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85% MAGNESIA INSULATION MANUAL

2nd Edition

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THE MAGNESIA INSULATION MANUFACTURERS ASSOCIATION

Washington, D. C.

M.I.M.A.

The Magnesia Insulation Manufacturers Association — MIMA — was formed in 1944 by producers of 85% Magnesia thermal insulation. Its objectives are to contribute to greater production economy in industry through the encouragement of research and education on heat insulation materials and their application, embodying product improvement and evaluation, fuel conservation and engineering practice.

In 1949, the Association published and distributed the first comprehensive manual on 85% Magnesia thermal insulation. Since that time, new information of interest to all users of the manual has become available, and some of the original material is no longer in accord with current insulating practice. In this second edition of the manual, the contents have been brought up to date in every respect.

In addition to the manual, the Association publishes a quarterly bulletin, MIMA NEWS, reporting current developments and uses of 85% Magnesia. This is available to anyone interested. Case histories of insulation applications in various fields also are available.

ASSOCIATION MEMBERS

The Philip Carey Manufacturing Company
Ehret Magnesia Manufacturing Company
Johns-Manville Sales Corporation
Keasbey & Mattison Company
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THE MAGNESIA INSULATION MANUFACTURERS ASSOCIATION

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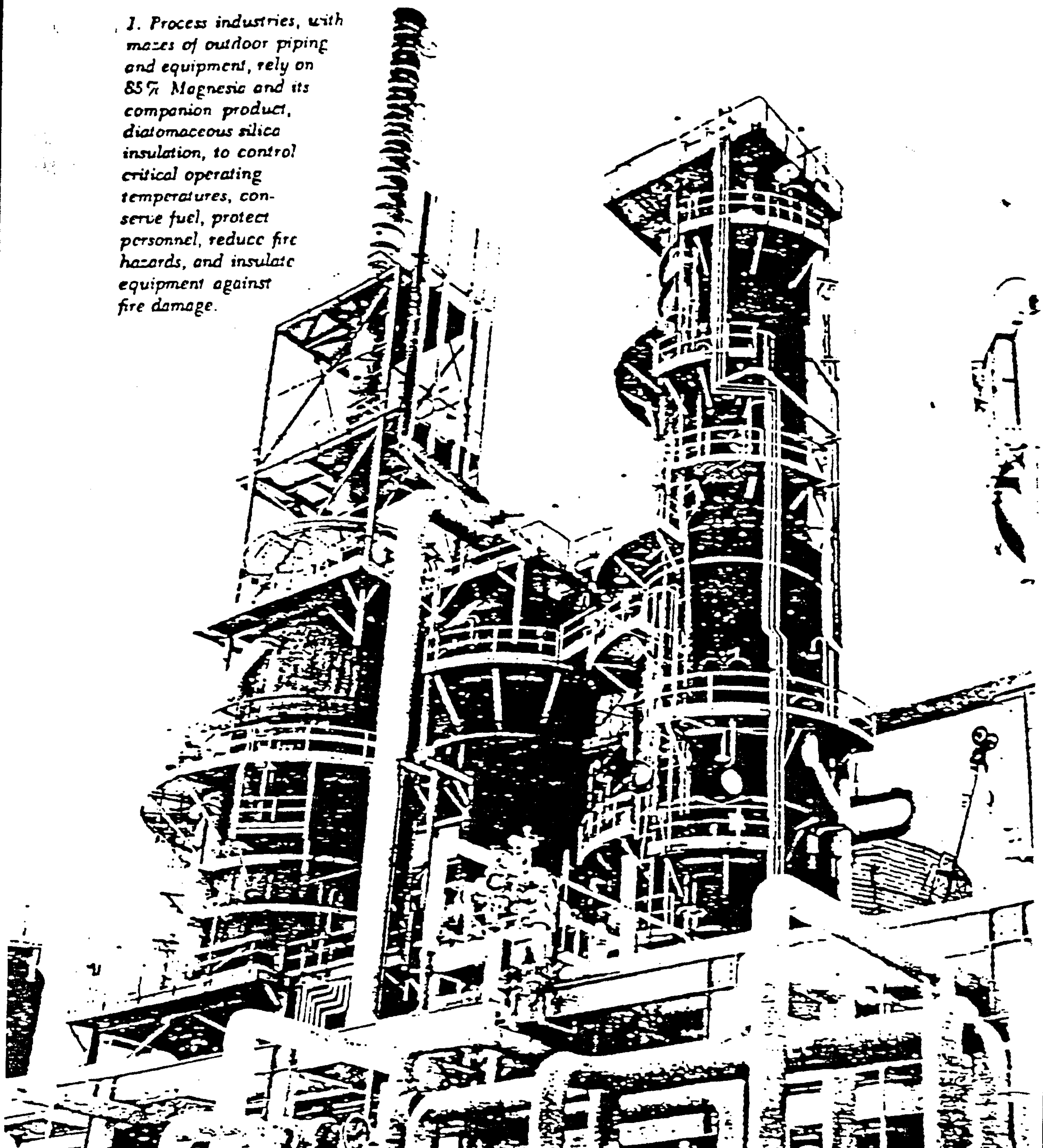

1. Process industries, with mazes of outdoor piping and equipment, rely on 85% Magnesia and its companion product, diatomaceous silica insulation, to control critical operating temperatures, conserve fuel, protect personnel, reduce fire hazards, and insulate equipment against fire damage.

