Piping: process materials

Inside, outside, and under the ground

By **HAROLD S. MARCH, PE**, Manager,
Mechanical Engineering Dept.,
Laramore, Douglass and Popham,
Engineers - Consulting, Chicago, Ill.

Process piping holds and moves fluids or solids suspended in fluids from one place to another. Most industries use process piping, and everyone is dependent upon it. Water and sewage are prime examples, and oxygen, fly ash, liquids, gases, mixtures of liquids, mixtures of gases, slurries, and vacuum systems all meet the process piping goal. There are countless processes in the world, and no one article will cover them all, but I will try to touch on many.

First, who is involved? Let's generalize. An owner designs or requires a particular process; a manufacturer designs and makes a type of pipe; a consultant puts the process and the pipe together; a contractor builds the system; and the operator maintains the result. Each party involved looks upon the project from a different point of view.

The process designer (owner) looks at conveying the fluids, etc., at a reasonable operating and capital cost. The pipe designer (manufacturer) is concerned with various base materials and forms to fit the physical conditions. The system designer (consultant) chooses among the many available sources of pipe that meet the conditions of the process. Sometimes he asks that the process and/or pipe be modified to fit each other. The assembler (contractor) puts the system together, checking and adjusting for final functions. Last, and equally important, is the maintainer (operator), who keeps the system operating by modifying and repairing when necessary.

The process or the pipe design, which came first? Most likely the process was first, and then a pipe was designed to fit the physical conditions of that process. Now, however, many piping systems are available, and an application of one of them to the process is very likely all that is required. But the pipe designer is still faced with the problem of finding new materials or a combination of materials to meet recently developed processes that are beyond existing piping limitations.

There are many parts to a process piping system. Valves, fittings, hangers, tanks, pipe, coverings, joints, insulation, converters, expansion joints, and pumps comprise a partial list. However, pipe, fittings, and joints are the basic components of a piping system, and hangers, insulation, and coverings are the first line of accessories. All other accessories, such as valves, controls, indicators, tracing, tanks, metering, etc., are applied to or connected with process piping. The total system should be designed with the acknowledgment of the limitations of each and all parts involved.

For example, in an application of glass fiber piping to a hot water system (190 F), hangers were spaced 3 to 6 ft apart on a 3 in. line, except at a duct crossing. Here, the span was 11 ft, and the resultant sag of about 3 in. looked bad. The pipe operated properly, but a channel holding the pipe, was added to the span under the duct. Thus, the limitation of anger spans had to be considered.

Pipe design is an involved science d somewhat of an art. Construc- on materials must be studied for trength, resistance to corrosion, lasticity, conductance (thermal d electrical), workability, ex- rudability, flow resistance, and fe. Process temperature, pressure, acuum, and toxicity demands are e main regulators. The external onditions are another set of reg- ators.

The Alaskan pipeline is an exam- e of an application that is affected y both internal and external reg- ators. The oil must be heated to ow well, and the outer surface of e pipeline must be cool to keep the rmafrost intact. The process de- gner's viewpoint is that the peline needs insulation to lower ating costs, and the environmen- ist thinks that it needs insulation keep the ground cool and undis- bed.

Obviously, both external and ernal needs must be satisfied. For ample, a laboratory complex re- ired the use of all glass drains be- se of the many chemicals em- oyed. The application of glass also owed for inspection to locate gging and finding lost items. nsidering the possible dangerous ure of the effluents, both exter- and internal needs were solved using glass pipe, and the installa- n was successful.

Where will the pipe be located? ee major areas are evident: out- e, inside, and underground. All e similar problems and some uliar problems as well.

Outside piping–Outside piping generally covered, probably lated, and may be heat traced. n areas allow the easiest han- g of thermal expansion through ral loops, but even outside pip- can use the ball joint loop. Ac- ories, such as pumps and con- may require small enclosures pecialized equipment. Weather major external regulator as is the bility of damage. A road cross- is a good example of an area where possible external damage could occur. Many outside piping runs are elevated and hung on sides of buildings or over roofs to reduce the possiblity of damage.

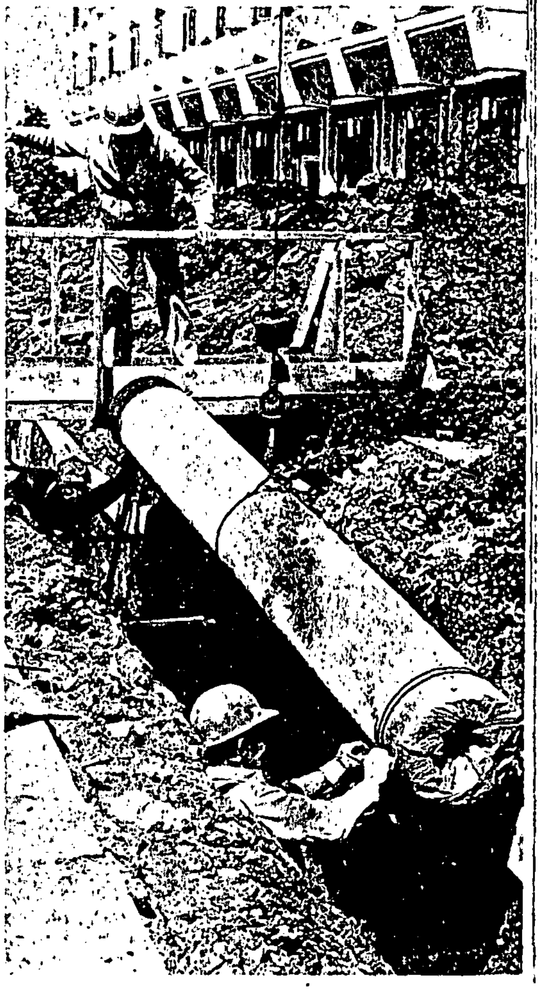
- *Inside piping*–Inside piping is the largest area of application. Physical space limitations, heat above furnaces, and explosive atmospheres are the main problems encountered. In these situations, banks of piping and a confusion of runouts can often be found. When inside piping space is at a premium, organization and layout are prime design considerations.
- *Underground piping* – Underground piping is complicated by the many different and changing ground conditions that exist. Salt corrosion has became a factor to be dealt with. Much underground piping parallels roads, and winter road salting runoff has been found to permeate the ground and attack buried piping. Concrete, clay tile, and plastic pipe are not greatly affected, but steel pipe is. It is now common to find steel and related piping encased in conduits of plastic and concrete; some are complete with insulation and expansion joints. Steel coated conduits require cathodic protection and a protective coating. Maintenance of anodes is mandatory. To handle high ground surface loads and/or internal soil pressures, tile or concrete piping can be placed in steel sleeves, or the portion of the piping that is particularly affected by these conditions can use ductile iron or high strength cement asbestos.

Another major factor in underground piping is thrust blocks. They should be placed carefully with regard to ground conditions, groups of pipes, and future needs. It is not easy to remove 5 yards of concrete wrapped around three pipes to allow for expansion.

Process piping can be divided into two main application classes. One encompasses normal or common applications, such as steel steam piping, Schedual 80 pipe for small condensate returns, galvanized steel for potable water, and Type L or K copper for refigerant lines. Many of these applications have been made over the years, and questions of use or selection are now given little thought. Some are well governed by code. For example, the City of Chicago specifies 1 to 2 in.

Piping design is an involved science and somewhat of an art

Both internal and external factors must be considered when piping systems are installed in the ground. The 13 ft length of steel core pipe in the photo is protected with a low conductivity insulation system.



lead pipe for small underground potable water service.

The other main class is hard to name. It encompasses all special and exotic applications: penton (plastic) lining in steel, teflon lining in steel, epoxy coated steel, cement-motar lining for cast-iron; and stainless, epoxy glass fiber, PVC, CPVC, ABS, glass, polypropylene, and polyester pipe, to name just a few. The list is long, and the applications are many. Acids, food, pharmaceuticals, cyrogenics, fats, asphalts, hydroxides, salts, and demineralized water are just a few samples.

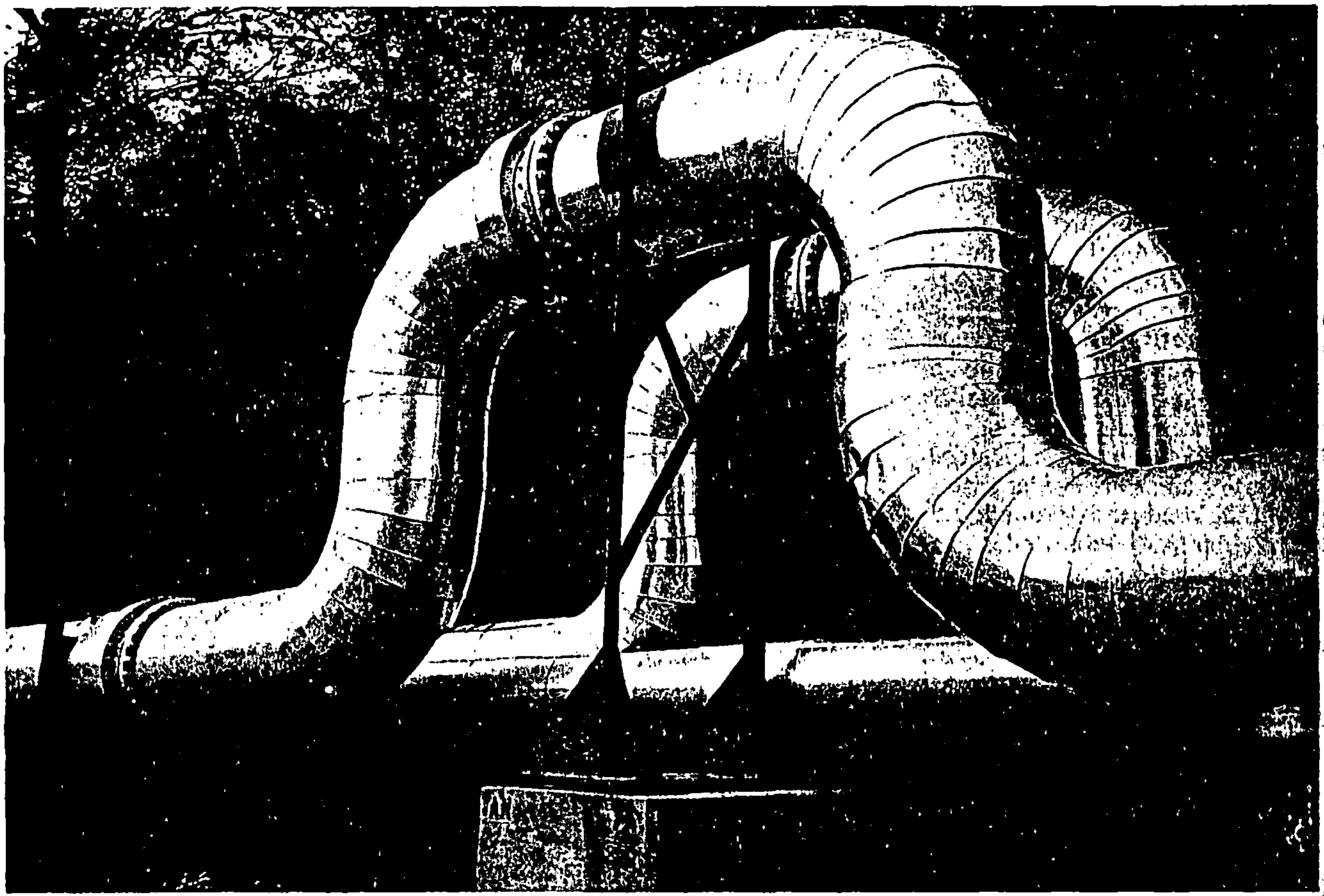
Let's look at an existing sewage treatment plant as an example of an application. The sewage, the air used to treat it, and the final effluent are all considered fluid process systems in the plant. The sewage system consists of various types of underground piping. PVC and epoxy reinforced pipe handle industrial wastes that eroded or corroded the previously installed pipe. Tile and cement asbestos pipe were used for smaller runs (under 18 in.) and where ground loading was normal. Ductile iron pipe was used on pressure mains and where high ground loads were experienced. Concrete pipe was used as the main carrier for the system. Very large pipe diameters were required, and corrosives are diluted to such an extent as to be ineffective.

In a basin at the plant, air is bubbled through the sewage. The compressed air (10 psi) in large quantities is conveyed by 6 ft square concrete pipe in the underground portion, and the above ground branches are steel. In the basin, the distributors from the branches are stainless and submerged in water. The large concrete air piping was epoxy lined to tolerate the 180 F temperature that exists due to compression heat.

Another application example is a plating process that uses coated, lined pipe. The coating is epoxy paint, and the lining was determined by the solution or fluid being circulated. Concentrated acids are not as corrosive as 5 to 15 percent solutions. Both polyester and epoxy coatings were used.

Each portion of the plating system was considered separately. The system was composed of a stripping tank, copper plating tanks, nickel plating tanks, chromium plating tanks, and various wash tanks. Piping lines had to be coordinated with the special air supply and exhaust hoods. All sewer lines and the neutralizing tank were coated with epoxy. Drain effluents were HCl, H_2SO_4, HNo_3 in various concentrations. Concentrated hydroxides were used as a neutralizer.

In an anodizing tank with 15 percent H_2SO_4 at 95 F, the acid had to be circulated, filtered, sprayed, and cooled. CPVC piping was used for the circulation system, and titanium was used for the cooling coil. A sec-



Piping installed outdoors is generally covered to protect it from the weather. Outdoor piping is often insulated to reduce energy losses, as is the case with the steam line shown in the photo.

What's new in Europe

Embedded-coil floor heating

By A. A. FIELD, London, England

Floor heating using embedded coils enjoyed widespread popularity in Europe and the U.S. during the 50s and 60s. The technique generated a new wave of specialist literature, including Raber and Hutchinson's now classic *Radiant Heating* in the United States, *Chauffage et Rafraichissment par Rayonnement* by the Frenchman André Missenard, and the German work *Die Strahlungheizung* by Kollmar and Liese, a work that is still untranslated. The UK is credited with having originated embedded coil heating, and the first installations designed by A. H. Barker go back to the beginning of the century.

Floor heating began to lose out against competition from other forms of heating in the late 50s, when the cost of piping became disproportionately high. The heaviest grade wall thickness was always used for steel coils, and test requirements were particularly stringent, making a high finished cost per square foot. Site-formed soft copper coils became expensive despite the prefabrication saving. The trend to very large glazed areas in buildings around this period also meant that it was often impossible to heat the building from floor heating alone, and supplementary heating had to be introduced. The problem of divided installation responsibilities caused building designers to turn away from embedded coil heating. The heating contractor laid the coils, but the main building contractor was left to lay the screed. The only guarantee that the steel coils would survive the life of the building was their complete embedding in concrete, and this needed intelligent cooperation between the builders, which was often lacking.

The final blow to embedded coil systems was undoubtedly off-peak electric floor heating, which enjoyed a vast upswing in popularity for about 10 years. The much lower first cost made this unbeatable, although the corresponding defects — the high running cost, lack of control, temperature buildup under carpets and furniture — eventually made it fall into disfavor.

Plastic pipe coils

The most important single factor in the new interest in floor heating has been the evolution of coiled plastic piping capable of operating continuously at temperatures of 120 F and higher at normal building pressure heads and having a life of over 30 years. Information on such piping made by a Swedish company was given in this column in September, 1974.

Against the generally depressed market for conventional heating systems in Europe, floor heating with plastic tubing is experiencing very high growth, at least 30 percent per year since 1972, sustained right up to the last reported statistics in 1976. This development has been centered in Germany and figures in all kinds of buildings. The 1976 turnover for all floor heating in Germany was estimated to have been about $50 million, representing a 4 percent share of the total heating market there. Considering that the new concept of floor heating did not take off until the early 1970s, this is a remarkable penetration of the market.

Piping configurations with new floor heating systems vary from the spiral coil (Thermo-apparatebau), already described in this column in September, 1974, to the differentially spaced sinuous coil (Multibeton). The differentially spaced coil has been the only means whereby buildings of high specific floor loading (Btuh per sq ft) can be heated from the floor alone, without the need for supplementary heat sources. The technique is to divide the heated floor area into a number of zones, using different center-to-center spacing of the coil. Closer spacing will produce higher floor temperatures, and close-spaced coils are used next to the outer walls. Wider spacings, and thus lower surface temperatures, are used for intermediate living and working areas.

The justification for this is based on work done in Germany by Kollmar and Frank, who showed that floor temperatures as high as 95 to 105 F are acceptable for transitory occupation. In the living and working areas, the average temperature must be kept to 75 to 79 F. Short-period rises to 79 to 82 F, however, are permissible, and this means that the floor coil can be designed for these peak temperatures at the minimum outside temperature. In a typical design described by Kollmar[1] for a corner room 16.5 ft by 11.5 ft with a total load of 8400 Btuh and a 63 F differential between outside and inside, the floor would have to be divided into three zones: one would be a perimeter strip of 2.5 ft, at a temperature of 100 F; the second, at 82 F, would form the intermediate zone enclosing the main living area; the third, the basic living and working area, would be at 79 F. The importance of the outer zone will be realized from the fact that it provides, in this case, half the total load.

Experience with floor heating has shown that the air temperature need only be 68 F in the winter for comfort equivalent to several degrees higher in other systems.

Installation

Various fixing aids have been developed to speed the installation of the Multibeton system, in particular, a placement grid consisting of steel strips and variable-position pipe cradles. The strips are secured to the over-floor insulation, and the cradles are positioned to give the prescribed coil spacings. The coil is softened with hot water and then formed into position. The operation is extremely rapid, the manufacturers claiming less installation time than for a traditional radiator system. The average figure quoted for a two-man team is 1000 to 1500 sq ft of panel area per day.

Coil ends (flow and return) are connected to a multi-tapped manifold consisting of balancing valves that can be preset to the required pressure drop. Like all panel systems, however, there is a considerable degree of self-balancing because of the relatively high pressure drop of the coils compared to the main distribution.

