company of America.

3. Stainless Steel -- The austenitic (18-8 variety) stainless steels, type 300 series, have been used in the fabrication of storage tanks and piping wherever contaminants such as iron, nickel, and chromium can be tolerated. But, these impurities cannot be tolerated in water used in most medical, pharmaceutical, and similar research fields. Unfortunately, pickling and passivation of the internal pipe surface do not eliminate or prevent traces of these impurities from being dissolved in water.

*Highly refined grade of tin, usually having a purity in excess of 99.97% tin.

4. Silver-tin Alloy -- As pointed out earlier, one of the problems in using pure tin tubing is its poor mechanical strength. Fortunately, this weakness has been overcome by the use of brass pipe in combination with a tin lining. Tin also presents a problem of mechanical stability and strength that is associated with changes in its crystalline structure caused by environmental temperature cycling. Two reasons for mechanical failures have been postulated: (1) a change in crystal structure leads to a change in density which can produce internal stresses exceeding the shear strength of the tin, and (2) since tin does not expand equally in all directions, auto destruction may occur. Either (or both) of these peculiarities may explain fractures and mechanical defects observed in thick sections of pure tin subjected to thermal cycling. The addition of an alloying element, silver, in small quantities strengthens grain boundaries and apparently prevents failure without detracting from the nobility of pure tin.

Costs

Generally, a cost study considers both material and installation costs; otherwise the study may be inaccurate, incomplete, and lead to erroneous conclusions. It should be recognized that data based on limited installation experience with a particular kind of pipe may also be misleading. This is especially true when plumbers are forced to work with a new material which requires novel or unique installation techniques in specialized applications. Without a doubt, a distilled water distribution system requires special care and attention regardless of the pipe material. For this reason, ordinary 'rule of thumb' estimates for installation costs may be far from realistic. In view of the limited installation experience with many materials it was decided to present only material cost comparisons and exclude labor and installation cost data.

In Table I, materials are arranged in ascending order based on the cost per lineal foot of one inch diameter pipe. The only exception is glass piping which is priced on the basis of one and one-half inch diameter pipe as indicated in the table. For simplicity, only one pipe size has been used for price comparison, but obviously, a distribution system may consist of pipe sizes ranging from one-half inch to at least two inches in diameter. Prices quoted in the table are applicable to pipe purchases of one hundred feet or less without benefit of quantity discounts.

In the case of lined piping, pipe wall thickness and thickness of liner vary not only with the material but also with pipe size. Generally, the pipe wall thickness is based on allowable stresses for a given service pressure or on adequate material to sustain threading, whichever is limiting. Liner thickness may vary from 1/32 (nylon and Teflon) to 1/16 inch (tin). The most common method of joining pipe is threading; however, Teflon lined pipe is manufactured with flanged, bolted joints, and polyethylene joints are frequently fused by the application of heat. Most pipe is manufactured and furnished in standard lengths at least ten feet long. However, one notable exception is glass whose standard length is only five feet.

TABLE I

Pipe Costs

Material	Cost[1] ($/ft)
Polyethylene, Schedule 40	$0.39
Polypropylene	
Schedule 40	0.398
Schedule 80	0.498
Polyvinylchloride, Schedule 80	0.546
Aluminum, Type 3003, Schedule 40	0.55 (1966)
Nylon-lined iron	1.13
Polycarbonate (unfilled)	1.72 (1/8" wall)
Glass (Pyrex)	2.00 (1 1/2" Dia.)
Stainless Steel, Type 304	3.56
Tin-lined brass	6.30
Teflon-lined iron	7.14

1/ Cost per foot of 1" nominal diameter pipe, in orders of 100 feet (or less), with discount in year 1965, unless otherwise noted.

Typical Installations

Probably no single distilled water installation can be considered typically representative of all others. In most instances, there are certain unique features which distinguish one installation from others. Because purity requirements are so diverse and feed waters vary geographically, system design is far from routine. As a matter of fact, changes in raw water composition may materially affect the performance of purification equipment. In recognition of these facts, several installations will be discussed in an effort to bring out typical features in selected applications. Accordingly, the following system types were chosen: (1) industrial applications, (2) pharmaceutical processing and research, (3) chemical, and (4) health research.