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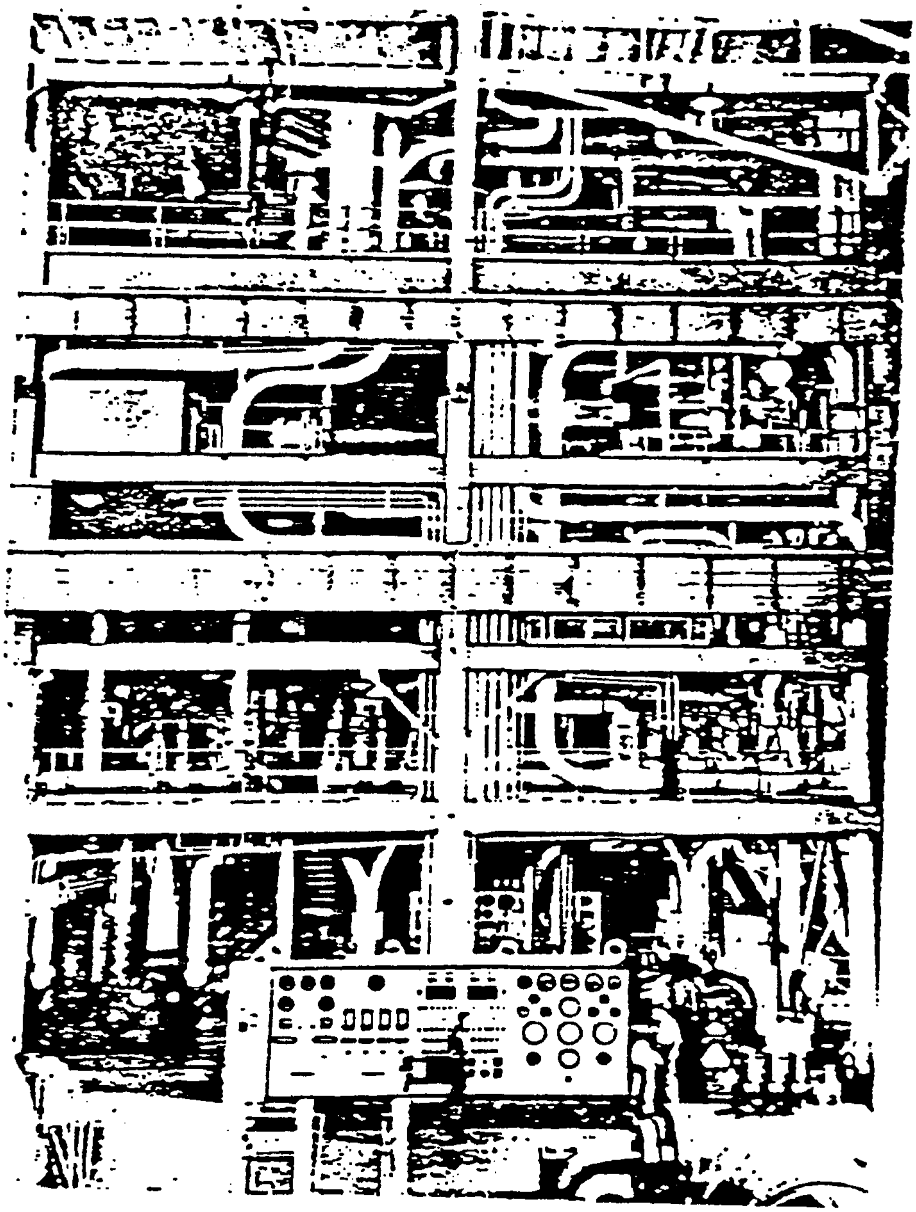
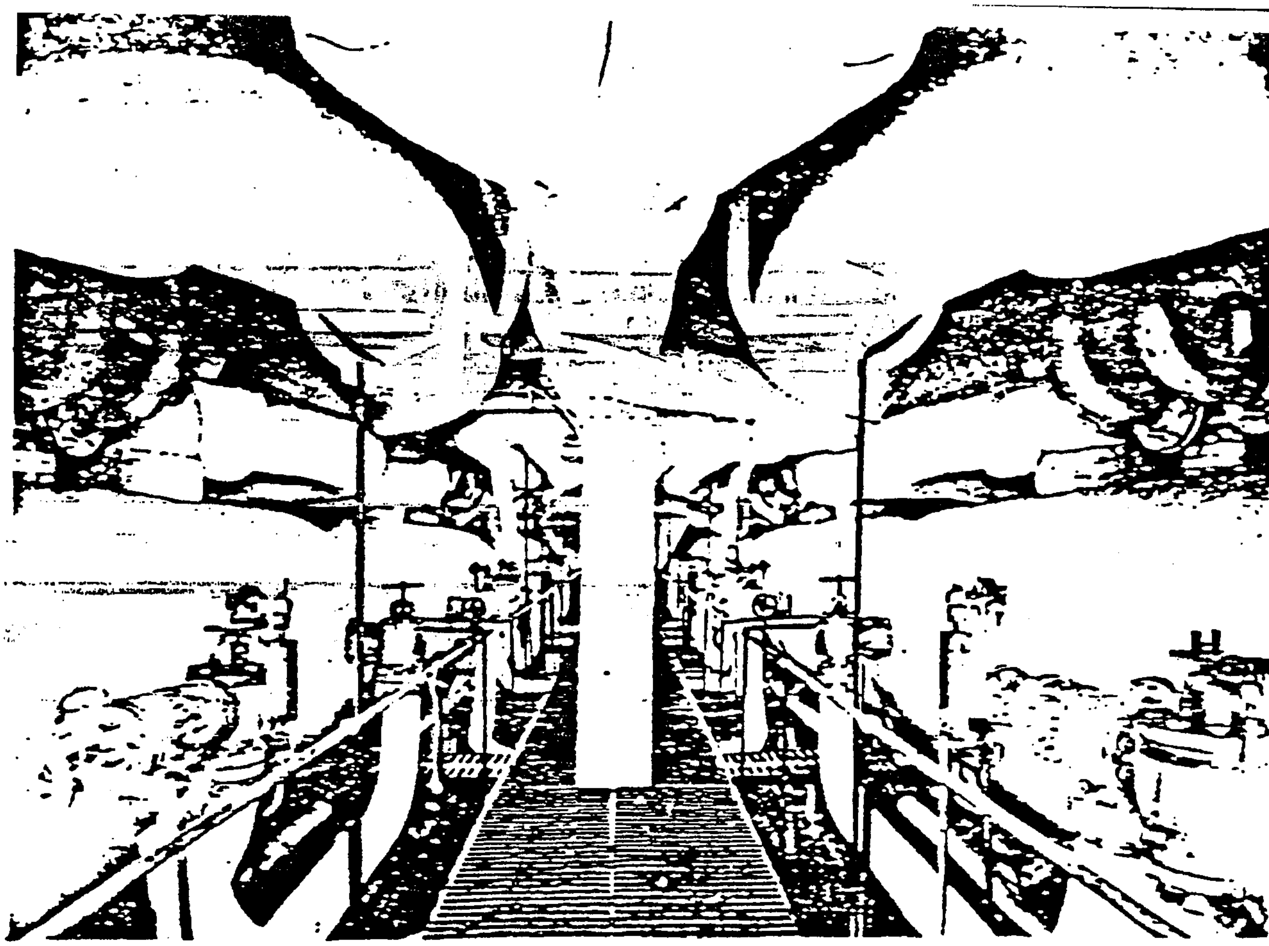
Wherever there is heat...