The finishing screed is treated with chemical additives that increase bending tension strength by 22.5 percent and compressive strength by 21 percent. The additives also improve bonding, surface finish, and drying time, as well as increasing thermal conductivity, which has the effect of reducing the surface temperature variation. The main floor construction follows common practices, the screed normally resting on top of the thermal-acoustic layer. The total height, including a ¾ in. insulating layer, is about 3½ to 4 in. Vertical edge insulation about ¼ in. thick isolates the screed from the boundary walls.

Applications

One notable application of the Multibeton system is at Zurich airport, where coils are embedded in the apron to keep aircraft towing and parking areas free of snow. Some 200,000 ft of 17 mm (approx. ⅝ in.) OD plastic coil is used to heat 170,000 sq ft of surface. The piping is spaced at 10 in. centers and embedded monolithically, with the structural slab at a depth of 4 in. Total heat output under maximum conditions is 16 million Btuh. For safety, the heated area is broken down into eight bays, each with its own pump and heat exchanger. A glycol solution is used as the heat transport medium. Under full load, flow temperature is 160 F and the temperature drop 36 F. Installation cost was $400,000.

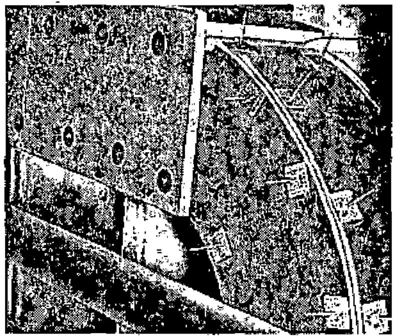
Floor heating is of course the ideal sink for the heat pump because of the low water temperature. A number of installations have been completed in Germany and Switzerland using this principle, and considerable interest is being shown by governments and local authorities. The main German electricity-generating authority, the RWE, is spending about $1 million on research into the use of electrically driven heat pumps for base load heat supply. Results so far indicate that a heat pump will provide two-thirds of the annual energy needs of a building.

Recently completed in Esslingen, Germany, is an installation for a group of 200 dwellings and commercial buildings using water from the nearby Neckar River as a source. Total load, provided by four BBC-York machines, is 2.8 million Btuh. The installation uses no supplementary heat emitters as back-up. The Neckar is also the source for another installation in Esslingen, a 100,000 sq ft office building heated by floor coils and supplied from a 4.8 MBtuh Sulzer-Escher-Wyss machine. The evaporator cools the river water 7 to 9 F and operates at water temperatures down to 39 F in winter.

Plastic piping is being used for both source and sink on a number of installations in Europe, although most of these are for houses. The technique is to bury the evaporator, usually at a depth of over 5 ft. Experience is suggesting that the ground area covered needs to be about two to three times that of the dwelling.

The relatively low sink temperature of floor heating means that it can be used to improve the efficiency of solar heating.

While it is possible to show a theoretical energy saving for floor heating in terms of lower air temperatures for equal comfort, few metered tests on actual installations have been reported. The only one to have been continued over a long period is the study by Prof. H. Reiher and P. Schultheis in Germany[2], financed by the Federal Housing Authority and carried out by the Frauenhofer-gesellschaft's Institute of Technical Physics in Stuttgart. The objective was to



compare the energy consumption of three ten-story buildings built around the same time, one with embedded floor coils, one with a two-pipe radiator system, and one with a single-pipe radiator system. The tests began in 1960 and continued for over ten years. The favorable results from floor heating for the first few years of operation caused the housing authority to switch to floor heating for a further 600 apartments.

Total energy measured over the period 1962 to 1972 showed on average that the buildings with radiator heating used about one-third more energy than those with floor heating. Although user habits produced wide swings in the energy consumption, making it impossible to correlate annual energy use with mean external temperatures, the saving of one-third is large enough to make it reasonably certain that the floor heating systems used less energy. The uncontrolled nature of the tests, however, makes it impossible to put a precise value on the degree of economy achieved.

The more advanced techniques being used today in floor heating would show better results, since in the test installations the coils were buried in solid, reinforced concrete slabs 6 in. thick with no thermal or acoustic insulation. The present technique of almost one-sided emission produced by floating the screed and coil on insulation would overcome the divided flow of heat to upper and lower apartments, and vertical edge insulation would prevent lateral conduction.

The most difficult phase in the marketing of new floor heating techniques is over — the re-establishment of the confidence of building designers, engineers, and owners. Most of the growth so far has been in Germany, but the technique is being taken up in other countries, and most recently in the UK. If Germany's experience is any guide, the other countries can expect to see remarkable expansion of the market.

References

1) Kollmar, A., *Berechnung und Technik der Multi-Beton-Fussbodenheizung*, 1974.
2) Reiher, H., and Schultheis, P., "Einsparung von Heizenergie bei niedertemperierten Flächenheizungen," *Heizung Lüftung Klimatechnik* 189, June, 1974.

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Heating/Piping/Air Conditioning

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Thermal insulation for buried piping

By **ROBERT W. ROOSE, PE**, Senior Editor and
TED PANNKOKE, PE, Engineering Editor

Underground insulated piping systems have been used for many years with varying degrees of success. The earliest known successful venture to supply heat to a group of buildings from a central source via buried pipes was at Lockport, N.Y. in 1877.[1] Some insulated underground systems have been in service for many years. Others, which have had the benefit of modern technology, have deteriorated badly within a few years of installation.

While it is generally more expensive to install piping below grade level than above, buried installations do offer important benefits. Piping and appurtenances are less subject to vandalism. The earth acts as an insulator, so the pipe and its contents are not exposed to as wide a seasonal temperature variation. Therefore, heating and cooling energy may be saved. Also, the possibility of freezing or the solidification of viscous fluids is reduced. At industrial sites, burying some lines makes above ground space available for other services. Finally, burial may be the only feasible design alternative because of esthetic considerations.

Buried and insulated piping systems are used for space heating and cooling and/or process applications via steam, hot water (either high or low temperature), and/or chilled water or brine from a central plant. These systems also find wide use in industry for transporting viscous liquids, cryogenic liquids, etc.

Federal agency interest

The United States Government, through various federal agencies, is perhaps the largest purchaser of insulated underground piping systems.

Since World War II, many installations have been made to serve various federal facilities. The initial investment was considerable. During the 1950s, system failures became a matter of major concern. Therefore, a Federal Construction Council (FCC) task group was formed in 1957 to determine the reasons for the failures and to develop design and installation criteria that would produce more reliable systems.[2]

The National Academy of Sciences-National Research Council published the findings and recommendations of the FCC in 1958 as Technical Report No. 30, *Underground Heat Distribution Systems*.* This report was revised and updated twice—the last time was in 1964.[3] FCC Technical Report No. 39, *Evaluation of Components for Underground Heat Distribution Systems*, was issued in 1960 and revised in 1964.

These two reports provided the basis for the construction specifications of various federal agencies. In 1964, the first interagency specification based on the work of the FCC was published. This is the Tri-Service Specification used by the Army, Navy, and Air Force.

In 1963, FCC Technical Report No. 47, *Field Investigation of Underground Heat Distribution Systems*, was issued.[4] This covered 121 field investigations of 15 different types of buried, insulated heat distribution systems. Both prefabricated and field fabricated systems were covered. The age of these installations ranged from 2 to 46 years.

The specification criteria developed through the efforts of the FCC reversed the failure trend of the early post WW II period.[2] To take advantage of new developments in materials technology, however, and to reduce costs where lower temperatures and pressures might be safely handled with materials other than steel, another FCC task group was formed to prepare underground heat distribution system design and evaluation criteria based upon current technology and the experience gained through use of the criteria developed previously. The recommendations of the task group may be found in FCC Technical Report No. 66, *Criteria for Underground Heat Distribution Systems*, published in 1975.[5]

An FCC Guide Specification, Section 15705, *Underground Heat Distribution Systems (Prefabricated or Pre-engineered Type)*, has been prepared. This guide specification will be used when a minimum of three systems suppliers have been qualified under the criteria requirements. When issued, it will be used by members of the Federal Interagency Group (which has superseded the Tri-Service Committee) and which currently consists of the three armed services, the General Services Administration, and the Veterans Administration.

Many construction projects are outside the realm o

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[1] *Superscript numerals refer to references at end of article.*

**The Building Research Advisory Board (BRAB) is a unit of the National Academy of Sciences. It undertakes to advance the art and science of building through a broad spectrum of activities. The resolution of specific technical problems is such an activity. Over the years, the BRAB Federal Construction Council has been very active in formulating recommendations for solving the varied problems that have been associated with underground heat distribution systems. The purpose of the National Academy of Sciences is to further the use of science for the general welfare of the nation. By the terms of its charter, it is required to act as an official yet independent advisor to the federal government. The Academy is not a federal agency, however, and its efforts are not restricted to government activities.*

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What you need to know

the federal government. However, the technology and the availability of systems that are improved, modified, or developed to qualify for federal contracts can be expected to have a definite effect on designs and construction practices followed on private and other nonfederal projects. Therefore, further reference will be made to FCC reports in the remainder of the article.

Since this article deals generally with underground insulated systems and not specifically with federal requirements, the reader should be aware that what are made as recommendations in the following text may be requirements for federal installations.

System classifications

Many types of insulated underground piping system concepts are in use. They may be classified in various ways, such as prefabricated, pre-engineered, and field fabricated.

Thermal distribution systems may also be grouped by temperature. Three ranges are generally accepted. These are: above 250 F, steam and high temperature hot water; 180 to 250 F, steam and low temperature hot water; and 35 to 180 F, chilled and dual temperature water.[6]

There are a number of piping materials commonly in use that are restricted by allowable pressure ratings to applications within the lowest or the two lower temperature ranges.

Systems also can be classified by types as shown below:[7]

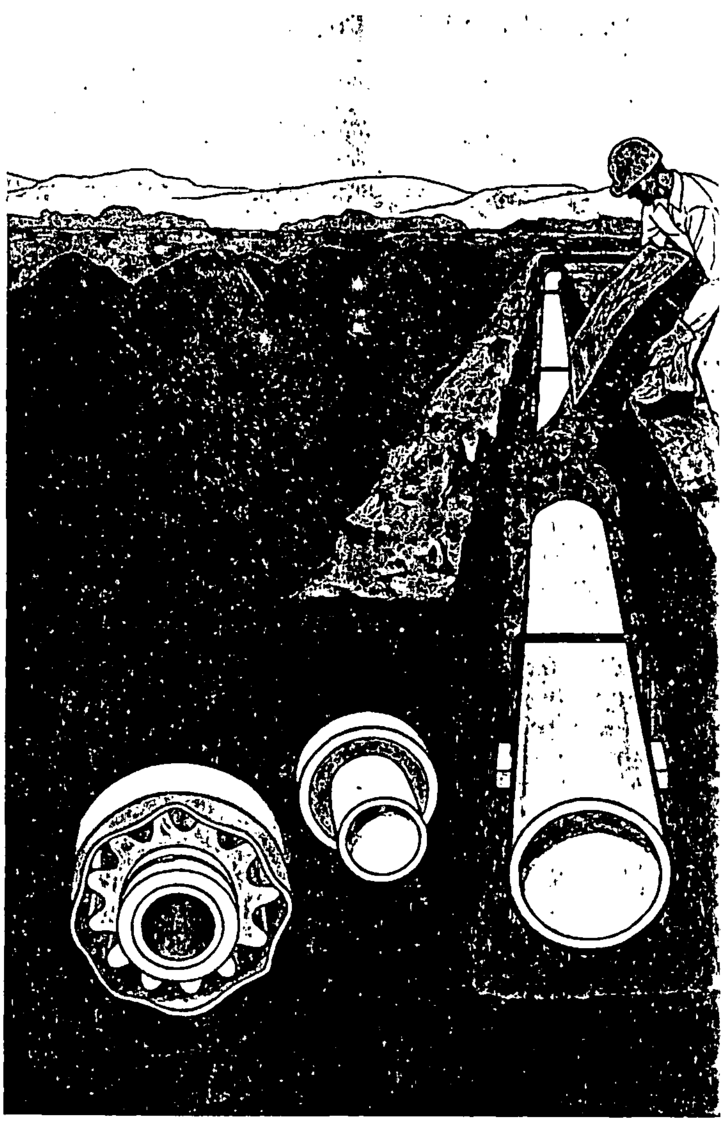
- Pressure testable conduit systems.
- Nonpressure testable conduit systems.
- Insulating envelope systems.

Because moisture in the form of ground water or pipe leaks has been the largest cause of insulation and pipe failure (by corrosion), emphasis today is on the development and/or use of systems that are either *drainable and dryable or that are capable of confining water to a limited section.*

Pressure testable conduit systems

These systems, sometimes referred to as air gap systems, are drainable and dryable when properly installed. They consist of a carrier pipe, pipe insulation, spacers, and an outer casing pipe or conduit. An annular air space around the insulation provides added resistance to heat flow and also provides the means to leak test the conduit (with pressurized air). It also permits the system to be drained if the conduit or pipe develop leaks (Fig. 1).

The outer casing may be of steel, galvanized steel, or cast iron. The steel and galvanized steel conduits are generally covered with either a glass reinforced coal tar enamel having an outer wrap of glass fiber reinforced pipeline felt or with a glass fiber reinforced epoxy resin. Cast-iron casings are not coated.



Pipe insulation is usually calcium silicate or preformed or molded glass fiber. The systems can be designed to handle fluid temperatures ranging from below freezing to 800 F or higher.

The carrier pipes are joined by welding, and the joints are covered with split preformed insulation sections. Steel conduits are joined by welding also. Cast-iron ones are connected by sleeves (plain end conduits), bolted together (flanged end conduits), or connected with mechanical joint fittings (mechanical joint conduit).

Steel conduit assemblies are available in 20 and 39 ft lengths. Cast-iron ones come in 13 and 18½ ft lengths.

Pressurized monitoring alarm systems are available that maintain the conduit at a pressure above atmospheric—typically, 5 to 8 psig. The unit signals any loss in pressure if a leak develops or if the casing is accidently ruptured by other construction. In the case of smaller leaks, the pressure source can restore pressure and prevent water from entering the conduit. Either an air compressor or compressed nitrogen gas may be used.

Manufacturers of pressurized conduit systems also offer prefabricated, pressure testable manholes to facilitate system installation and to provide watertight construction.

Nonpressure testable conduits

These are available in a variety of material combinations to meet the requirements of many types of applications.

Many conduits are factory fabricated and consist of a carrier pipe surrounded by insulation that in turn is enclosed in an outer nonmetallic casing. The area between the carrier pipe and outer casing is completely filled with insulation; and generally the ends of the insulation are sealed with a watertight enclosure, thus limiting the spread of moisture if the pipe or outer covering fails (Fig. 2).

Other types of nonpressure testable conduits are field fabricated. These may be a factory engineered system consisting of components specifically manufactured for underground heat distribution components, or they may be concrete trenches or other nonproprietary designs.

Prefabricated conduits of the type shown in Fig. 2 can be obtained with a variety of components. Carrier pipes may be made of copper, carbon steel, stainless steel, polyvinylchloride (PVC), fiber glass reinforced plastic (FRP), or epoxy lined asbestos-cement. Outer casings generally are PVC, FRP, or asbestos-cement. Insulations commonly used include foamed polyurethane, calcium silica/asbestos, and preformed foam glass.

PVC carrier pipes are suitable for lower temperature applications, such as chilled water and brine service. The maximum allowable working pressure decreases rapidly above 73 F, and its use above 120 F is not recommended.

Copper, FRP, and epoxy lined cement carrier pipes are commonly used below 250 F. Copper may be used with fluid temperatures up to 250 F. FRP pipe generally is not used above 225 F, and some carries a maximum rating of 150 F. Asbestos-cement pipe has an allowable operating temperature range of 35 to 210 F. Steel pipe is used exclusively on hot water and steam installations operating above approximately 250 F because of the pressures and temperatures encountered.

Stainless steel pipe is selected for any operating temperature when the characteristics of the fluid conveyed require this material.

The insulation selected for prefabricated insulated conduits depends primarily upon the operating temperature of the pipe.

Foamed polyurethane insulation may be used in applications between approximately −320 to 260 F.* Polyurethane resists water penetration. Nevertheless, it must be covered with a vapor barrier of some type. Ground water under a sufficient head may rupture the cells. Damage during construction or pipe flexing due to ground settling after installation may cause cracks to develop in the foam. Also, if the pipe is used for chilled water service without a vapor barrier, the difference in vapor pressure resulting from a pipe temperature lower than the ground water temperature may draw moisture to the pipe.

Composite insulations, consisting of an insulation suitable for higher temperature service next to the pipe, which in turn is covered with a lower temperature rated insulation, are also used. A combination of calcium silicate or calcium silicate and asbestos covers the pipe and in turn is surrounded by polyurethane. Pipe systems having this insulation construction are rated for temperatures to 450 F and a maximum operating pressure of 500 psig.

Formed cellular glass insulation is also used with prefabricated pipe construction. The insulation itself will withstand temperatures between −450 F up to 800 F. Prefabricated piping with sufficient insulation thickness to protect the outer jacket is available for this temperature range.

Prefabricated insulated pipe lengths vary with the manufacturer, carrier pipe material, and pipe size. Typical lengths are 20 ft for copper, steel, PVC, and FRP carrier pipe sizes up to 12 in. Asbestos-cement carrier pipe sections typically come in 10 and 13 ft lengths with carrier pipe sizes ranging from 4 to 16 in. One manufacturer offers 55 ft lengths with carrier pipe diameters (steel) up to 36 in.

Joining methods

Various methods are used for joining prefabricated pipe sections. For high temperature service, most systems are joined by welding, although one system uses couplings designed to operate at 450 F and 500 psig. Below 250 F, couplings generally are used with steel and copper pipe. The coupling forms a leakproof joint, while it permits sufficient movement at the joint to allow for expansion and contraction within the operating temperature range of the system, often eliminating the need for expansion loops.