Industrial

The discovery and later manufacture of solid state electronic devices such as transistors, rectifiers, lasers, and others has imposed demands for ultrapure water in quantities previously unequalled. To produce ultrapure water better than 1.5 megohm-cm specific resistance requires an exotic array of treatment equipment including considerable pretreatment of the feed water. Distillation alone is usually not sufficient to attain this level of purity. In fact, coagulation, filtration in several steps, and deionization may also be needed. In one instance the train of equipment consisted of a coagulant feeder and filter, organic-removal filter, four-bed demineralizer, high-purity still, storage tank, mixed-bed demineralizer and submicron filter in the order cited. It is interesting to note, that, while demineralizers remove ionizable matter, trace contamination from the demineralizing resin may render the treated water unfit unless special precautionary measures are instituted.

Pharmaceutical Processing and Research

Probably the greatest single concern in pharmaceutical and drug processing is the need for water that is free from pyrogens (organic-type impurities producing fever in humans and animals). In many pharmaceutical installations the distribution system is periodically flushed with live steam to destroy bacterial growth. By comparison, inorganic contamination may be of little concern. In some cases, the presence of certain inorganic compounds may be not only desirable, but necessary. For example, in blood and blood products manufacturing, sodium chloride may be added to the water employed in preparing blood plasma and serum to make them ideally compatible with human blood.

Since ion exchange methods do not remove sugars and other organic compounds, viruses, bacteria--and in particular pyrogens--it can be assumed that distilled, rather than demineralized water must be used in the preparation of intravenous solutions. Of course, this does not preclude the use of ion-exchange equipment ahead of the still to maintain constant feed water quality and to give improved still life.

By way of contrast, in pharmaceutical research, water purity requirements may be considerably different from those existing in drug and pharmaceutical manufacturing. Drug research usually involves biological systems and living cells which are sensitive to the slightest trace of foreign matter.

Chemical

A notable example of a typical purification system for chemical research laboratories is the new installation for the National Bureau of Standards, Gaithersburg, Maryland. In this three-story chemistry research building the distilled water system is designed to supply water of about 2 megohm-cm specific resistance to 30 per cent of the laboratories. Tin-lined brass distribution piping from the central distilling source supplies 50-60 distilled water taps. Raw water is treated in several steps before it enters the still. It is filtered by a carbon filter, demineralized, and treated for organic material removal. Thereafter, a steam generator converts the water to steam which operates the still. The resulting condensate is scrubbed with filtered air and then fed back to the still, where it is reboiled and recondensed as distillate. Finally, the water is transmitted from storage tanks throughout the building as distilled water. On the basis of previous experience, this system should be completely satisfactory.

Health Research

The typical distilled water installation in a health research facility will consist of at least two centrally located stills, adequate storage tanks, and a distribution system serving about two-thirds of the laboratories. Provisions should be included for expanding service to additional laboratories if research programs are apt to change.

Generally, high purity water of 1 megohm-cm specific resistance will meet the purity demands of health research programs. However, this purity level may not satisfy all users, as evidenced by a sampling of the scientific staff at the National Institutes of Health, Bethesda, Maryland. The following information was collected through contacts with a representative group of forty user scientists at this facility. In this group, 30 per cent expressed a need for water with a purity greater than 1 megohm-cm, while 55 per cent felt that high purity water of 1 megohm-cm specific resistance was adequate. Both factions voiced concern over contaminating elements such as copper, lead, iron, and other heavy metals in the water because of their possible toxic effects on biological cells and systems. The remaining 15 per cent of the group felt that almost any purity of distilled water was sufficient.

System Design Features

It has already been suggested that the need for centralized stills and distribution piping should be based on the scientific program needs. Such a centralized system may not be needed because purity requirements are so diverse that several small stills in various building locations would be more effective. A number of small stills strategically located may eliminate all piping except short runs to corridor outlets or high demand laboratories, and thereby offer not only a decided economic advantage but, in addition, minimize possible contamination.