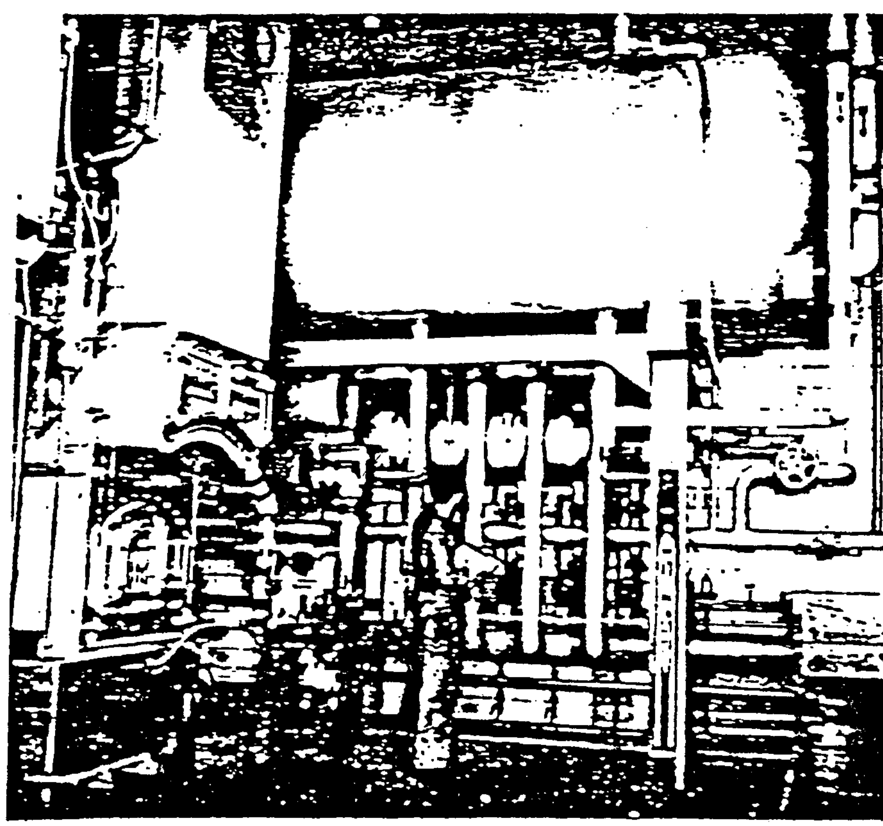


2\. . . . 85% Magnesia conserves it in the piping and equipment of most public utility power plants . . .