Nonmetallic pipes may be joined with couplings; or they may have bell and spigot ends, which are connected with rubber sealing rings; or they may be cemented together, depending upon the carrier pipe material.

Asbestos-cement pipes are coupled together. PVC pipes—bell and spigot types—use sealing rings; plain end PVC pipe is joined with rubber gasketed couplings. FRP pipe with bell and spigot ends is cemented together.

The adhesive needs to cure before pressure can be put on the line. Depending upon the outdoor ambient temperature and the adhesive formula, approximately 20 to 30 hours may be required. To speed up the curing process or to assemble an FRP system at ambients below 45 F, electric heating collars (115 v AC) designed for this application may be used. Heaters cut the cure time down to less than an hour and in some cases to only

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**Discussions with insulated pipe manufacturers on the subject of maximum allowable pipe temperature with polyurethane material and a review of manufacturer's literature indicate that 250 F is an accepted maximum value. At least one manufacturer rates his system at 260 F. Several stated that development of polyurethane derivatives suitable for 300 F or higher was in process. One manufacturer stated that they could supply urethane foam that would withstand 300 F.*

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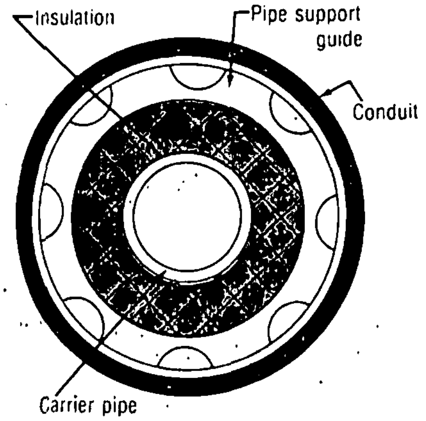
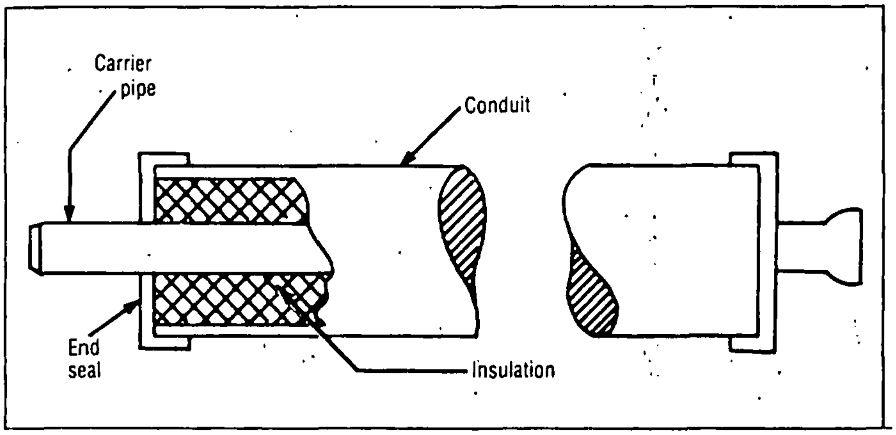


1 Section of a pressure testable, drainable, and dryable metal conduit.



2 Detail of a water spread limiting conduit is shown.

10 minutes. Pipe size, FRP material, and adhesive type govern the cure time when heaters are used.

Heating lines and heating/cooling lines are insulated at the joints. (The construction of some prefabricated piping systems joined with couplings precludes the need to insulate joints.) One method utilizes a sleeve that is slipped over the conduit prior to making up the joint, and foam is applied in the field between pipe and sleeve. The ends of the sleeve are sealed with a double wrap of coal tar enamel pipeline wrap. Another method utilizes a sleeve that shrinks when heat is applied to it, forming a watertight covering over the joint insulation.

The joints of insulated chilled water lines generally are not insulated. The heat loss to the ground or the gain from an adjacent hot line is insignificant when compared to the overall ratio of insulated to uninsulated areas.

Tees, elbows, reducers, and other fittings are available in steel, copper, PVC, FRP, and asbestos-cement. PVC fittings generally are not insulated, since they are used in lower temperature service applications for the reasons given in the preceding paragraph.

Field fabricated conduit systems

Field fabricated pipe conduits are nonpressure testable and may or may not have an air space around the pipe. They may be pre-engineered in that the conduit consists of an assembly specifically designed to house underground insulated pipelines. One type consists of a poured concrete structure formed so that it has a trough for water — either ground water or pipe leakage — to collect and be drained away. Cast-iron pipe supports, rollers, etc. are mounted on the base. Vitrified clay side pieces and half-round covers cemented together complete the conduit. The cemented joints are covered with a waterproof mastic to seal the conduit.

Concrete trenches are also applied (Fig. 3). These may be considered mini-tunnels, since they are similar to walk-through tunnel systems. The bottom and sides are formed and poured. The top consists of concrete slabs. After the pipes are installed in the trench, the top is set in place. Tar or other sealing material is used to provide a barrier to ground or surface water entrance at the joint. The top of the trench often is at grade level and serves as a walkway. This facilitates access to the pipe, since the ground does not have to be dug up when checking for leaks, adding a line, replacing a line, etc. It is recommended that the bottom of the trench be set on a vapor barrier and the sides be coated with a mastic material to provide greater resistance to moisture penetration.

Vitrified clay tile and concrete sewer tile also are sometimes used to construct pipe conduits. These and other field fabricated conduits may serve well where drainage is good and the system is installed above the water level.

Years ago, concrete trenches and field fabricated conduits sometimes were completely filled with insulation. However, examination of such systems after they were in operation for a period of time revealed that it was not unusual for the insulation to be wet and the pipes corroded. Therefore, it is recommended that the pipe be insulated and the insulation be covered with a moisture barrier. The air space around the pipe permits water to drain from the system, and the heat from the line can dry the insulation if it becomes wetted.

Insulating envelope systems

These are pre-engineered systems that are designed to surround the pipe with a poured in place insulating media, which may be any of the following:

- An insulating concrete.
- A granular hydrocarbon fill—both noncuring and heat curing types are available.
- A treated calcium carbonate fill.
- An insulating granular perlite fill.
- Field installed polyurethane foam.

Insulating concretes are available with two types of aggregates, vermiculite or expanded polystyrene beads. It is the aggregate that provides the insulating value to the concrete.

Fig. 4 shows the recommended form of installation. A structural concrete base pad is poured to the desired grade. Precast insulating blocks and drain vents are set on a waterproof membrane that covers the structural slab and lines the trench or forms. The pipes rest on top of the insulating blocks, and the insulating concrete is poured over the slab, pipes, and internal drains. The waterproof membrane is wrapped around the top of the concrete and sealed.

If required, cathodic protection can be achieved by the installation of a continuous ribbon zinc anode parallel to the pipes inside of the concrete.

Internal electrical sensors can be installed inside the internal drain channels to detect and locate leaks.

Added drainage can be had if conditions warrant it by installing an external drain tile.

In addition to providing thermal insulation, insulating concrete provides continuous support and alignment of the piping and resists heavy loads.

Granular hydrocarbon fills are installed in an open trench. A bed of the material is placed in the bottom of the trench. The pipe is installed and more fill is placed around and over the pipe. The material is then compacted to the proper density. The material resists wetting; however, installation of drain tiles along the pipe path may be required, depending on the natural drainage characteristics of the earth and ground water conditions, to avoid build-up of hydrostatic heads that would penetrate the fill.

Natural hydrocarbon mineral material does not have to be heat cured. It is suitable for temperatures between 35 to 500 F.

Heat cured granular fills are derived from petroleum residuals. These are available for various temperature ranges between 150 and 520 F. An asphaltic binder in the fill melts and bonds to the pipe during the curing process. Surrounding the pipe and binder is a sintered zone, and the outer layer of the fill is unaffected by the curing process.

Since these materials are used with metal piping systems, cathodic protection should be installed whenever material selection and soil conditions dictate.

Powdered calcium carbonate, which is treated to resist water penetration, is another insulating material. It is rated for temperatures up to 480 F. Side forms in the trench are all that is required. The material is installed around and below the pipe to the proper dimensions, compacted, and covered on the top with a plastic film. The manufacturer states that due to the hydrophobic properties of the material and its high electrical resistivity — $R = 10^{14}\ \pi/\text{cm}/\text{cm}^2$ — cathodic protection is not required.

Expanded perlite particles are also used as a buried insulation. Powdered perlite is heated to a high temperature, causing it to pop or burst into granular air-celled particles. These particles are mixed in the field with an asphalt binder. A base pad, consisting of the insulating material and binder, is poured in a formed trench. The pipes are laid on the base, tested as required, and then the pad and pipes are primed with a corrosion resisting compound. The installation is then completed by pouring more material over the pipes to the depth of the forms.

Operating temperatures range from 15 to 800 F, and the material is said to have a high electrical resistivity.

Polyurethane foam may be poured or blown around pipes in the field. The systems are ready to be backfilled within an hour after the foam has been placed around the pipes. Forms are required for the froth-pour type of insulation, and a vapor barrier liner and covering generally are used to seal off ground moisture. The direct spray method does not require side forms. Again, vapor barriers are recommended.

Buried tunnels

Buried walk-through tunnels generally are the most expensive way to house underground piping. However, they greatly facilitate piping maintenance, and when properly drained and ventilated, they greatly minimize the development of corrosion on pipe and appurtenances.

Concrete tunnels constructed by forming and pouring are the most expensive. To reduce the cost of tunnels, prefabricated steel tunnels have been developed. These are complete with pipe racks and hangers. The sections are dropped into the excavation and joined together. The steel is factory coated and cathodic protection can be applied to provide additional protection against corrosion.

Large diameter concrete sewer pipe has also been successfully used to construct tunnels. The joints must be sealed and caulked, and as with other tunnel systems, provisions for drainage should be made as job conditions require.

Preliminary design considerations

Many factors must be considered when selecting an underground piping system. Among the most important is knowledge of soil conditions along the proposed route, with respect to soil type(s), ground water conditions, corrosivity, soil stability, alkalinity, and drainage patterns. All have a major bearing upon what types of systems should be considered for a specific installation.

FCC Technical Report No. 66 goes into considerable detail on soil types, their relation to ground water conditions, and corrosiveness.[8] Four ground water classifications are set forth in the document; these are: severe, bad , moderate, and mild. Briefly, these classifications are based upon the frequency that the water table will or *will not* be above the bottom of the piping system combined with the length of time that accumulated surface water will remain in the soil around the pipe. Table 1 shows the relationship of these two criteria with the four classifications. This report recommends that only drainable and dryable, pressure testable systems be used with the severe classification. Both these systems and water spread limiting ones are considered suitable for the remaining classifications.

A soil survey should be made to determine the conditions along the pipeline route. It should include the determination of the soil pH, since the acidity or the alkalinity of the soil may adversely affect some materials. For example, asbestos-cement may be harmed by soils having a pH less than 5.5.[9]

The services of a corrosion engineer should be utilized when metal conduits and/or piping are contemplated. Corrosion of buried ferrous structures is very common unless they are properly protected.

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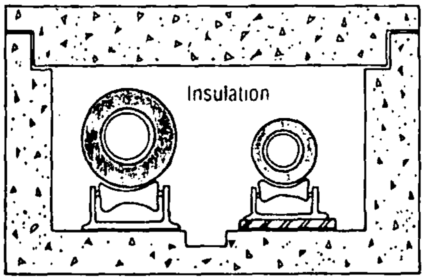
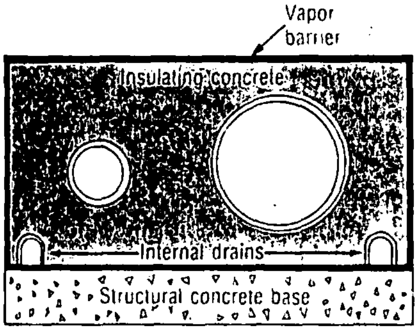
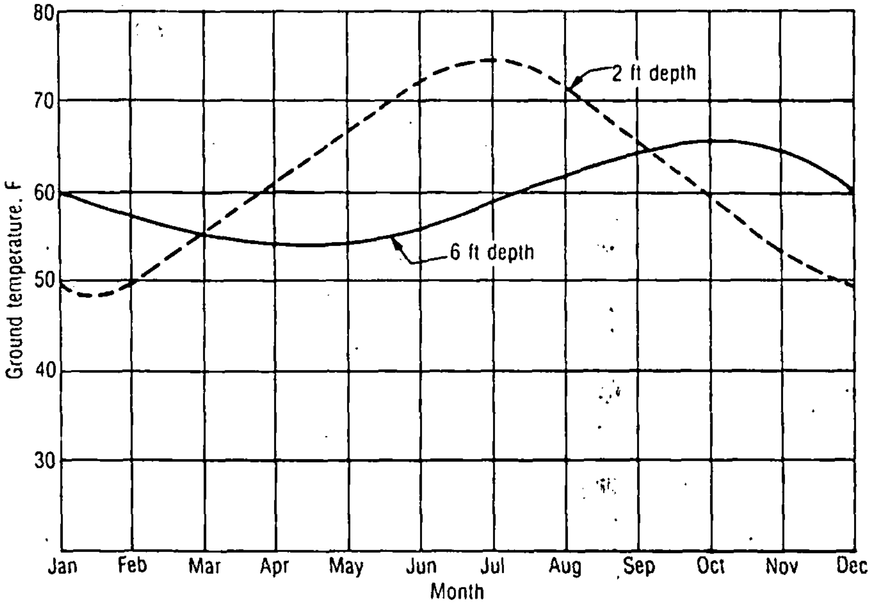


3 Concrete trench system.



4 Insulating concrete insulation around pipe.



5 Seasonal variations in ground temperatures. Variation decreases as depth increases. Actual temperatures vary with location, type of soil, etc.

Table 1 — Underground water conditions classification.*

Classification	Water table above bottom of system	Duration that surface accumulation remains in soil
Severe	Frequent or occasionally	Long
Bad	Occasional or never	Long
Moderate	Never	Short
Mild	Never	Not expected to remain

*This table is based upon criteria set forth in Reference No. 8. Additional information regarding soil types encountered with above classifications, precipitation, and irrigation practices may be found in this reference.

soil resistivity test. This measures the electrical resistance of the soil— the lower the resistance, the higher the corrosivity. Wet soils, organic soils, and soils having a high soluble salt content generally are corrosive.[10]

Corrosion problems can sometimes occur with high resistance soils, so soil resistivity, while a good guideline, does not always give absolute results when higher resistance soils are encountered. Stray electrical currents also may cause corrosion. Stray currents may emanate from direct current transmission lines and electrified rail systems and from industrial operations that require direct current power. It is almost impossible to know whether a stray current problem exists without checking the ground along the job route.

Some system design considerations

Chilled water lines often are installed without insulation. Earth temperatures often are assumed to be relatively uniform year 'round and low enough not to impose a significant load on the system. Often the latter assumption is correct, particularly at the temperatures normally encountered with comfort air conditioning applications. However, ground temperatures can vary widely on an annual basis (Fig. 5). In some areas of Florida and Texas, for example, earth temperatures higher than 80 F can be encountered at depths that pipelines are commonly installed.[11]

It is also not unusual to install chilled water lines in the same trench with heating lines.* Earth temperatures in the vicinity of heating lines will be raised, even though these lines are insulated, when they are in operation. Methods have been developed to determine the heat transfer effects of the earth on buried lines and of parallel buried lines operating at different temperatures to one another.[12] The results can aid in the decision whether or not to insulate chilled water lines.

The anticipated temperature of the earth when heating lines cross buried electrical lines, telephone cables, etc., should be determined to assure that the operation of these facilities will not be impaired. More insulation may be used at these points, or the line elevation may be raised or lowered to provide greater clearance.

Pipe expansion can be handled with expansion loops, expansion joints, and/or ball joints. Prefabricated expansion loop assemblies are available for both pressure testable and non pressure testable conduit systems. Expansion chambers can be designed into the encasement at corners and loops of insulating concrete installations. Expansion loops may be used with various types of loose-fill insulation, usually with some limitation on the amount of lateral movement that may be accommodated.

Ground water level is not as great a concern with either pressure testable drainable and dryable conduits or water spread limiting conduits as is with some other types of systems. Some types of soil will retain surface water for extended periods. Also, the trench that the pipe is installed in may disrupt normal drainage patterns and become a catch basin for surface water. Therefore, installation of drain tile along the route may be necessary to assure satisfactory performance of insulating envelopes and some types of field fabricated conduit systems.

**Chilled water lines can and are installed in prefabricated conduit systems with heating lines also. With this form of construction, the chilled water lines would always be insulated.*

Thermal insulation for underground piping systems

Steel and cast-iron conduit systems should be cathodically protected unless a corrosion survey determines otherwise. Cathodic protection should also be applies to piping in loose-fill hydrocarbon type insulations when warranted.

Some other types of insulating fill are said not to require protection due to their high dielectric constant and resistance to water penetration. However, it must be remembered that the possibility exists for dirt to contaminate the insulation during installation, thus providing a path for current to flow to the pipe, or a washout could occur later and expose the pipe to ground water. Either condition could create a hot spot where localized corrosion could occur.

Cathodic protection systems should not be designed for built up areas without consulting with the local utility companies to learn what installations they have. They in turn may have records of other cathodic protection systems. Cooperation among all parties utilizing cathodic protection is essential to assure that all systems will be adequately protected.

Insulation should be specified for all pipes, valves, and other appurtenances in heat distribution manholes. The insulation should be covered with sheet metal jacketing to prevent mechanical damage. Manholes should also be vented. Excessive manhole temperatures have been found to be a major cause of inadequate inspection and maintenance of underground heat distribution systems.[13]

Drainable and dryable systems should be sloped so that water will drain from the entire length of conduits, concrete trenches, etc. Provisions should be made for water removal from manholes should a major inflow occur.