If it is found that a central system consisting of stills, storage tanks, and piping is the best solution to the production and distribution of distilled water, then certain features necessary to good system design and operation should be considered.

In the interest of keeping a constant supply of distilled water available, at least two stills should be installed, so that, when one is being repaired or is out of operation for inspection or maintenance, the other can continue to produce water. Still maintenance is usually unavoidable. In this connection, the use of pretreatment equipment, such as water softeners or demineralizers, may be a wise economic investment because still cleaning and maintenance are reduced considerably.

Stills and storage tanks should be sized so that an adequate daily volume of water is assured. Still size can be determined on the basis of 24 hour, continuous still operation provided adequate storage tanks are used. The tanks can store up water produced during the night so that the following day's needs can be met by the combined supply of the still and the tank. The still should be equipped with adequate automatic controls. A penthouse location for stills and storage tanks is best because sources of contamination, such as pumps, packing and gaskets, are eliminated by a gravity-feed system. With regard to piping layout, the system should be designed to preclude pipe in which water would stagnate, become unduly contaminated, or foster bacterial growth. Experience has shown that the inclusion of flow metering devices is a valuable asset in identifying leaks from faulty or open faucets. As a matter of fact, it may be worthwhile to include an alarm system which would detect unusual rates of drain off, particularly at times when the use is expected to be low. A decided economic saving of both piping and volume of distilled water can be effected by purposely sizing the pipe to limit water flow rates from laboratory faucets.

Summary

A combination of purification processes and treatment steps are frequently necessary to remove contaminating impurities from raw water. Because raw water impurities vary according to seasonal changes, geographic location, and the water source, it is to be expected that water conditioning equipment as well as methods of purification will differ from place to place and facility to facility. The most notable reason for variations in procedures, methods of treatment, and equipment to obtain purified water is that standards of purity vary considerably. As already indicated, distilled water is a relative term indicative of the purification process rather than the purity of the water. The scientific community may refer to "double" or "triple" distilled water as a means of characterizing its purity, but these terms are nebulous and inexact.

From a cost standpoint, the initial installation costs as well as operating and maintenance costs are important. Budgetary restrictions may compel the designer to select piping, storage tank materials, and equipment with care. Many equipment producers, particularly still manufacturers, are anxious to supply information and guidance to solve not only engineering design problems but budgetary problems as well. In this connection, it should be recognized that the production, handling, and transmission costs of purified water increase rapidly with increased purity requirements. A thousand gallons of raw water costs approximately 40 cents, while distilled water in quantity from a single-effect still costs $10-$20 per thousand gallons. Redistillation will add another $5-$20 per thousand to the original distillation cost. In spite of its cost, it is very important to recognize that water of the proper quality (and quantity) is absolutely essential to conclusive research work and progress in many other areas. Many experimental results can be altered entirely by the continued use of improper water quality. Self-closing faucets, as well as leak detectors and/or flow monitoring devices judiciously placed in the piping system, will minimize loss of water by accidental (or careless) means and serve to eliminate shortages which would deprive users of precious distilled water.

From an operational viewpoint, it is well to install equipment, storage tanks, and associated items in a cluster rather than 'piecemeal'. A clustered arrangement contributes to effective maintenance and surveillance of equipment. If a centralized system is not considered feasible because of diverse or stringent water purity requirements, then a minimum number of separate units should be strategically located throughout the building.

Finally, one of the most important but often neglected factors contributing to a successful distilled water system is the care with which it is installed. Cleanliness, too, is very important, especially in the piping installation, but is seldom recognized by plumbers and inspectors. Pipe threading compounds, greases, oils, acids, and other contaminating materials must be prevented from getting into the system. Otherwise, these compounds will be a constant source of contamination.

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Additional copies of this leaflet may be obtained from: Office of Architecture and Engineering, Division of Research Facilities and Resources, National Institutes of Health, Bethesda, Maryland 20014