3\. . . . 85% Magnesia maintains critical temperatures in antibiotics laboratories . . .



4. . . . 85% Magnesia insulates the power plants of great sea-going vessels . . .



5. . . . 85% Magnesia reduces fuel costs for schools . . . and hospitals, hotels, office buildings, apartment houses, and other structures.

85% Magnesia insulation plays a part in every product or service of modern life. Wherever there is heat, there is a place for 85% Magnesia.

85% MAGNESIA INSULATION

As a footnote to insulation history, the development of 85% Magnesia is generally credited to a Philadelphian in the 1880's. It is significant that the Philadelphian had chronic stomach trouble, and also that he was in the insulation business. To ease his pains, he used to eat pieces of magnesium carbonate, which was known at that time only for its medicinal properties. By chance one day he left a solid block of his medicine on top of a hot stove. Upon returning, he was surprised to find the top of the block quite cool, although the side in contact with the stove was much too hot to touch.

The possibilities of the material were clear to him immediately, but he also knew that the heavy, chalky mineral would have to be made lighter and stronger. This he proceeded to attempt, carrying out a number of experiments over a period of years. Success came in 1886, when he was granted a patent on an insulating material composed of magnesium carbonate with a fibrous binder. Thus, Hiram Hanmore developed a new thermal insulation which was eventually to become the most widely used product in its field.

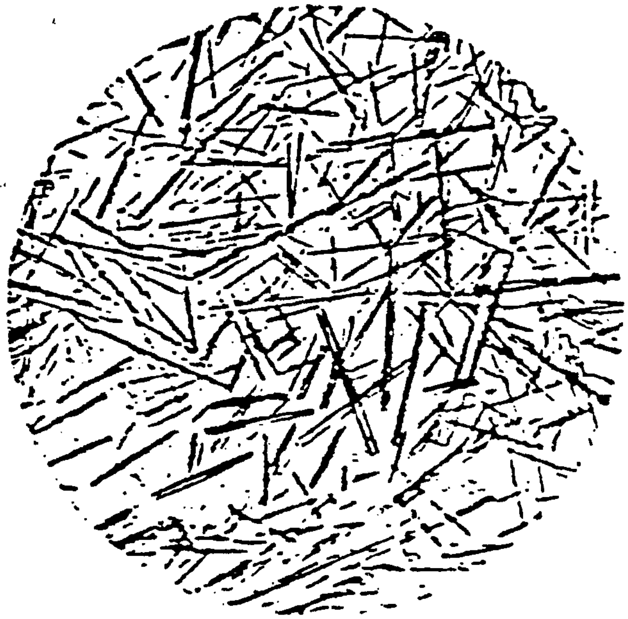
Manufacturers soon standardized on the composition of the new product, using not less than 85% basic carbonate of magnesia with asbestos fiber as the binder. In use, its name was quickly shortened to "85% Magnesia."

Although this story tells us *what* 85% Magnesia thermal insulation is, it does not explain its remarkable properties. And it fails, of course, to bring history up to date because today's 85% Magnesia bears about as much resemblance to Hiram Hanmore's product as a modern central power station does to the first Edison station in New York—where, by the way, magnesia insulation was used.

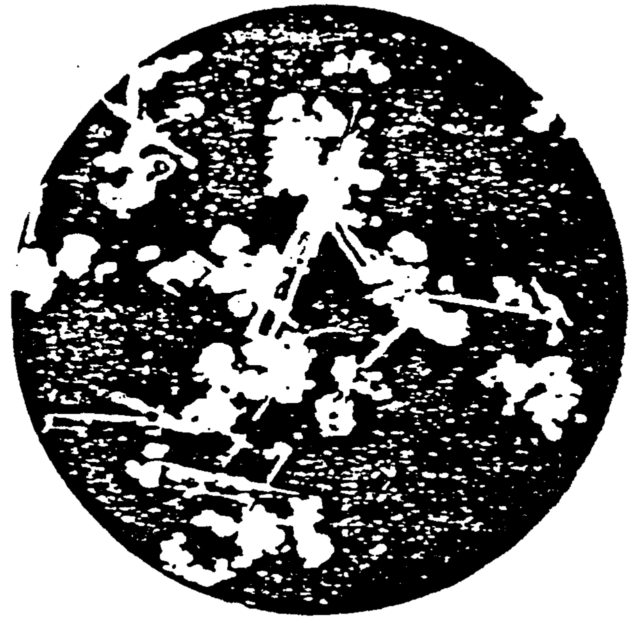
In the 70-odd years since Hiram Hanmore produced the first magnesia insulation, much has been learned about the chemical and physical nature of the material, and over that span this knowledge has been applied to product improvement. Today, 85% Magnesia is much lighter in density, and has better insulating properties, than its 1886 prototype. The changes have taken place as new laboratory techniques and equipment have been developed, and as more knowledge has been accumulated about the theory of thermal insulation.