Installation and backfill

All piping should be installed in accordance with applicable codes and industry standards. The condu or pipe should be firmly supported along its enti length by virgin earth, compacted sand, or insulating fi so as to minimize the possibility of excessive strain du to ground subsidence and the possibility of washou that could remove protective fill from around the pip

Pipe laid in insulating backfill should not rest o bricks, timbers, etc. These provide a moisture path t the pipe, and severe concentration cell corrosion m occur.[9] Remove all temporary pipe supports as backfil ing occurs.

All fill type installations must be installed to t proper depth and properly compacted in accordan with the manufacturer's requirements. Care must b taken to avoid contaminating the fill with dirt or oth construction debris.

Insulating concrete should be permitted to dry pri to covering with a waterproof membrane and backfil ing.

Any damage to protective coatings incurred duri shipping or construction must be repaired in acco dance with methods compatible to the original coatin

All welding should be done in accordance with t ASA B31.1 Code for Pressure Piping. Manufacture requirements for joining coupled pipe should be fo lowed to avoid leaks on low pressure lines and dama to high pressure systems. When plastic pipes are to joined with solvent welding techniques, the meth should be practiced prior to actual pipeline constr tion. This is no place for on-the-job training!

All lines should be tested for tightness prior to co plete backfilling. All joints and fittings should rem exposed until the test is completed. Pressure should n be put on lines before concrete anchors and thr blocks have cured sufficiently to withstand the stre

Manufacturers of plastic pipe *do not* recommend te ing with air. Hydrostatic testing should be employ

Product guide

Circle the appropriate number on the Reader Service Card to obtain more information

Accessible Products Co.

Jacketing for pipe, ducts, or vessels resists weathering, salt water, and most oils, grease, mild acids, and alkalis. Jacketing does not require painting or refinishing. Material is manufactured with polyurethane foam for temperatures from −50 to 200 F or glass fiber for up to 450 F. Thicknesses range from ½ to 2 in. Jacketing can be cut to required lengths at the job site and snapped on.

Circle 141 on Reader Service Card

American Gilsonite Co.

Company offers natural granular insulation for underground piping and tanks operating from 35 to 460 F. Material does not require curing and provides corrosion protection. Insulation can be installed with or without supports for pipe, regardless of size or operating temperature. Company provides installation assistance on government jobs of 20 tons or more and all other jobs of 30 tons or more.

Circle 142 on Reader Service Card

Ceel-Co.

Data sheet describes pipe and fittings covering designed for outdoor and underground application. Material is resistant to weathering, oxidation, and corrosive and abrasive chemicals. Covering is 0.020 preformed to the diameter of insulation it will cover. Operating temperature range is −40 to 180 F. Adhesive sealer is also available.

Circle 143 on Reader Service Card

E. B. Kaiser Co.

Manufacturer offers a complete line of metal and nonmeta insulated piping systems for underground installation. Both a gap and completely filled foam insulating systems are availab Insulated steel carrier pipes within cast iron, coated steel, or gl fiber reinforced carrier pipes having an air annular space a available. Polyurethane foam insulated systems have a gl fiber reinforced casing. Carrier pipes may be of steel, copp PVC, or FRP. Prefabricated manholes are available as well pressurization and alarm system for monitoring the tightness the air-gap systems.

Circle 144 on Reader Service Card

Insta-Foam Products, Inc.

Company offers piping systems preinsulated with uretha foam and an outer jacket of PVC. Systems are available for liq process piping between −350 to 250 F with a choice of car pipe material; chilled water, low temp hot water, and steam c densate return to 250 F with a FRP carrier pipe; chilled water low temperature hot water systems with an epoxy li asbestos-cement pressure carrier pipe; and chilled water s tems with a PVC plastic carrier pipe. Systems are corrosion moisture resistant. Dual piping can be accommodated. A available is a multipurpose system furnished with either foam polyurethane (k factor is 0.14 at 50 F) for −450 to 250 cellular glass insulation (k factor is 0.38 at 50 F) for −450 to 80 Other insulation types can be furnished. A casing of polye *resin reinforced with glass fiber is included. System can be* with these materials. It is recommended that lines handling cryogenic fluids also be tested with the fluid to be handled, since at low temperatures, contraction rather than expansion will occur.

Care should be taken during backfilling to prevent damage to protective coatings, conduits, and vapor sealing membranes.

System maintenance

Careful inspection and regular maintenance will reduce the likelihood of premature failure of buried lines. Procedures to follow should include the following:

- Monitoring of steam pressures or water temperatures at points of send out and use. This will warn of excessive heat loss caused by damaged or wet insulation.
- Periodic patrolling of the line. Burned grass over the route, water or steam coming to the surface, and melted snow indicate problems.
- Periodic inspection of manholes and vaults. Water in the vault or signs of moisture in insulation or in the ends of conduits are further signs of problems.
- Maintaining a regular program of checking the performance of cathodic protection systems. This includes taking anode readings, monitoring rectifier installations, and checking all electrical insulating fittings.

Central heating/cooling plants offer many advantages. They can be more efficient in the use of resources than individual building heating/cooling plants. They provide a means to alleviate the solid waste disposal problem by disposing of combustible trash. And it is easier to control air pollution at a large central installation than at many small ones.

Underground insulated piping systems are an integral part of the central plant concept. In the past, they sometimes have been the weakest link. With the vast amount of past experience to draw from, however, and present technology, buried heating and cooling distribution systems can be installed that will give reliable, economical service for any application that is not beyond the limitations of the system itself.

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9) Fitzgerald, J.H., "Corrosion Control for Buried Piping," *Heating/Piping/Air Conditioning*, March 1974, pp. 83-88.

10) *Piping-Handbook*, 5th ed, R.C., King, ed., McGraw-Hill, New York, N.Y., 1967, Chapter 9, p. 12.

11) *Criteria for Underground Heat Distribution Systems*, FCC Technical Report No. 66, pp. 64-74.

12) Kusuda, T. "Heat Transfer Studies of Underground Chilled Water and Heat Distribution Systems," *Underground Heat and Chilled Water Distribution Systems*, NBS Building Science Series 66, U.S. Department of Commerce, National Bureau of Standards, Washington, D.C., 1975, pp. 18-41.

13) *Field Investigation of Underground Heat Distribution Systems*, FCC Technical Report No. 47, p. 3.

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ced, and modular sealed sections are available for fast installa-
n. Construction allows any entering moisture to be confined,
insulation can be dried.

Circle 145 on Reader Service Card

hns-Manville

Company offers piping systems preinsulated with
lyurethane foam. The following systems are available: chilled
ler and low temperature hot water from 35 to 210 F are available
izes from 3 to 30 in. Insulation is bonded between asbestos-
ment casing and epoxy lined pipe core. A copper core and PVC
sing system is offered for 35 to 260 F applications. Average k
lue is 0.14 at 50 F and 0.16 at 150 F. Pressure range is 0 to 150
. Insulation for temperatures up to 450 F and operating pres-
re to 600 psig is a combination of lime-silica-asbestos and high
mperature polyurethane foam in a corrosion-resistant casing.
so offered is a PVC piping for chilled water to 73 F and up to 160
. Insulation is protected by PVC casing. Condensate return
ping is insulated with 1 in. of polyurethane jacketed with PVC.

Circle 146 on Reader Service Card

rmanent Piping Systems

Manufacturer offers a complete line of prefabricated systems
high and low temperature application. Air-gap systems feature
insulated steel carrier pipe enclosed within a coal tar enamel
epoxy coated steel conduit with a dead air space between
ulation and conduit. Urethane foam insulated piping within an
P jacket, is available for lower temperature service. Carrier pipes of steel, copper, PVC, FRP, and asbestos-cement may be specified. Prefabricated manholes and tunnel systems are also available. For the air-gap systems, a pressurization and alarm system is available to monitor system tightness.

Circle 147 on Reader Service Card

Pittsburgh Corning Corp.

Company offers cellular glass insulation for low pressure, underground steam, hot water systems, and chilled water systems. For typical situations with nominal parameters, a thickness of 1½ in. for pipes less than 6 in. nominal and 2 in. for pipe sizes of 6 in. nominal would be recommended. A detailed thermal analysis report for various conditions to determine correct thicknesses is available from local sales offices. Insulation jacketing is applied in a cigarette type wrap with the overlap to be heat sealed.

Circle 245 on Reader Service Card

Porter Hayden Co.

System consists of a poured concrete slab, which has a drain slot, onto which cast-iron pipe supports, guides or sleeves are mounted. Insulated or bare pipe is installed as job conditions require. The assembly is then covered with a vitrified clay tile envelope consisting of side pieces and half-round top sections, which are cemented together. The cement joints are then covered with a waterproof mastic.

Circle 246 on Reader Service Card

Continued from page 19

Speeding piping insulation

By A. A. FIELD, London, England

Prefabrication was once thought to be the only way to speed up the installation of piped services in buildings. Now the trend is partial prefabrication combined with other techniques, such as soft coiled piping for run-outs to terminal equipment, flexible hose couplings for equipment connections, and thin wall steel and copper tubing with compression joints.

Limits to prefabrication

Piped assemblies that are entirely made up in a factory can only be used as part of a packaged unit, such as a transportable boiler house. The growing popularity of such units throughout Europe testifies to the cost savings offered over built-up facilities.

Only parts of a normal building services piped distribution — heated and chilled water, sprinklers — can be prefabricated. The main limitation is variation in the structure's dimensions, and the second is variation in batch-made piped assemblies. Size is important also. Large piped units are difficult to handle.

The extent to which building dimensions vary between key points (for example, between columns or from story to story) was recently studied by the U.K.'s Building Research Establishment (BRE).[1] Over 30,000 separate measurements were taken on 200 building sites throughout the country. The configurations studied included verticality, squareness, levels, internal openings, and separation distances. Table 1 summarizes the error between as measured and specified dimensions for columns and walls. The greatest variation occurs with timber panels and in-situ concrete walls. Precast columns showed slightly less variation than in-situ ones.

An interesting result of the study is that size of error is influenced only to a very limited extent by the absolute value of the distance involved; thus, error is not a proportional relationship, as might be supposed.

The survey also showed that even if the designer called for a greater precision in the location of basic structural elements, the accuracy achieved in practice was not discernibly different.

Errors in batch-produced pipe assemblies depend on the initial accuracy of the cut pipe length, variation in the pipe/fitting penetration distance, the accuracy of any machine produced bends, and the reliability of equipment dimensions — particularly the geometry of the connections.

Where pipe lengths are measured with an ordinary steel tape and then cut by machine, errors of about 5 mm can be expected from the specified length. A Building Services Research and Information Association (BSRIA) study[2] in 1970 showed that the pipe was undersized more frequently than oversized. More sophisticated tooling, of course, reduces this error but does not eliminate it.

Piping assembled with screwed fittings is likely to result in greater errors in the finished length than welded fittings, although adjustable powered screwing machines and taper-to-taper joints reduce errors. Also, errors tend to cancel out when the assembly is made up of a number of joints.

Errors in pipework manipulated with a machine bender can be reduced with presetting devices or by working from a prototype bend.

Dimensional variations of components, such as terminal equipment, plus the variation in screwed connections, can be considerable. In the BSRIA investigation, measurements of pressed steel radiators (a form of heating surface used widely throughout Europe for hydronic systems) revealed a possibility of error of around ±9 mm in the overall length across the valve union tailpieces. The length tolerance in the radiator alone was 2.5 mm; thus, the largest errors were produced by screwed connections.

Prefabrication in practice

Today, the trend is to use prefabricated piping modules with only a few fittings. In its simplest form, each module consists of the appropriate length of straight pipe with one fitting, valve, or other component on one end only. The modules are then used to build up the installation without having to cut or screw piping at the site.

All piped systems can be broken down into such straight pipe plus fitting modules.

Time savings, even with this relatively simple technique, are possible. For example, on an installation of hydronic heating for a multi-story office block, one man took six hours to part assemble all the material for one floor (27 radiators) and 500 ft (150 m) of pipe. A subsequent installation took a further 25 hours with two men working.[3]

A well documented example is a study by BSRIA[4] of an installation of induction units for an office block. Prefabrication was broken down into four basic assemblies: flow and return risers (a length of straight pipe with fittings at one or both ends); a branch assembly containing an elbow, regulating valve, and union; a straight run-out section, which could be used to make up any run-out configuration; and a final connection assembly. Installa-

Table 1 — The accuracy of building work. Errors between as measured and specified dimensions for columns and walls. (Separation distances up to 23 ft.)

			Mean standard deviation							
			Floor level				Ceiling level			
Material	No. of sites	Size of sample	in.	mm	in.	mm	in.	mm	in.	mm
Walls:										
Brickwork	14	373	0.08	2.0	0.22	5.7	0.05	1.2	0.34	8.7
Blockwork	9	318	0.04	0.9	0.30	7.7	0.20	0.5	0.41	10.3
In-situ concrete	16	460	0.09	2.3	0.43	11.0	0.13	3.3	0.41	10.4
Precast concrete	11	403	0.03	0.7	0.27	6.8	0.08	2.0	0.31	7.8
Timber panels	7	219	−0.03	−0.8	0.52	13.2	0.10	2.5	0.57	14.6
Columns										
In-situ concrete	20	611	−0.09	−2.3	0.30	7.5	−0.04	−0.9	0.38	9.6
Precast concrete	14	406	0.02	0.5	0.28	7.1	0.03	0.8	0.24	6.2
Steel sections	7	245	−0.04	−1.3	0.22	5.5	−0.03	−0.8	0.19	4.8

Table reproduced from BSE News, Summer 1976, courtesy of the Building Research Establishment.

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What's new in Europe

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tion time based on conventional methods was reduced 58 percent by prefabrication.

In designing the prefabricated assembly, a distinction can be made between dimensions that are structure dependent and those that are not. Examples of the latter are piping connections to equipment or between equipment items where the building itself does not impose special constraints. Examples of structure dependent dimensions are those limited by openings in walls or floors, floor-to-floor heights, column-to-column distances, etc.

Errors within piped assemblies (for example, in matching flow and return connections to a piece of equipment) can be compensated for by the use of site measured closer pieces or by the use of flexible connections.

Critical structure dependent dimensions must be measured on-site. In a study of prefabrication techniques for a 10 story office block, BSRIA found that two-third of the 1500 prefabricated assemblies could be sized from the architect' drawings alone, and only one-third depended on site measurement.[2]

When determining the cut pipe lengths to make up prefabricated assemblies, the designer always works from centerline sketches Therefore, he must derive the necessary straight pipe length. This depends on the type of fitting and the amount of pipe absorbed by the fitting. Welded and sweated joints allow a fair amount of latitude, but screwed joints are critical to within a few millimeters.

The calculation for screwed joints, however, has been simplified by the so-called Z-dimension method developed by the Swiss firm of George Fisher. The Z-dimension is the distance from the center line of the fitting to the end of the tube after it has been screwed the correct distance into the fitting. The manufacturer lists the Z-dimensions appropriate to the range of fittings and from the center-to-center measurements to be satisfied in the prefabricated assembly the designer can work out the exact cut length of pipe needed.

In a survey of plant room installation procedures, the BSRIA concluded that the potential for time savings and labor cost reductions through prefabrication was small.[1] Heavy equipment cannot be placed with the degree of accuracy needed; actual dimensions of the plant often differ from stated sizes; and welded pipework does not offer any great economies through being prefabricated. The study concluded that the answer rests with specialist teams; more sophisticated detailing methods, such as the use of models; and drawings with transparent overlays.

Prefabrication routines

The prefabrication approach necessarily generates more paperwork than conventional installation. The designer must break down the system into prefabricated assemblies and detail the work. He must prepare cutting schedules for the site workshop, assembly sheets for making up the units, and keyed sketches showing the location of the assemblies in the building.

A distinct system of labelling must be used to mark up the finished

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What's new in Europe

continued from page 132

assemblies. Transport from the site workshop to the building is another initial design consideration. Large assemblies may simplify installation, but the need for cranage, special forms of transport, and building access difficulties are minus points.

With prefabrication techniques, the workers must be deployed differently. Workshop personnel engaged solely on batch production can be less skilled than those assembling the prefabricated modules on location.

On some contracts, notably those where considerable repetition exists, for example, in large housing developments, assemblies can be made in a remote central workshop. Such base workshops are better organized than those on-site, which have to make the best use of lightweight, temporary structures, and are usually difficult to get to, which makes delivery of materials a problem.

Avoiding prefabrication

Some of the most difficult pi configurations are at equipme connections, particularly with suspended ceilings or in servi ducts. These situations are on partly amenable to prefabricati methods.

Here, armoured flexible hose more effective. Previously, ho was more expensive because it w produced to meet much higher te peratures and pressures than r quired in building services, but ne developments have made it ec nomically feasible. One type of tul made in France is composed of sy thetic rubber reinforced with outer cover of galvanized or stai less steel braiding. Diameters ran from 0.4 to 1.6 in. ID (10 to 40 mm) lengths from 1 ft (0.3 m) upwards. I addition to screwed or compressi connectors, the flexibles are al made with swivel ends. Worki pressures vary from 290 psi (20 ba at 10 mm ID to 65 psi (4.5 bar) at 4 mm ID. Continuous temperature ra ing is from 4 to 230 F (−15 to +1 C). Installation limitations are: must not be subject to traction (fo example, expansion); it should n be bent to a radius less than fo times the OD; and a straight of n less than twice the OD should b maintained at each end.

Tests on samples of these flex bles were made in 1972/73 by th CSTB (the French building resear laboratory) for endurance, resi tance to repeated flexion, failur pressures, and the value of insula tion in preventing condensatio when carrying chilled water. Durin prolonged trials at temperatures o 230 F and pressures of 145 psi (110 and 10 bar), there was an initial los of elasticity that subsequentl stabilized, retaining its value afte further thermal shocks with alter nating temperatures of 70 and 180 (20 and 80 C). No breakdown wa observed following repeated bending (200,000 cycles) at 200 F (95 C) and burst pressures corresponded to a safety factor of at least five ove the recommended working pressure. Condensation tests using chilled water at 40 F (5 C) showe no vapor transfer when the tube wa insulated with a 0.4 in. (10 mm thick flexible sleeve.