"DEAD" AIR AS AN INSULATOR

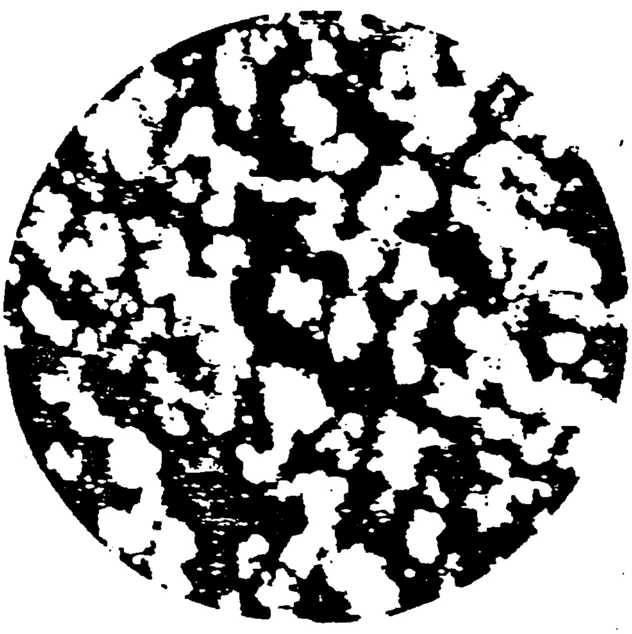
It is well known that to be effective an insulating material should contain a high proportion of dead air space. In simple terms, dead air means total absence of convection. Dead air spaces should be very small, numerous, and evenly distributed. In many insulating materials the air spaces are formed mechanically, as in products made from laminated paper or felted fibers. Air spaces made mechanically are large enough to be seen by the unaided eye and, because of their size, are relatively few in number. Just the opposite is true of 85% Magnesia. In it the air spaces are microscopic, and are uniformly distributed.



6. "Needle" crystals of normal carbonate of magnesia before conversion into basic carbonate, 200 magnifications.



7. Normal carbonate crystals in process of "sprouting" spheroidal units of basic carbonate of magnesia, 300 x.



8. Magnesia units after complete conversion to basic carbonate, 375 x.

9. Single unit of basic carbonate, 1,500 x, is composed of millions of magnesia crystals (inset, 10,000 magnifications).

CHEMICAL AND PHYSICAL STRUCTURE OF 85% MAGNESIA

To look at this another way, a block of 85% Magnesia appears to be a hard, solid material. However, a typical cubic foot weighs only about 12 lbs. Yet chemistry books say that a cubic foot of solid magnesium carbonate should weigh 130 lbs, over 10 times as much. The difference in weight is due to the fact that a cubic foot of 85% Magnesia contains only about 10 per cent solid material by volume. The other 90 per cent is air.

The unusual ability of 85% Magnesia to retard heat transmission is directly related to its physical composition. Only recently has it been possible to "see" this by the indirect method of the electron microscope. Under the extreme magnification possible with this new laboratory tool, the basic physical structure appears as a mass of spheroidal crystals.

It is evident that a material of this nature could not be produced mechanically, but must be the result of chemical change which also brings about physical change. That is exactly what happens during the manufacturing process.

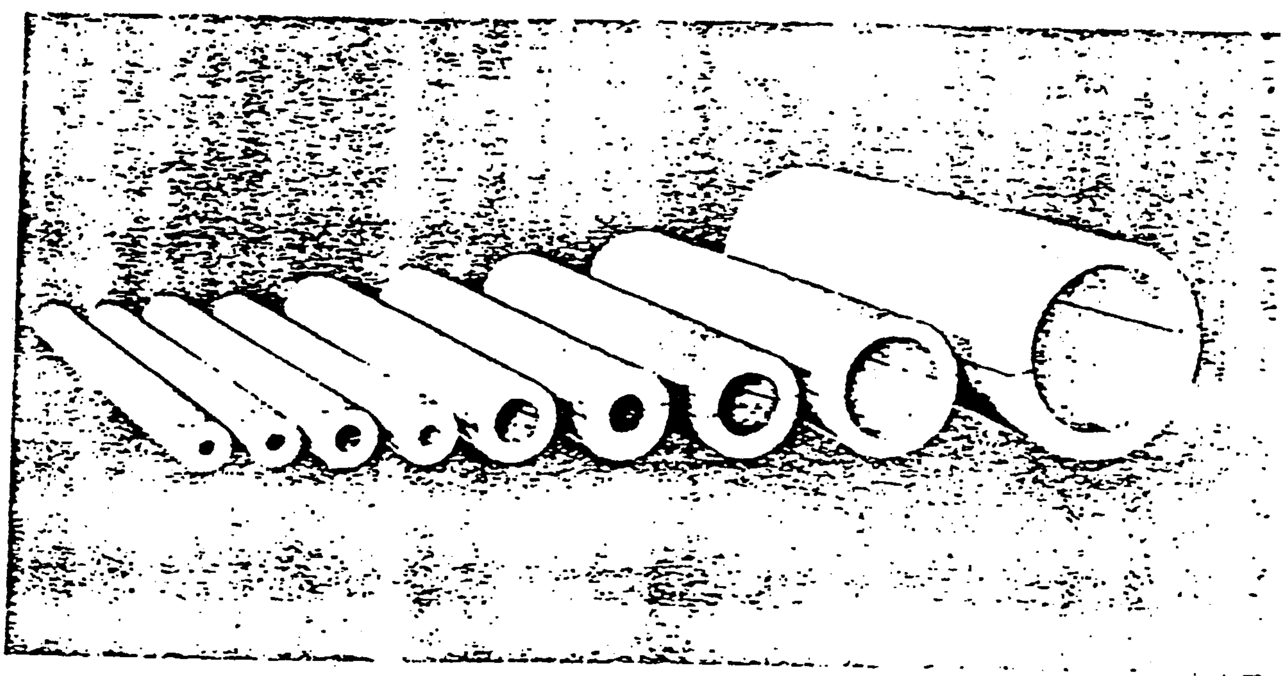
Carbonate of magnesia, before conversion into the basic carbonate form, exists as a mass of needle-like crystals. These crystals have an average length of about one- or two-thousandths of an inch and a diameter of about two ten-thousandths of an inch, about one-fifteenth the diameter of a human hair. In this form, carbonate of magnesia is unstable. When heat is applied, the crystals give up some of their carbon dioxide.

As this takes place, a change in structure also occurs. Each needle crystal "grows" many spheroidal crystals of basic carbonate of magnesia. Under the continued application of heat, the process goes on until the needle crystals have been entirely converted into the basic form of smaller, spheroidal crystals.

The crystalline structure, which even under 10,000 magnifications is hard for the untrained eye to identify, creates tens of thousands of minute air pockets per cubic inch and gives 85% Magnesia its high insulating value.

MOLDED FORMS

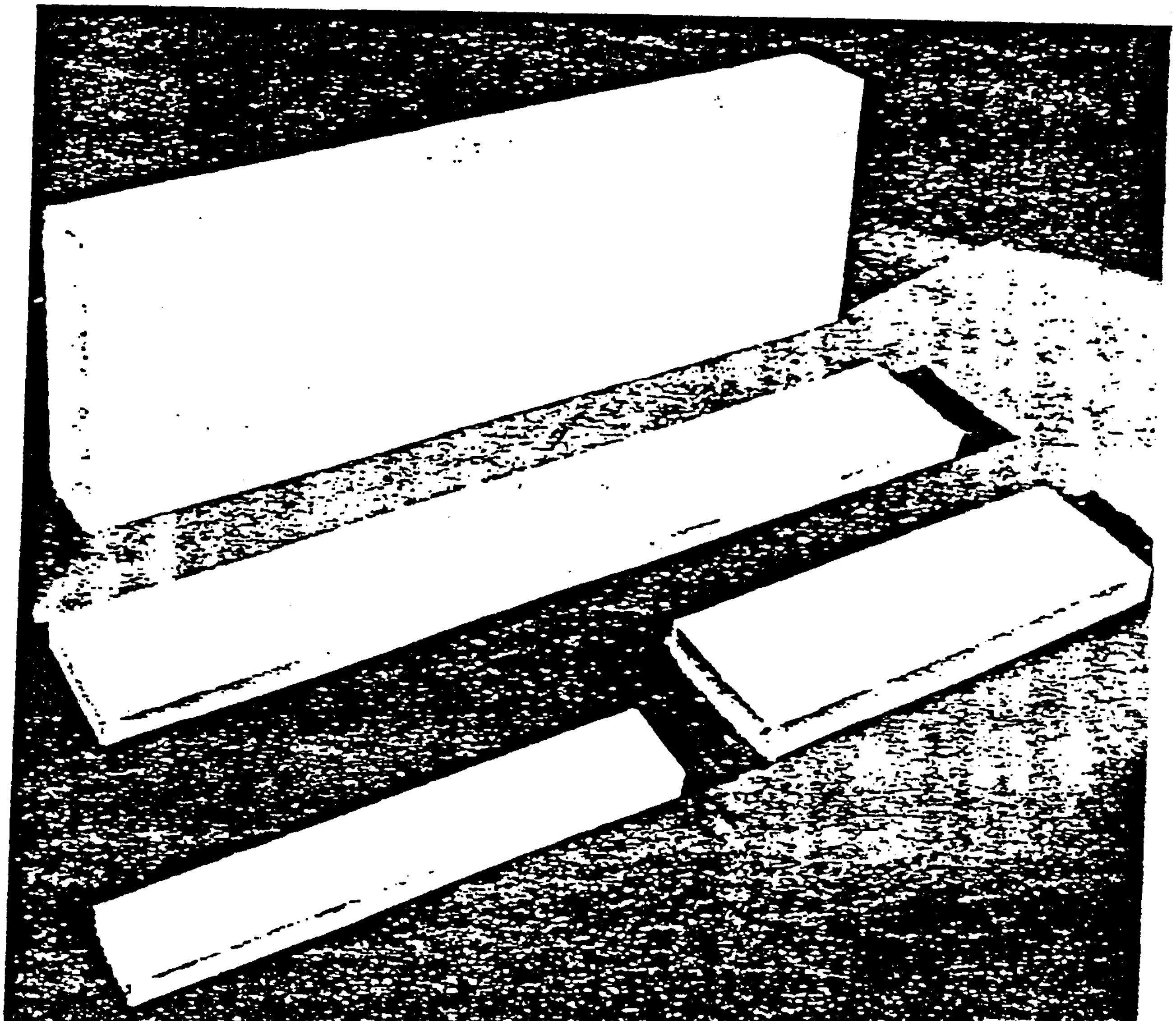
85% Magnesia is molded insulation for use on all hot surfaces having temperatures up to 600 F. It is manufactured in semi-cylindrical sections for use on piping and in curved segments corresponding to the outside diameter of larger pipes and vessels. The semi-cylindrical form is called *sectional* insulation.