Soft coiled piping in steel, copper, or plastics can be used for run-

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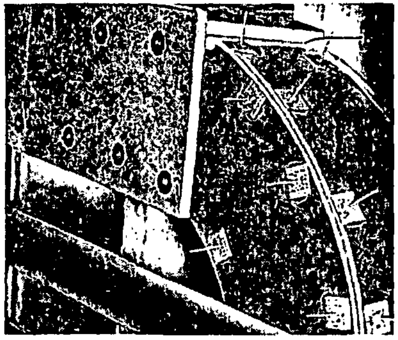
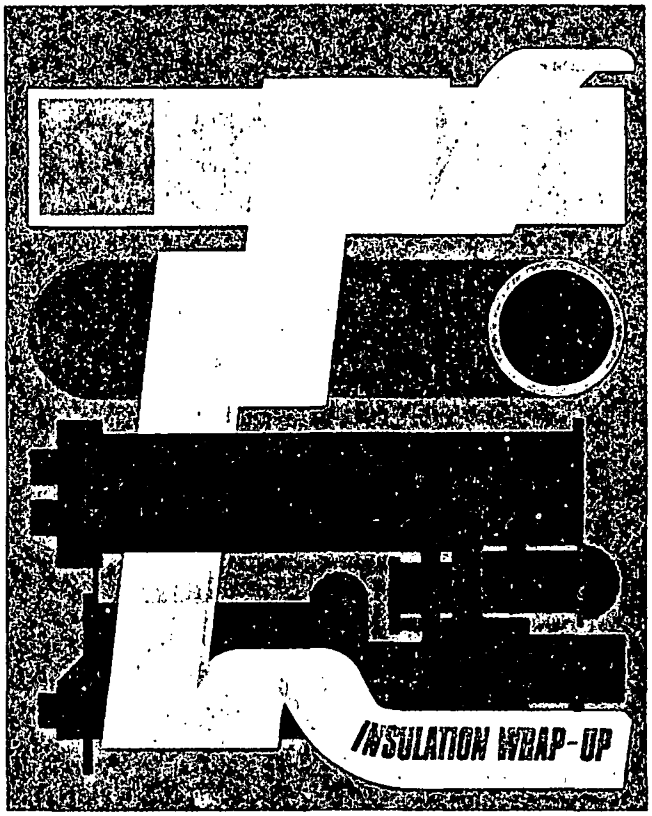


Heating/Piping/Air Conditioning

April 1976



A complete guide to insulation for: ducts, equipment, and piping

BERT V. ROOSE, PE, Senior Editor

eed **for insulation** to conserve heat is obvious. ever, rising fuel costs and the need to save energy the selection of insulation for mechanical systems uilding more critical a choice than ever before. fore, it is very important to know as much as ble about the available types of insulation, the mical amounts to apply, and how best to apply Good insulation of mechanical systems within a ng is certainly one of the important methods of erving energy.

e results of a recent *HPAC* survey indicate that, on verage, a 10 year old building wastes 40 percent of nergy delivered to that building! Furthermore, the ey showed that over 50 percent of existing induscommercial, institutional, and public buildings are 10 years old. This survey also revealed that good improved insulation systems scored very high in lans for designing the heating, piping, and air conning systems for new buildings and for the energy ervation methods to be applied in existing build- Hence, it is for these reasons that this information been assembled for your immediate use in the deof future systems and in improving existing ones.

heat flows

nce it is the purpose of insulating materials to cone energy by retarding heat flow, it is important to how heat transfer occurs. When a temperature rence exists between the hot and cold surfaces of material, heat transfer takes place by means of uction, convection, and radiation.

nduction is a molecular transmission of heat; the rial in question transmits the heat from particle to cle of its own substance. This conductive heat fer occurs only between two sections of the matehat are at different temperatures; the heat will ys flow from the higher to the lower temperature. is required for conduction to take place, and the of heat transfer varies with the distance between sections, the temperature difference, and the cter of the material. Poor conductors or insulators it a very slow rate of heat flow.

nvection is the transmission of heat by the circulaof a fluid or a gas over the surface of a hotter or r body. The molecules of the moving substance e into close contact with the hotter body and are lly heated by conduction during the period of this ct; but immediately pass on, carrying what heat have acquired along with them, and cooler cules succeed them. This circulation may be ed by natural forces or may be produced by anical means. Heat transferred by convection ds on the velocity of the moving substance, on the and dimensions of the body, and on the temperadifference between the moving substance and the

diation always takes place in straight lines, obeye same laws as light; so its intensity or amount per of surface varies inversely as the square of the nce from the source of radiation to the surface. nt heat continues to travel in the same straight line intercepted or absorbed by some other body. nt heat is also similar to light in that it is reflected various materials, and those substances possess-

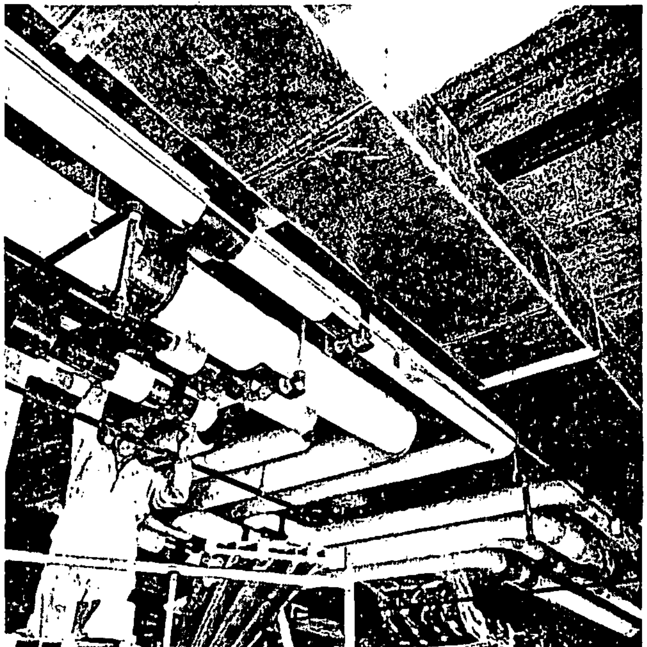
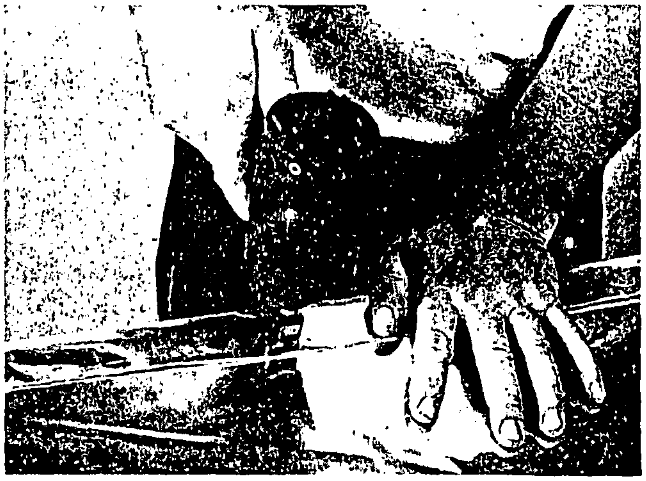
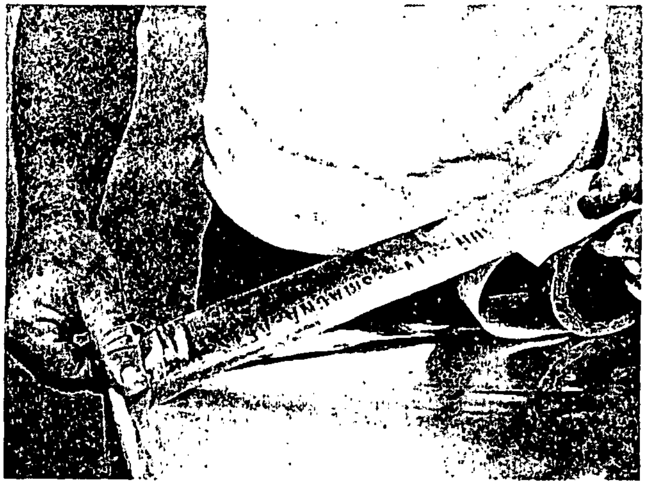


Photo courtesy of Johns-Manville



For all types of glass fiber duct, the first step in application is to staple the closure flap (top). Pressure sensitive tape is pressed down firmly to complete the job (courtesy of TIMA).



ing a high power of radiation have a low reflecting power. The amount of heat emitted by a surface radiating equally in all directions depends only on the nature of the surface, the difference in temperature between the surface and surroundings, and the absolute temperature.

Mass insulations

Thermal insulating materials of the mass type rely on the presence of a large number of small pockets of still air to limit the flow of heat through material. The heat transmission through the air pockets by natural convection is small because of the low conductivity value of still air and the size of the air pockets. Therefore, it is important in the manufacture of insulation to have the air pockets neither too large nor too small. If the air pockets are too large, the convective heat flow within them will be too high; if the pockets are too small, the conduction through the solid parts containing the air pockets will offset the insulating value of the pockets themselves. It is for these reasons that the specification of a thermal conductivity for a particular insulating material should include information about its density and the temperature range in which it is most effectiv As shown in Fig. 1, the temperature of application an the type of insulation material determine the conducti ity.

Mass insulations are produced in many forms. Som of these are: rigid boards, blocks, sheets, semi-rig boards, flexible boards, blankets, batts, preform shapes, tapes, and loose fill.

Reflective insulations

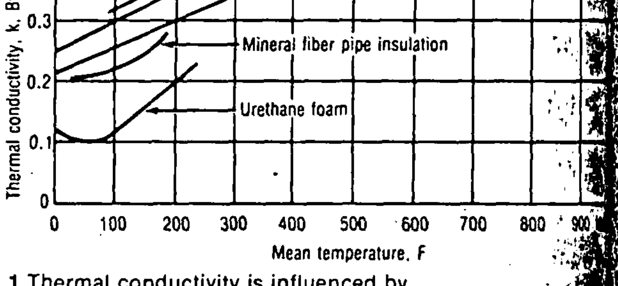
Reflective insulations restrict heat transfer by radi tion since the surfaces have a high reflectivity and a lo emissivity. These insulations can be a single sheet o multiple layers of metal foil. In a single sheet of met foil, most of the impinging radiant energy is reflected only a small amount passes through the reflective laye by conduction to be emitted from the back.

The ability to reflect heat varies with the temperatu in accordance with the laws of radiation. The reflectiv capacity has, as its counterpart, the ability to emit he slowly from the surface away from the heat source. Th two together represent 100 percent; if the reflectivity o a material, such as bright aluminum foil, is 95 percen then its emissivity is 5 percent. Thus, if foil is mount on some nonreflective material that first receives th heat, its low emissivity is just as effective as its hi reflectivity to heat approaching its exposed face b radiation.

Reflective insulations are not commonly used as th primary insulation for mechanical systems. Howeve by applying bright coverings over insulation on h surfaces, a low radiant loss will occur because of th low emissivity of the surface.

Insulation selection factors

When considering the selection of an insulation sy tem, it is the cost of the completed system that is o primary importance, not merely the cost of the insul tion alone. Naturally, the first cost of any insulatio system is important, but it should not be the maj



1 Thermal conductivity is influenced by temperature of application and material.

factor in the selection process. The life of the system and the benefits that will be derived from the insulation over the life of the system must be considered. In all cases, the type of insulation to be used should be decided during the design or retrofitting stages, because afterthought insulation is invariably more expensive to apply.

Numerous insulation materials are available, and the choice of one for a particular application is inevitably a compromise dependent on cost and many other factors, which may include:

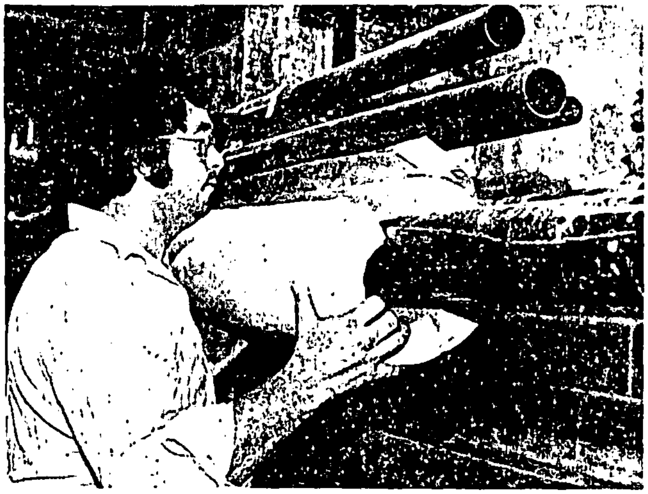
- Conductivity of mass insulation.
- Effective temperature range.
- Density.
- Ease of application.
- Cost.
- Resistance to combustion.
- Resistance to moisture.
- Resistance to damage and deterioration.
- Resistance to distortion and shrinkage.
- External finish.
- Corrosivity, odor, and health hazards during installation.
- Ability to support a surface finish.
- Ability to prevent vapor condensation on surfaces having a temperature below the dew point of the surrounding atmosphere.

Which insulation to use?

Maximum temperatures that insulation materials can withstand serve as a common basis for determining the type to use for various applications. Since temperature is the first element to consider in designing the mechanical system insulation requirements, it is a practical and logical consideration.

High temperature insulations may be applied where temperatures between 200 and 2300 F are to be experienced. High temperature insulation is used on heat exchangers, boilers, steam and process piping, high temperature water systems, and stacks.

Low temperature insulations range from 200 F down to as low as −400 F. Naturally, some insulation materials will be applicable in both ranges, depending on their composition. Since heat flow is inward in low temperature applications, condensation on the surface or in the insulation is a major concern. If water is permitted to condense in the insulation, it will reduce the insulating value of the material. Therefore, it generally pays to install thicker insulations for low temperatures than for high ones. If water vapor cannot be prevented from entering the insulation by its thickness, the insulation should have good moisture resistance, or a good vapor barrier should be applied. Resistance to vapor absorptivity in a low temperature insulation is expressed as vapor permeability, which is measured in terms of the amount of water vapor that passes through one inch thickness of the material. An insulation with excellent moisture resistance may not possess the highest insulating qualities; so selection must result in a compromise.



First step in installing glass fiber pipe insulation is to slip it over the pipe (top). The closure flap is stapled down after the insulation is in place (courtesy of TIMA).

High temperature insulations

Mineral wool insulation has a recommended temperature limit of 1200 F in the form of blankets and batts. Mineral wool consists of fibers formed from fused limestone or furnace slag. The fibers are bonded with an asphaltic compound and molded to specified shapes. Also, a flexible covering made of loose mineral wool may be used, or slabs may be secured to metal lath or wire netting with an outer casing. The recommended temperature limit for mineral wool preformed in blocks is about 1900 F.

Rock wool insulation is formed from molten rock of a siliceous nature into short fibers, which are bonded into slabs, pipe covering, and flexible blankets. Limiting temperatures are 450 F for nonbonded rigid rock wool material and 1400 F for loose fill.

Glass fiber insulation has a maximum operating temperature of 850 F. It is produced by blowing steam through streams of molten glass. The composition of the material and the fiber diameters determine the type of service, temperature, and user specifications for which various types of glass fiber insulation can be recommended. Semi-rigid boards can be as thick as 8 in.

Insulation wrap-up

Lightweight glass fiber duct sections are lifted into place and connected to other sections (courtesy of TIMA).

Glass wool insulation is available for service to 1000 F. The flexible type in rolls is easy to apply over irregularities. Moisture absorption of these insulating glass wools is low.

Cellular or foam glass is produced by grinding glass to a very fine powder that is passed through high temperature ovens to cause the cells to bond. A rigid, close-cell insulation permits cutting to flat or curved sections. The temperature limit for cellular glass is 1200 F.

Low temperature insulations

Polyurethane is a two-component synthetic resin material. The two component plastics may be mixed at the site or in the manufacturing plant. Carbon dioxide is used to expand the plastic and the resins to produce a tough, cellular material of good insulation and mechanical properties. Limiting maximum temperature is 200 F, while the minimum is −60 F. The use of this insulation on pipes, tanks, and vessels may present a fire hazard unless coated with an approved thermal barrier.

Polystyrene is a transparent, hard, and relatively brittle material possessing good insulation properties and dimensional stability. It is resistant to dilute acids and alkalis, but it is attacked by many solvents. It is manufactured by incorporating a suitable low boiling point substance in the polymer. Upon heating, the volatile substance boils, and the resultant vapor expands the softened polymer, giving a noncommunicating cell structure. The maximum application temperature is 175 F. Both molded and expanded polystyrene will burn if ignited, but they are self-extinguishing when the flame is removed. Nonflammable types are available.

The mineral fibers type of insulation and the glass fiber type are applicable in the low temperature range down to −60 F. Also, cellular glass, which is impervious to moisture, is a good low temperature insulation. Where joints meet, however, a vapor barrier needs to be used.

Expanded silica is mainly used as a fill, or in molded form, with a protective coating or jacket.

Aluminum foil has a low emissivity and rate of reflection of radiant heat. It is usually applied in such a way that an air space is enclosed between the foil and the hot surface. Improved performance is obtained by use of several layers of aluminum foil with an air space between each adjacent layer.

Insulation for ducts

Insulation of duct systems is not only necessary to conserve heat from heating ducts but to prevent condensation on duct exterior surfaces in cooling systems. Insulations with vapor barriers are available to provide this needed thermal insulation and condensation protection when applied to the exterior surface of sheet metal ducts.

As suggested in ASHRAE Standard 90-75, all air handling systems delivering conditioned air (both supply and return) and installed in nonconditioned spaces (−20 to 160F limits) shall be thermally insulated to provide a minimum resistance of R-6 overall from exterior to interior surfaces. Required insulation thickness can be calculated, or thicknesses in Standard 90-75 may be used.