10. Sectional 85% Magnesia pipe insulation is produced in a wide range of thicknesses and diameters to fit standard pipe sizes. New simplified thicknesses permit nesting for double-layer construction. Curved segments are available for larger pipes.

the curved form *segmental* insulation. It is also made in the form of blocks for application to flat or slightly curved surfaces, and in ground form for use as an insulating cement. 85% Magnesia pipe insulation is made in simplified thicknesses to permit the use of double-layer construction in all pipe sizes and thicknesses since the outside diameter of the pipe insulation is approximately the same as that of standard steel pipe. Various sizes and thicknesses of pipe insulation are shown in Table I, page 50.

11. Blocks of 85% Magnesia insulation (and diatomaceous silica) are produced in two lengths, four widths, and a wide range of thicknesses.



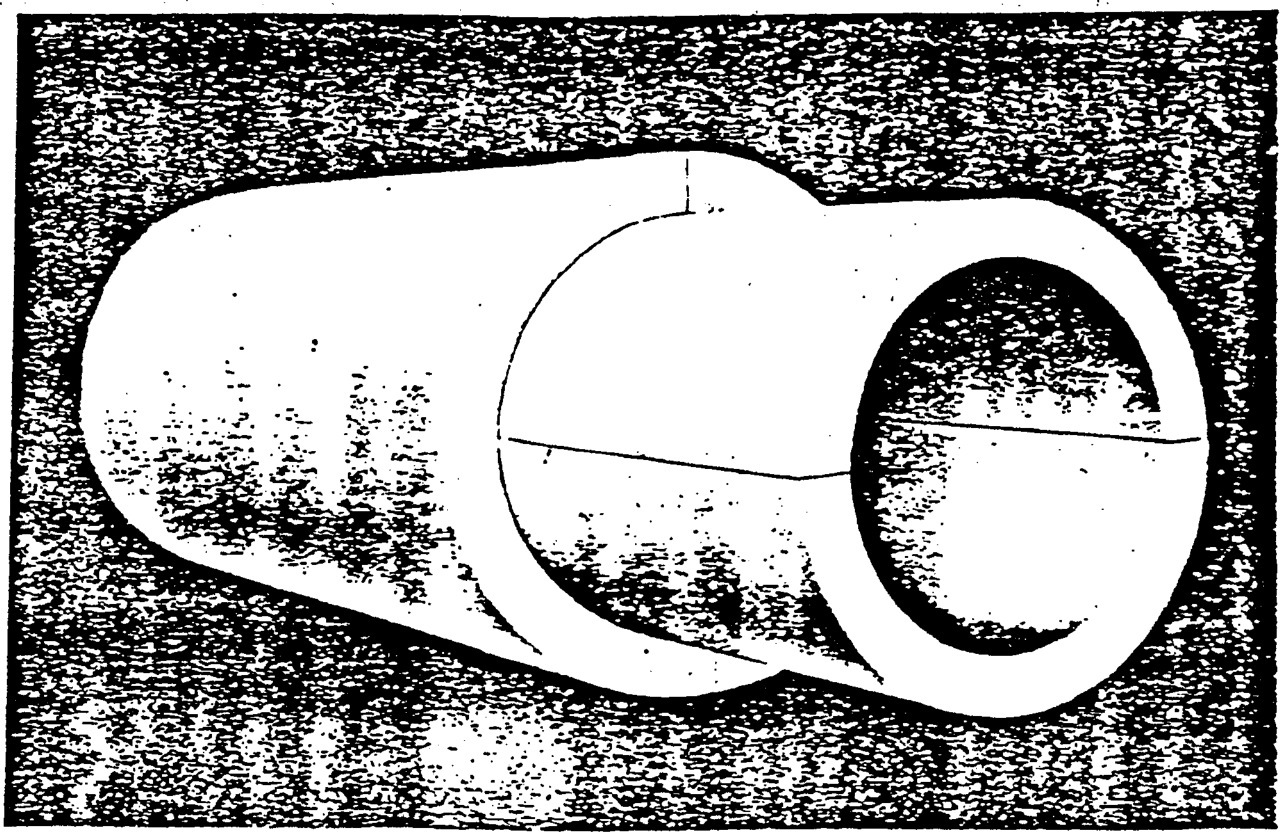
COMBINATION INSULATION

85% Magnesia is used to insulate surfaces up to approximately 600 F. When surface temperatures are above 600 F, it is the practice to use an inner layer of diatomaceous silica high temperature insulation composed of diatomaceous silica, mineral fiber and inorganic binders. It is molded in the same forms as 85% Magnesia, and has a temperature service range up to 1900 F. 85% Magnesia is used for the outer layer.