The rigid fire hazard requirements of the National Fire Protection Association Standard 90A for the installation of air conditioning and ventilation systems must be met for all duct insulations. Although adoption of NFPA Standard 90A is not universal, most building codes require compliance with it.

Ducts can be insulated with duct wrap, liner, or any of three types of self-insulating ducts—rectangular, round, or flexible glass fiber ducts can be used.

Flexible glass fiber blankets (duct wrap) are used to insulate the outside surfaces of sheet metal ducts. Duct wrap with vapor barrier facings is supplied in 1½ and 2 in. thicknesses. Unfaced duct wrap is available in thicknesses ranging from 1 to 4 in. Duct wrap generally is designed for use at operating temperatures from 40 to 250 F, although some unfaced blankets can be used at operating temperatures up to 350 F. A good vapor barrier should be applied over the insulation, especially where the ducts carrying cooled air are installed in unconditioned spaces. Joints and laps in the vapor barrier must be tightly sealed to prevent condensation from collecting in the insulation.

Flat glass fiber duct board is used to fabricate rectangular, nonmetallic duct systems. Boards are supplied in standard 1 and 1½ in. thicknesses in 4 by 8 ft and 4 by [illegible] ft sizes. Duct boards are furnished with precut or molded male and female shiplap edges or with plain edges. They are designed for low velocity applications of up to 2400 fpm at 2 in. WG static pressure, and at temperatures up to 250 F.

Rigid round glass fiber ducts are used for entire air handling systems and as run-outs from main supply ducts, return ducts, and from mixing boxes to diffusers. Standard 6 ft lengths are manufactured in 4 to 36 in. (inside diameter) sheet metal sizes for use at velocities from 2000 to 5400 fpm at 2 to 8 in. WG, depending on the product. Sections are factory finished with or without male and female shiplap ends for joining sections. The ducts are jacketed with glass reinforced aluminum fo vapor barriers and are designed for use at temperatures up to 250 F. Semiround ducts can also be fabricated from duct board.

Duct liner is used to insulate the inside of sheet metal ducts during fabrication. The surface exposed to air flow is designed to withstand erosion and minimize friction loss. The glass fiber liner is designed for use at temperatures up to 250 F and at velocities of 2000 to 6000 fpm, and should not delaminate. Liner is supplied in flexible rolls or as rigid boards in thicknesses from [illegible] to 3 in.

Most glass fiber air handling insulation products also provide sound attenuation by helping reduce noises associated with the operation of equipment and rushing air.

Preinsulated flexible ducts should also be considered. These ducts have the insulation as an integral part of the duct and are used as connectors—usually where sharp bends and offsets preclude the use of rigid duct. Flexible ducts are manufactured with or without wire and vinyl air barrier cores and have exterior vapor barriers. Sections come in 7 and 25 ft lengths, the latter compression packed. Flexible ducts are manufactured in 4 to 18 in. (inside diameter) sheet metal sizes.

Methods and materials for applying duct insulations vary from product to product. Therefore, manufacturers' application instructions always should be followed. The most common methods are noted below.

Duct wrap is attached to sheet metal ducts with adhesive, mechanical fasteners, outward clinch staples, wire, or tape. Combinations of these materials also are used.

Duct liner is installed with mechanical fasteners and adhesives. It should be installed according to the requirements of the Sheet Metal and Air Conditioning Contractors' National Association (SMACNA) Duct Liner Application Standard, second edition.

Closures are used in the fabrication of glass fiber ducts and to install rigid round ducts and flexible ducts. Closures are the sealing devices that provide structural integrity in a duct system and also block air leakage at seams and joints. When used as part of a UL 181 Class I air handling system, closures must be tested as part of that system. The various closures are not always interchangeable with the glass fiber air handling systems on the market.

Table 1 — Representative types and characteristics of insulation for duct systems. The ranges of conductivities, densities, and temperatures are broad and do not represent any single product.

Insulation types	Temperature range, F	Conductivity, Btu per hr per deg F per sq ft per in.	Density, lb per cu ft	Application
Boards and blankets with vapor barrier on one side	Up to 250 F	0.23 to 0.36	0.75 to 6.0	Ducts—hot or cold
Thermal and acoustical duct liner blankets and boards	Up to 250 F, 4000 to 6000 fmp	0.20 to 0.48	1.5 to 3.0	Ducts—hot or cold—and acoustical treatment
Glass fiber boards, 1 in. thick	Up to 250 F, 2400 fpm, 2 in. WG	0.21 to 0.29	1.5 to 6.0	Rectangular ducts hot or cold
Rigid and flexible preinsulated ducts	Up to 250 F, 2400 to 5400 fpm, 1.5 to 4 in. WG	0.23 to 0.26	5.0	Round ducts

Four types of closure systems have passed UL 181 testing with fiber glass products:

- Pressure sensitive tape—the most commonly used closure system.
- Glass fiber and joint mastic—closures formed by stapling glass fiber fabric along duct joints and applying mastic over the tape.
- Thermally activated closures—closures that, when heated, melt into the pores of the duct facing, chemically bonding to it.
- Mechanical extruded aluminum closures—closure strips with channels that slip over the edges of plain duct board and are used to form rectangular duct sections and to connect sections.

Contact adhesives under the closure flaps also are used, as are combinations of systems.

To minimize application problems associated with some pressure sensitive tapes, SMACNA recently developed standards to upgrade tape systems—Performance Standard AFTS-100-73 and Application Standard AFTS-101-73. Both are included in the 1975 edition of SMACNA's Fibrous Glass Duct Construction Standards.

All manufacturers of nonmetallic duct board recommend that when the closure system is pressure sensitive tape, only tapes bearing the AFTS-100-73 designation be used. Other closures that are part of a UL 181 listed systems and that meet the manufacturer's recommended fabrication practices are acceptable also.

Reinforcement requirements for glass fiber ducts are also contained in the duct construction standards. Schedules for the size and placement of reinforcements, based on duct size, static pressure, and board type, are provided. Sheet metal channels or tee bars are specified as reinforcements.

For the first time the use of tie-rod reinforcing with 12 gauge or heavier wire and washers is permitted by the standard—but only for positive pressure systems.

Trapeze hangers with 1 by 2 by 1 in. channels are recommended as supports for glass fiber ducts. Supporting straps should be 1 in. wide and should be made from 22 gauge or heavier material. Rods ¼ in. in diameter also can be used instead of strap hangers. Other supports, such as bar joists, ceiling joists, etc., may be used, provided they meet the hanger specifications listed in the duct construction standards. All support systems must be capable of withstanding a load three times the anticipated load.

Table 1 shows representative types and characteristics of insulation for several applications. The ranges of conductivities, densities, and temperatures are broad and do not represent any single product; they are shown here to illustrate the varieties of products for various types of ducts.

Insulation for equipment

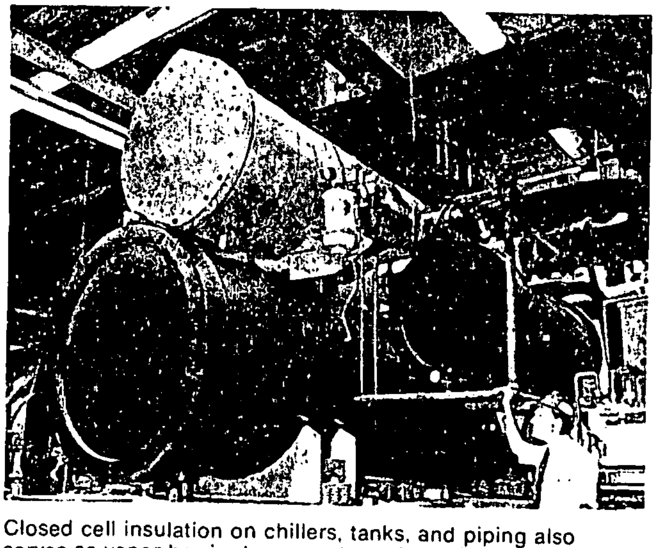
Insulation for boilers, tanks, chillers, heat exchangers, and breechings is normally in the form of flat or curved blocks, blankets, and sprayed-on types. The method of securing the insulation may include banding around the insulation on the equipment, the application of a wire mesh over the insulation, and the application of the insulation to various types of welded studs and angle iron supports on the equipment.

In selecting an insulation for equipment, the degree of flexibility of the blocks and blankets and their shapes are of primary concern so as to minimize the need for cutting and fitting on the job. Availability of insulation in flexible materials is increasing to meet this need. As an example, the scoring of blocks increases the flexibility of rigid insulations for easier application to irregular shapes.

Large flat and curved calcium silicate blocks are commonly used on large tanks and boilers. For above ambient temperature conditions, the insulation should have a finish covering with a wire mesh tightly stretched and secured. A finish coating of hard cement is generally used to fill the joints and to seal the wire mesh covering the blocks. Paint may be applied over the cement.

Mineral wool or glass fiber blankets may be used on surfaces with odd shapes. A metal mesh or wire ties are commonly used to hold the blankets in place. A metal jacketing may also be used to protect the blanket.

Spraying of insulation is one method that is used to cover large surfaces. Urethane and polystyrene foams are applied in this way. It is most important that the temperature of the surface onto which the foam is being sprayed will permit the foaming reaction to be completed. A desirable wall surface temperature of 90 F will achieve this desired foaming reaction. If the tank or equipment is in service, the surface temperature may be controlled by varying the temperature of the contents to reach the 90 F outside surface temperature. Obviously, it is essential that the spraying technique be correct and that wind and moisture be at a minimum. A reinforcing wire mesh should be applied on the surface to serve as a bond for the sprayed-on foam.



Closed cell insulation on chillers, tanks, and piping also serves as vapor barrier to prevent condensation (photo courtesy of Armstrong Cork Co.).

Table 2 — Representative types and characteristics of insulation for equipment. The ranges of conductivities, densities, and temperatures are broad and do not represent any single product.

Insulation type	Temperature range, F	Conductivity, Btu per hr per deg F per sq ft per in.	Density, lb per cu ft	Applications
Urethane foam	−270 to 225	0.11 to 0.14	2.0	Tanks and vess
Glass fiber blankets	−270 to 450	0.17 to 0.60	0.60 to 3.0	Chillers, tanks (and cold) pro equipment
Elastomeric sheets	−40 to 220	0.25 to 0.27	4.5 to 6.0	Tanks and chille
Glass fiber boards	Ambient to 850	0.23 to 0.36	1.6 to 6.0	Boilers, tanks, a heat exchang
Calcium-silicate boards, blocks	450 to 1200	0.22 to 0.59	6.0 to 10	Boilers, breech and chimney
Mineral fiber blocks	to 1900	0.36 to 0.90	13.0	Boilers and ta

For temperatures below ambient, the insula should have a high resistance to moisture; this require some sacrifice in thermal conductivity. Cel glass blocks, plastic foams, and cellular rubber sh are common materials used because of their mois resistance. If condensation may develop on the sur of the insulation, a vapor barrier must be applied. vapor barrier should provide the necessary degre vapor sealing to avoid entry of moisture from the rounding air.

Vapor barriers include sheets of aluminum, forced plastic, metal foils, treated papers, or jacketing. Fastening may be accomplished by bands, or by sealing the joints with tape. Coating asphaltic or resinous materials may also be used. age to the vapor barrier during application must prevented. If a vapor barrier is punctured, its effecti ness is lost, and therefore extreme care must be e cised on the job.

For dual temperature service where equipmen alternately hot and cold, the insulation and the va barrier seal must be carefully selected for withstand expansion and contraction and still maintain the va seal.

Representative types and characteristics of ins tion for several applications are given in Table 2. ranges of conductivities, densities, and temperatu are broad and do not represent any single product; are shown here to illustrate the varieties of products various types of equipment.

Insulation for piping systems

Proper selection of insulation for piping syste within the building must take into account not only thermal properties but the mechanical properties well. Also, the chemical properties of the insulati must be considered to be sure the piping materials

3 — Representative types and characteristics of pipe lation. The ranges of conductivities, densities, temperatures are broad and do not represent single product.

lation types	Temperature range, F	Conductivity, Btu per hr per deg F per sq ft per in.	Density, lb per cu ft	Applications
ane am	−400 to 300	0.11 to 0.14	1.6 to 3.0	Hot and cold pipes
ar ass ocks	−350 to 500	0.20 to 0.75	7.0 to 9.5	Tanks and piping
fiber nket for pping	−120 to 550	0.15 to 0.54	0.60 to 3.0	Piping and pipe fittings
fiber formed pes	−60 to 450	0.22 to 0.38	0.60 to 3.0	Hot and cold pipes
fiber ats	−150 to 700	0.21 to 0.38	0.60 to 3.0	Piping and pipe fittings
meric formed pes tape	−40 to 220	0.25 to 0.27	4.5 to 6.0	Piping and pipe fittings
fiber th vapor rier ket	−20 to 150	0.20 to 0.31	0.65 to 2.0	Refrigerant lines, dual temperature lines, chilled water lines, fuel oil piping
fiber out por barjacket	to 500	0.20 to 0.31	1.5 to 3.0	Hot piping
ar ass cks and rds	70 to 900	0.20 to 0.75	7.0 to 9.5	Hot piping
ane am cks and rds	200 to 300	0.11 to 0.14	1.5 to 4.0	Hot piping
ral or premed pes	to 1200	0.24 to 0.63	8.0 to 10.0	Hot piping
ral fier blan-	to 1400	0.26 to 5.6	8.0	Hot piping
fiber: ld apd jackr exsed	500 to 800	0.21 to 0.55	2.4 to 6.0	Hot piping
ral ool ocks	850 to 1800	0.36 to 0.90	11.0 to 18.0	Hot piping
cate ocks	1200 to 1800	0.33 to 0.72	10.0 to 14.0	Hot piping

be compatible with the insulation. Basically, insulation installed on steel piping should be neutral or slightly alkaline, and that installed on aluminum should be neutral or slightly acidic. However, these are very broad guides, since chemical attack may result if salts or other components leak out of the insulation.

The types of insulation that are available for piping system applications are glass fiber, cellular glass, calcium silicate, mineral wool, and rigid urethane foams. Representative types and characteristics of various insulation materials are presented in Table 3. The ranges of conductivities, densities, and temperatures are broad and do not represent any single product; they are shown here to illustrate the varieties of products for various applications.

Recommended thicknesses of thermal insulation for hot piping have been increased about 50 percent in the recently released revision of the General Services Administration Guide Specification PBS 4-1516. The specification applies to insulation for piping within buildings built or maintained by GSA. These thicknesses generally conform to those determined by the ECON method developed by the Thermal Insulation Manufacturers Association (TIMA). The accompanying Figures 2 and 3 for recommended pipe insulation thickness have been reproduced from PBS 4-1516. Copies of the specification may be obtained from GSA, Washington, DC 20415.

The forms of insulation for piping applications consist of preformed sections, wrapping blankets, and in-

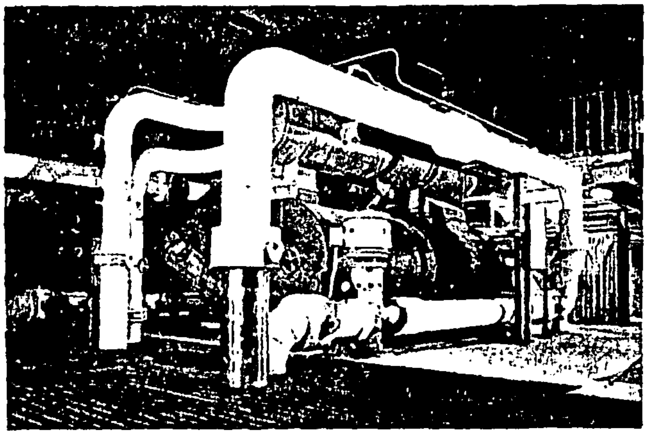
Pipe size, in.	Insulation material						
	Mineral fiber			Cellular glass			Flexible unicellular
	Temperature class						
	Above 35 F	35 F to 0F	Below 0F to −30 F	Above 35 F	35 F to 0 F	Below 0F to −30 F	Above 35 F
	Insulation thickness, in.						
Under 1½	1	1½	1½	1½	2	2½	½
1½ to 3			2		2½	3	Not to be used
3½ to 5	1½	2	2½				
6 to 10				2			
Over 10		2½	3		3	3½	

2 Recommended insulation thickness for low temperature pipe insulation from the General Services Administration.

Pipe size, in.	Insulation material							
	Mineral fiber					Calcium-silicate and thermal pipe covering		
	Up to 450 F		451 to 1000 F					
	LP	MP	LP	MP	HP	LP	MP	HP
	Insulation thickness, in.							
Under 2½	1½	2	1½	2	3	2½	3	4½
2½ to 3	2½	3	2½	3	4	4	4½	5½
3½ and over	3	3½	3	3½	4½	4½	5½	7

KEY: ■LP. Low pressure steam is up to 15 psig, or temperatures to 250 F.
■MP. Medium pressure steam is from 16 to 75 psig at temperatures from 251 to 320 F.
■HP. High pressure steam, is from 76 to 200 psig at temperatures from 321 to 400 F.

3 Recommended insulation thickness for steam and hot water piping systems from the General Services Administration.



Chiller equipment and piping. Pipe is covered with glass fiber insulation with canvas and metal jacketing. Urethane foam blanket insulation is used on tanks (courtesy of Johns-Manville).

Insulating cement is troweled into place. In this instance, the insulation is being applied to a breeching in a utility shaft (courtesy of TIMA).

sulating tapes. Adhesives with banding and/or jacketing are common methods of attaching the insulation. Before applying the insulation to the piping system, all connections should be inspected for leaks. Also, it is suggested that draining of the piping during installation should be avoided to eliminate the possibility of moisture entering the insulation. Lengths of pipe insulation are available to provide the most advantageous value for field application. This optimum length is generally 2 to 3 ft, which eliminates the need for frequent cutting as the piping changes direction. Pipe fittings may now be insulated with preformed shapes that provide a snug fit; however, where odd shapes, such as valves, are to be

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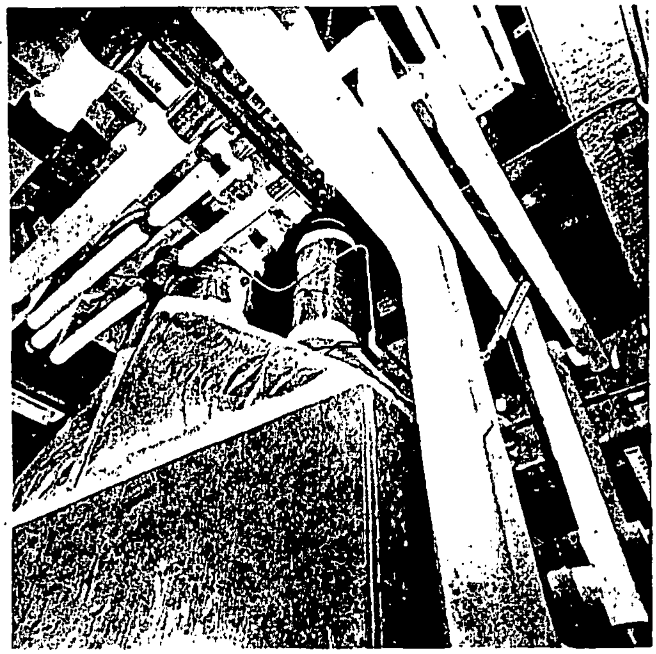
Product Guide

Mechanical systems insulation product guide

Manufacturer	Insulation types	Applicatio
Accessible Products Co. **Circle 200**	☐ Polyurethane foam in preformed shapes, blankets	☐ Pipe, ducts to 200 F
Armstrong Cork Co. **Circle 201**	☐ Elastomeric preformed shapes	☐ Piping: −40
	☐ Elastomeric sheets	☐ Tanks, piping 220 F
	☐ Elastomeric tape	☐ Pipe, fittings
	☐ Urethane preformed shapes	☐ Piping: −250
Celotex Corp. **Circle 202**	☐ Expanded perlite blocks and preformed shapes	☐ Piping, equi & tanks: to 150
Certain-teed Products Corp., CSG Group **Circle 203**	☐ Glass fiber preformed shapes	☐ Piping: −20
	☐ Glass fiber blankets	☐ Pipe fittings 550 F
	☐ Glass fiber blankets	☐ Tanks: −270
	☐ Glass fiber boards	☐ Boilers, ducts equipment to 850 F
	☐ Glass fiber duct board	☐ Ducts: to 250 5400 fpm
	☐ Glass fiber duct blankets	☐ Ducts: dual systems
	☐ Glass fiber flexible round	☐ Ducts: to 250 2400 fpm
Cle Con, Inc. **Circle 244**	☐ Flexible preinsulated ducts with vapor barrier	☐ Ducts: −20
Eagle-Picher Ind., Inc. **Circle 204**	☐ Mineral fiber blocks	☐ Boilers, equi 1900 F
	☐ Mineral fiber blankets	☐ Piping, tanks to 1400 F
	☐ Mineral fiber preformed shapes	☐ Piping: to 12
	☐ Mineral fiber boards	☐ Boilers, duct to 1050 F

Insulation wrap-up



Typical equipment room systems scene shows hot and chilled water piping and hot and cool air ducts. Chilled water lines are covered with glass fiber pipe insulation and all-purpose jacket; hot water pipe is covered with calcium sisicate with canvas covering. Air ducts are insulated with a glass fiber duct insulation 500 and 800 F (courtesy of Johns-Manville).

insulated, wrapping tapes may be used to achieve the desired results.

Pipe insulation should have true concentric cylindrical surfaces, and it should have the necessary strength to withstand considerable handling. Insulation materials that have good tensile strength in all directions will meet this requirement and are also more suitable for cutting and fitting into the desired finished shapes. If the ends of the pipe insulation are not square and true, the gaps must be plugged with insulating cement or the end recut to fit. When the insulation is secured by bands or wires, the material must resist the tendency to crack along the wire or bands, because a strapping tool will exert a 600 to 800 lb tensile pull on a strap to draw the joints up tight.

Expansion and contraction of piping can cause serious damage to thermal insulation of preformed shapes and the coverings. Most high temperature insulations shrink as the temperature rises, while the metal pipe expands. Therefore, some provision must be included to allow for these dimensional changes. If cracks in the insulation occur with these temperature changes, the size of the crack is not important. The problem that must be prevented is that water or moisture may enter the crack and cause the insulation to lose its insulating value. Therefore, it is imperative that expansion joints in the insulation be provided under these conditions.

Insulations of the flexible type that are slit for ease of installation on piping should be sealed at the butt joints with an adhesive and/or a sealing tape. Pipe fittings and valves should be insulated with the same material in sheet form of the same thickness. The joints should be sealed with an adhesive in the same manner.

Flexible blanket pipe insulation may be covered metal jacketing that locks along the longitudinal s when the jacket is drawn up tight. Other types of ins tions that also rely on the jacketing for long-term p tection of the insulation include scored blocks and p formed shapes.

Metal jacketing can be a part of the insulation as delivered from the manufacturer, or it can be applied the job. Corrosion resistance of metal jacketing is portant if used in corrosive atmospheres. The m corrosive services may require stainless steel jacket Another jacketing material commonly used is asp saturated asbestos felt that is reinforced with a g threaded fabric.

Plastic jacketing may be used in applications w ambient temperatures and other environmental co tions will not affect the life of the material.

Pipe elbows may be jacketed in metal or in plas Bands and tapes used with adhesives permit the c nection of the jacket to the insulation of the piping the prevention of heat loss and entry of water.

The insulated piping should be supported by hang and metal protection shields. For piping 2 in. and lar an insert consisting of a piece of mineral fiber, cork wood block should be placed between the shield and piping. The insert should be shaped to fit not less t half the pipe circumference. Protection saddles pref ricated to include the insert material and a vapor bar may also be used. Flexible cellular types of insula should be protected from compression at all pipe han locations by using compression resistant insulation serts, of the type mentioned above, and protect metal shields.

The article by Robert Curt of York Research Cor ration, which immediately follows this article, prov a comprehensive analysis of how to determine the insulation thickness for piping systems.

The author wishes to thank the Thermal Insula Manufacturers Association (TIMA) for their help cooperation in providing information for the duct in lation section of this article.

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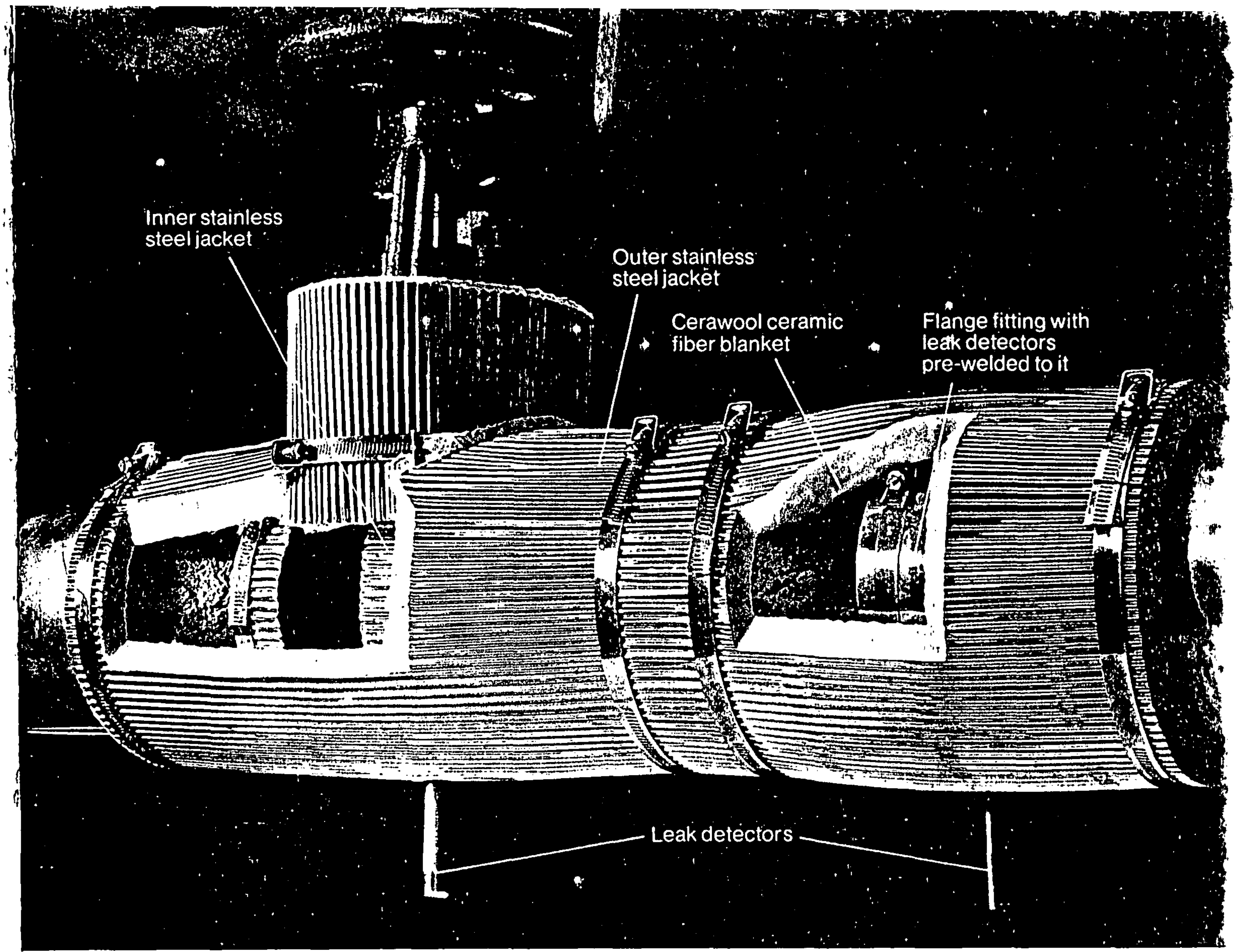

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Temp-Fit is re-usable, too. If, at some time, you need to remove the insulation, it can be reinstalled rapidly and effectively.

For the full story on Temp-Fit, contact your J-M distributor or contractor. Or write Larry Hall, Industrial Products Division, Johns-Manville, P.O. Box 5108-IPD-B, Denver, Colorado 80217. Or call (303) 979-1000, Ext. 2319.

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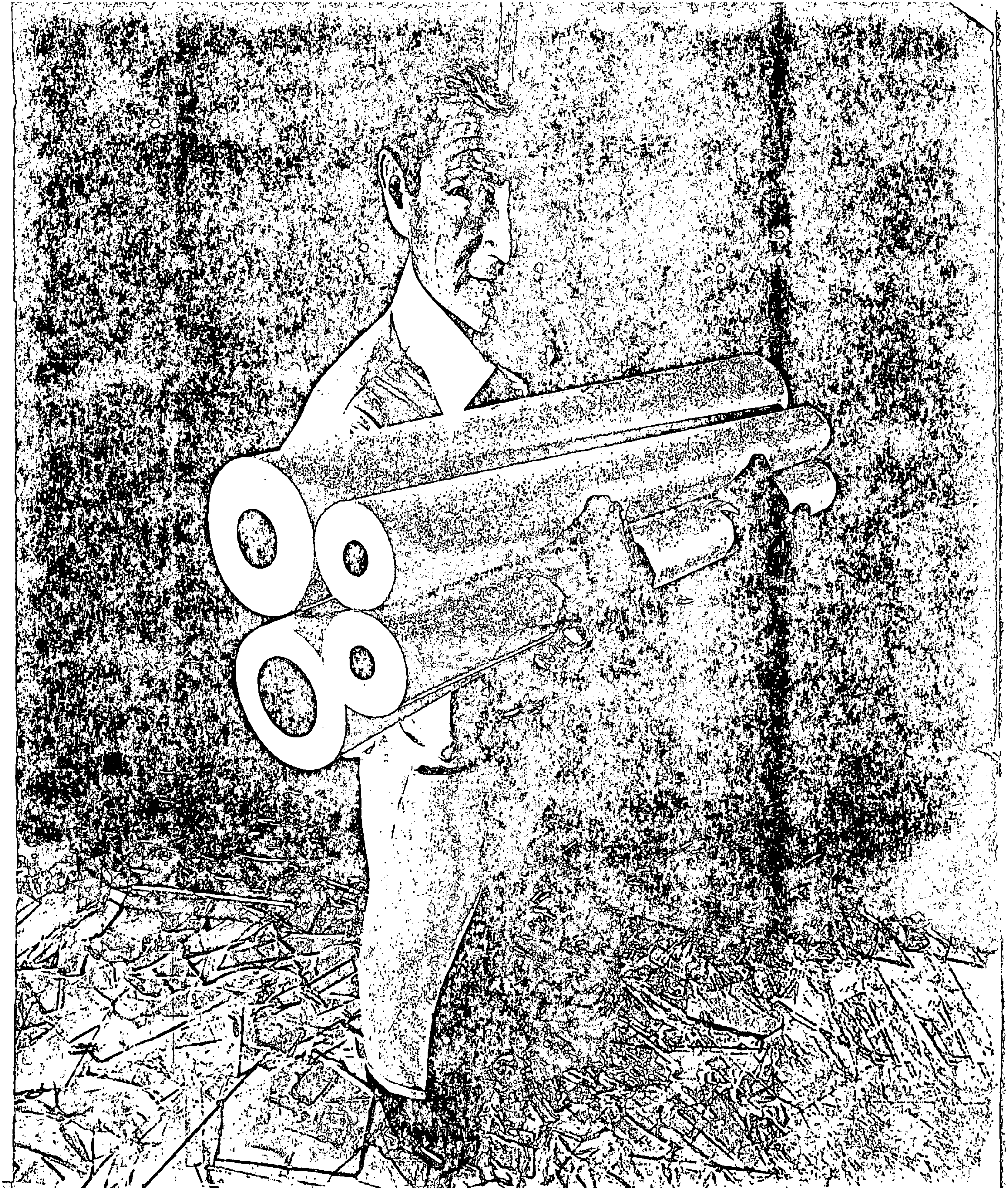

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Its vapor barrier is a lamination of aluminum foil and white kraft paper.

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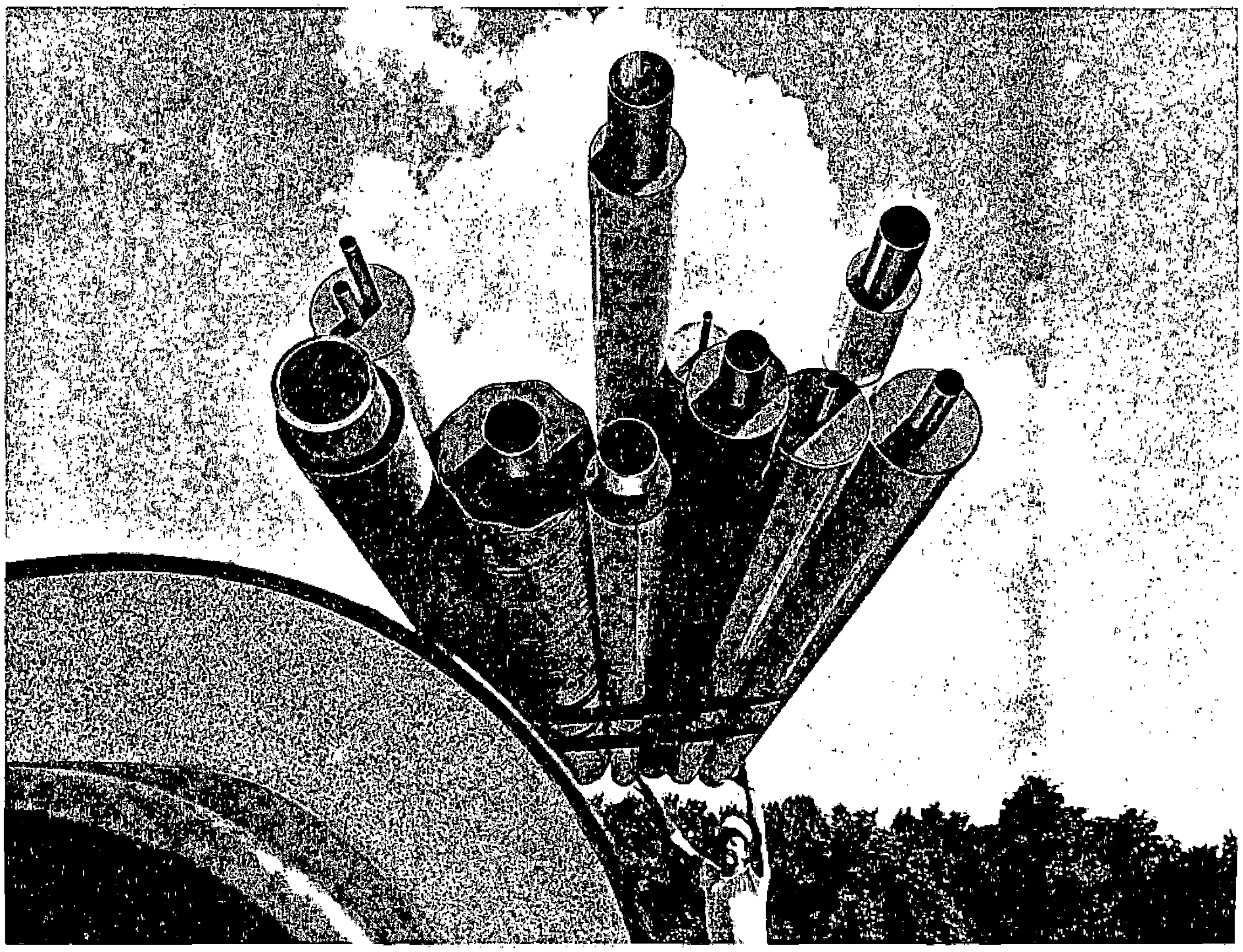

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How to lay out a thermal liquid heating system

Considerations in component selection and location, guidelines on piping configurations, and examples of graphic analyses of system and pump characteristics

S. AGNON, S. Agnon & Partners Ltd., Consulting Engineers, Haifa, Israel

In LAST month's article, we established a criterion on which to base the selection of a thermal fluid system. In this article, we shall discuss various considerations involved in the choice of equipment and layout of the heating plant. Among these are the construction of the liquid heater and the location of the circulating pump and expansion vessel in relation to the heater.

As is well known, at higher temperatures all mineral oils have a tendency toward thermal disintegration (cracking) as well as toward oxidation, especially in the presence of air. This deterioration depends on a number of factors, one of which is the heat concentration on the fire side of the heater surfaces and another the thermal resistance of the boundary fluid layer on the liquid side. Under otherwise equal conditions, the higher the viscosity of the fluid, the thicker is the boundary film and the lower is the heat flux per unit area. The flow velocity will also be lower, assuming the same kind of centrifugal pump is employed. And as shown in Fig. 1 of the February article, a low flow rate means an even higher film resistance, and consequently the danger of local overheating is more pronounced for slow moving liquids. Thus, to keep the velocity as high as possible, to contain as little thermal fluid as possible, and also to provide as much heating surface as possible per unit volume, thermal liquid heaters are always designed with liquid passages as narrow as practicable. These may be in the form of coiled or serpentine tubes, or in the form of thin annular walls. And to assure turbulent flow, velocities are usually kept between 4 and 10 fps.[1]

In this connection, the position and arrangement of the burner are also of importance. Ample combustion space must be provided, and care must be taken to avoid flame impingement on the heating surfaces. The combustion gases should be guided through the flues countercurrent to the flow of liquid so that the greatest heat concentrations occur in the heater sections containing fluid at its lowest levels of viscosity, and vice versa. To no small degree, these factors dictate the design of a liquid heater. Fire linings, to the extent that they cannot be avoided, and insulating walls must be made from refractories with no or minimal heat storage capacity.

The products resulting from the disintegration of thermal fluid are partly more volatile than the original fluid, partly more viscous. The latter tend to form cokelike deposits on the liquid side of the heater surfaces, which further increase the wall resistance and reduce heat transfer. The former tend to form gas pockets at the high points of the heater, resulting in uncooled heating surfaces; if not immediately removed, the gas pockets will interfere with the proper circulation of fluid.

To guarantee safe operation, it is therefore necessary not only to assure constant circulation but also to eliminate air and other gases from the system as quickly as possible and to keep heating rates within safe limits. Safe rates of heat flux across the heating surfaces usually range from 3000 up to 9000 Btuh per sq ft depending on the type of thermal fluid, the flow rate, and certain other applicable factors.

Even when the system is purged of air in the cold state and otherwise safe working conditions prevail, water originally contained in the thermal fluid, or condensed out in the expansion vessel during a periodic stoppage, or remaining from a hydraulic test of the piping system may evaporate and form steam pockets. These have the same detrimental effects as air or gas pockets and must be removed immediately.

Removal of gas and air is effected in the expansion vessel, which is situated at the highest point of the piping system. The expansion vessel is always connected on the suction side of the pump (see Fig. 1a) and should be able to accommodate at least twice the total increase in fluid volume when it is heated up. On the other hand, the vessel should present as small an area as possible for the interface of liquid and outside atmosphere so as to avoid oxidation of the thermal liquid. Floating covers and blankets of nitrogen gas have been employed to prevent air from contacting the fluid surface. Alternatively, special piping hookups can be exe-

Next in this series:
a generalized method
for calculating
viscous friction loss

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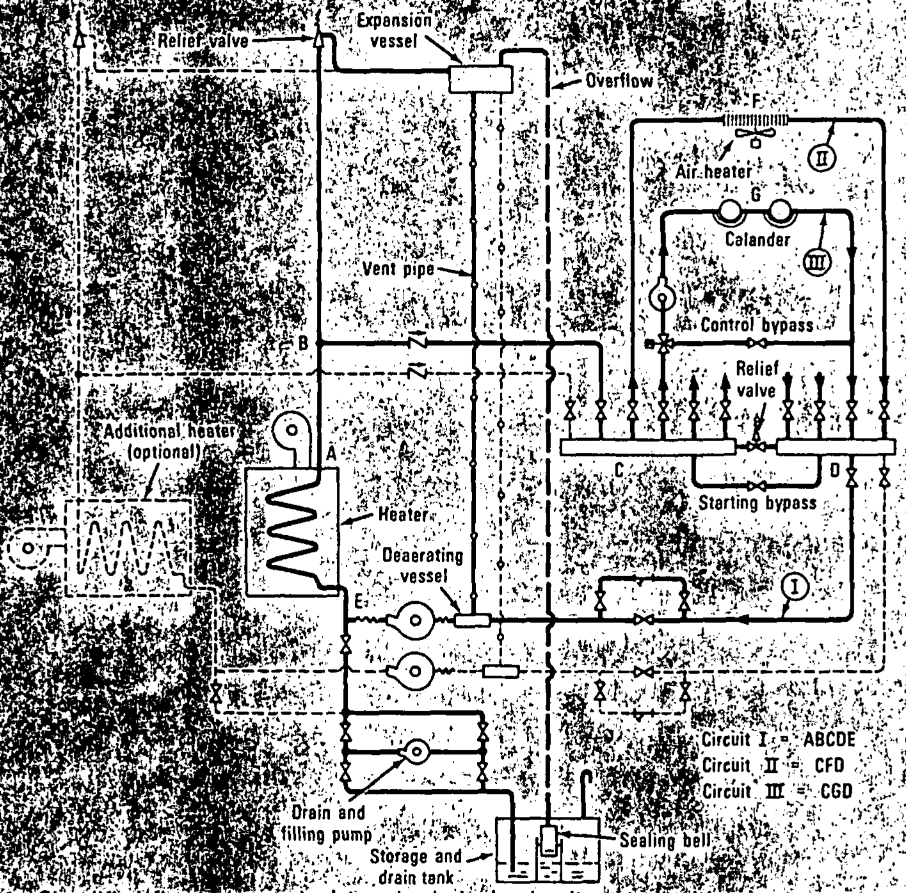
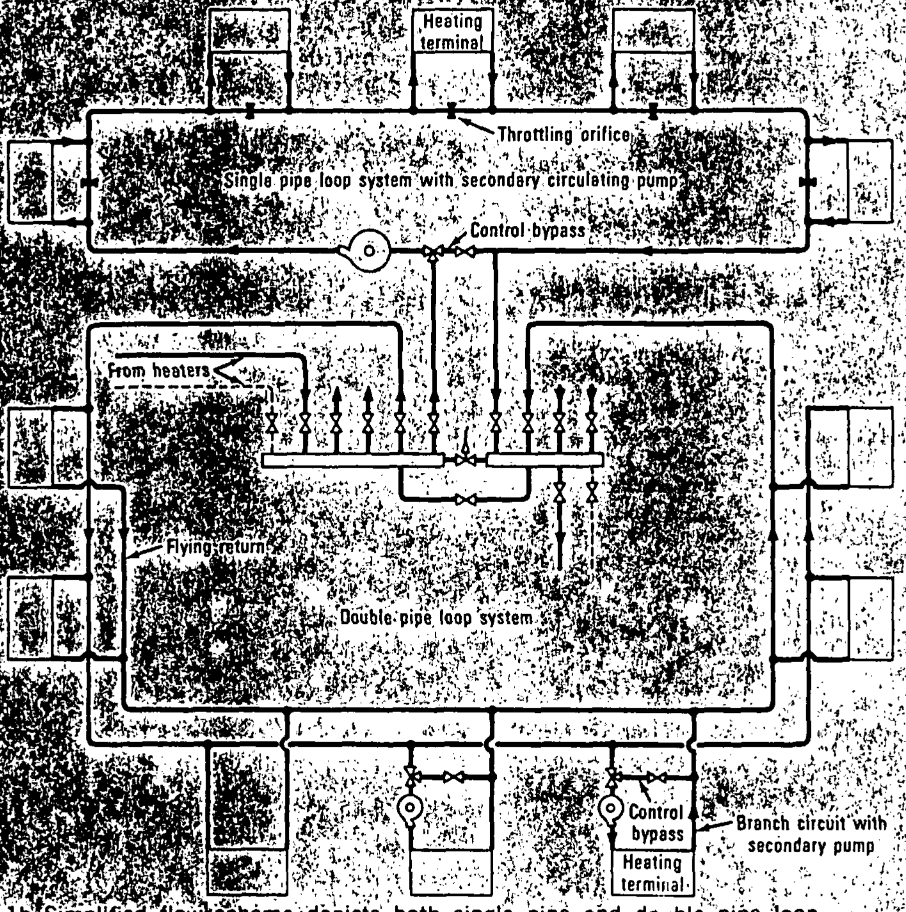
[1] *Superscript numerals indicate references at end of article.*



1a Simplified flow scheme depicts mixed single circuit system with common supply and return manifolds. It includes a main circuit, Circuit I; a branch circuit with no secondary pump, Circuit II; and a branch circuit with a secondary pump, Circuit III. System and pump characteristics are analyzed in Figs. 3a,b.



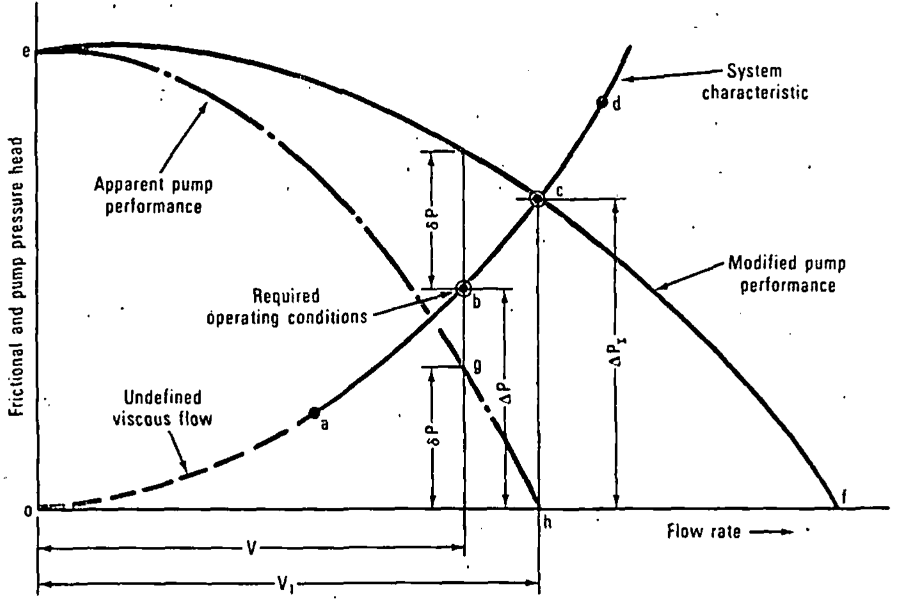
1b Simplified flow scheme depicts both single pipe and double pipe loop systems with common supply and return manifolds. Note that two-pipe loop is laid out with flying return. Branch circuits having their own secondary pumps can be considered as separate loop systems.

cuted to keep the vessel cont shut off from the atmosphere as as from heating up and endang the system. For example, liquid may be arranged in the overfl connection to provide a seal ag the outside atmosphere; and to p vent the vessel contents from hea up by gravity circulation, ch valves can be fitted in the ex sion line in the manner shown Fig. 2. Coefficients of expansion the calculation of volume incr vary from 0.035 up to approxim 0.055 percent per deg F temper rise for organic fluids in the hi temperature ranges, as compared 0.06 percent per deg F in the c of hot water at 300 F.

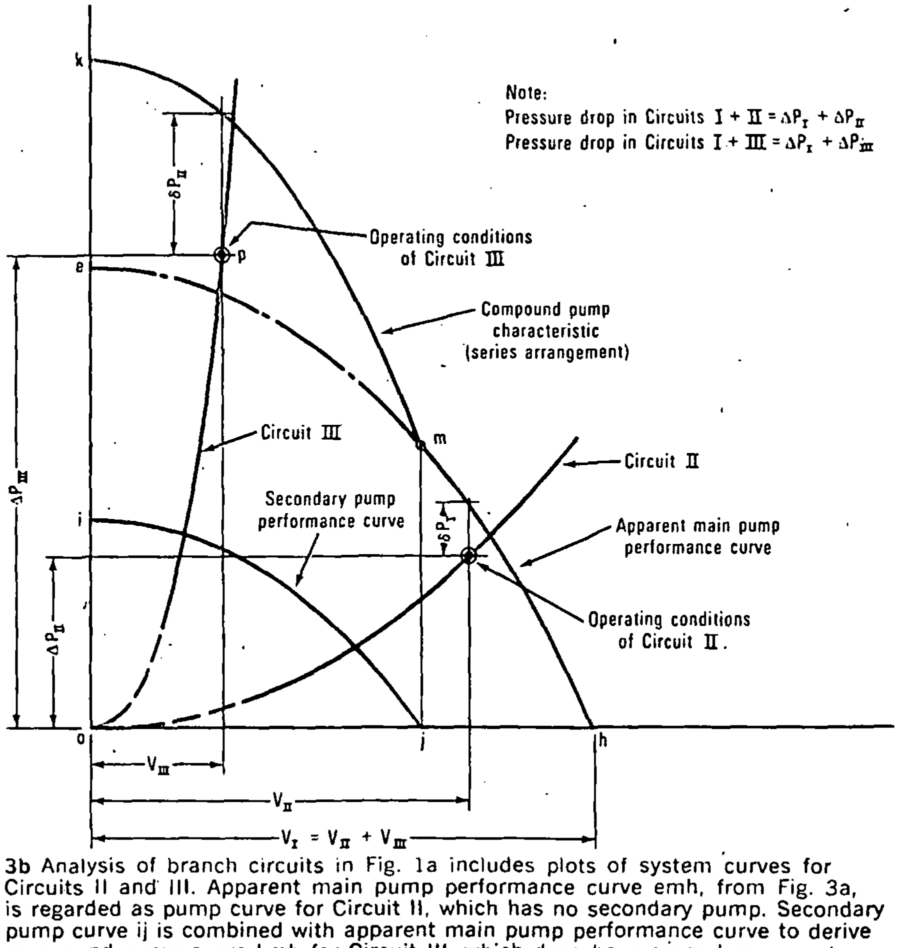
Air pockets in the heater body c be vented by means of hand oper air cocks; but if the circulating p is located at the heater outlet, venting process can proceed natu ly, without mechanical means, demonstrated in Fig. 2. This arra ment is preferable in many resp it also enables the heater body to quickly drained in case of emerge without any special manipulation the event of a heater tube or wall failure, the entire system be emptied immediately; other the highly flammable fluid might ter the firebox, with disastrous sequences. If vent valves are they must be opened to break vacuum—a task that under these cial circumstances is a very carious one to say the least.

Air and gases can be driven f the piping system itself by a st circulation and vented by ma valves at the high points of the tem. In smaller plants, this pur can be accomplished by means o deaerating vessel only, fitted into return line and vented into the pansion tank. Under normal co tions, once air and water vapors h been purged from a system, it sho operate without further attention venting. As will be discussed i subsequent article, the location of circulating pump in relation to thermal liquid heater also has cer effects on its performance chara istics because of the difference tween liquid temperatures at the h er inlet and outlet.

Aside from the location of main circulating pump, how there are two principal piping rangements for supplying the hea terminals with thermal fluid. first, shown in Fig. 1a, consist single circuits connected to a co mon supply and return manif with or without secondary circul



3a System and pump characteristics are analyzed for main circuit, Circuit I, in Fig. 1a. System curve, 0abcd, is plotted through operating point b, but pump curve (modified to reflect specific viscous fluid handled), ecf, intersects it at point c. Surplus head, δP, must be used up by means of throttling. Construction of "apparent pump performance curve," also illustrated, simplifies analysis of branch circuits, shown in Fig. 3b.



3b Analysis of branch circuits in Fig. 1a includes plots of system curves for Circuits II and III. Apparent main pump performance curve emh, from Fig. 3a, is regarded as pump curve for Circuit II, which has no secondary pump. Secondary pump curve ij is combined with apparent main pump performance curve to derive compound pump curve kmh for Circuit III, which does have secondary pump.

0abcd in Fig. 3a. But to simplify analysis, it is advantageous to combine the system characteristic the main circuit with the perfo ance characteristic of its circula pump. By subtracting the pres loss values on the system curve the operating head values on pump performance curve, one construct a new "apparent pump formance curve." labeled egh in 3a, which in the course of fur analysis will be regarded as the tual curve.

Circuit II in Fig. 1a, the bra that has no pump and derives its culation from the main circuit, now be thought of as containing accelerator pump with the perfo ance curve labeled emh in Fig. which is identical to curve egh Fig. 3a. Circuit III in Fig. 1a is branch having a small second pump, and its performance is plo in Fig. 3b as curve ij. The compo characteristic of the two pumps series is then obtained by adding operating pressure heads, resulting the broken curve kmh in Fig. 3b

The system parabolas for branch circuits can now be plo on the same chart, as described ab Again, the intersections between pu and system characteristics will pro bly not occur at the required conditions, and the respective sur pressure heads, δP, will have to removed by throttling. *No throttl however, is required in the main cuit in this case.*

In the event that a system tains several liquid heaters opera simultaneously, each with its pumped main circuit, the proced is quite similar. The only extra is to first construct a compo characteristic for parallel opera from the several apparent perfo ance curves of the main pumps adding their respective flow rates the usual manner.

The next article in this series present a new method for calcula viscous friction loss, applicable only to thermal fluid systems but piping systems conveying visc fluids in general.

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