When the two materials are used together, the application is called combination insulation. The diatomaceous silica is applied to the hot surface in sufficient thickness to reduce the temperature at its outer surface to 600 F or lower. The combination total thickness used is in accordance with the desired insulating results. This double-layer construction effectively utilizes the higher heat-resistance of diatomaceous silica as well as the lower thermal conductivity of 85% Magnesia.

Combination insulation with staggered joint construction also serves to prevent joint openings due to the expansion of hot piping or equipment. This not only avoids heat losses from exposure of hot metal surfaces at the joints with possible scorching of canvas jackets or other finishing materials but also protects against a possible fire hazard.

12. Combination insulation with inner layer of diatomaceous silica and outer layer of 85% Magnesia produces desired heat saving on piping of any size for operating temperatures over 600 F.



PHYSICAL PROPERTIES

Average figures for thermal conductivity (k factor) and density of 85% Magnesia insulation are as follows:

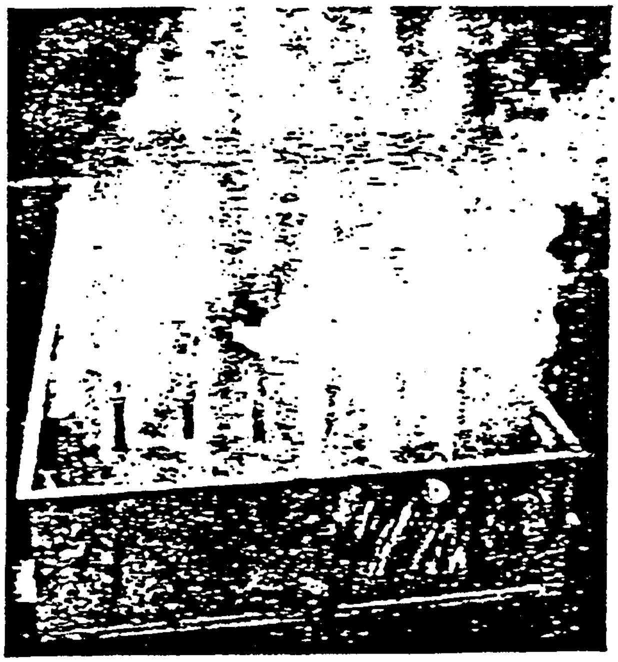
Density, lb per cu ft	12
Thermal conductivity, Btu in. per hr per sq ft per F.	
mean temp. 100 F	0.35
200 F	0.35
300 F	0.42
400 F	0.46

These figures are suitable for all general calculations. For specification values refer to current ASTM and Federal specifications.

85% Magnesia is a structurally stable material; it does not deteriorate with age, nor does it shrink significantly or distort regardless of the length of time it is exposed to heat. The snug fit and tight joints of a good installation are therefore retained. 85% Magnesia is durable. It can withstand an appreciable amount of compression and the mechanical abuse normally encountered. Moisture and condensation do not cause it to disintegrate. Heat savings have remained constant for more than 50 years in many installations.

INSULATION FOR WET CONDITIONS

To meet the demands for an insulation which would have special resistance to water damage in the event of flooding of underground conduits containing insulated hot lines and other severe wet conditions, the Association and its members developed water resistant magnesia insulation.

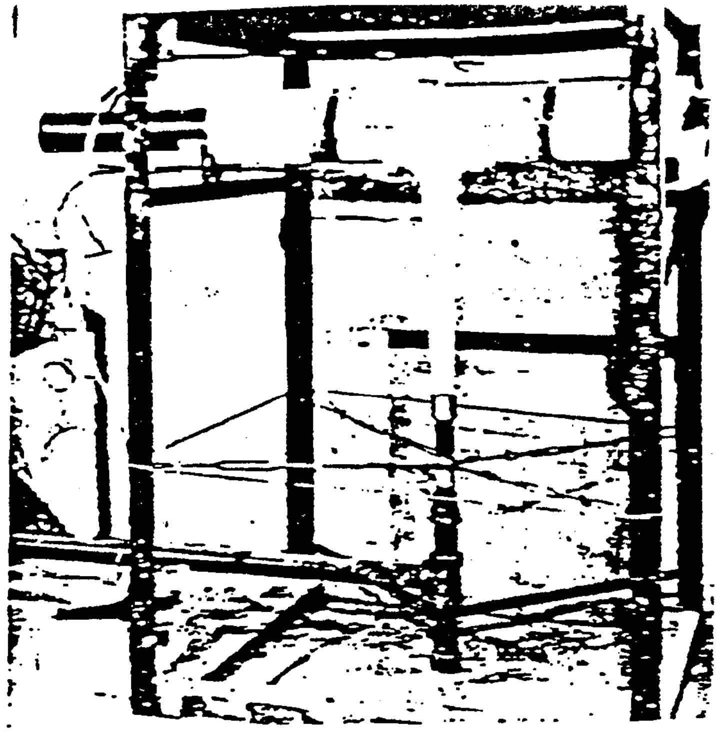


13. Boiling water test of water resistant magnesia insulation involved 378 hours of intermittent immersion with no effect on insulating effectiveness.

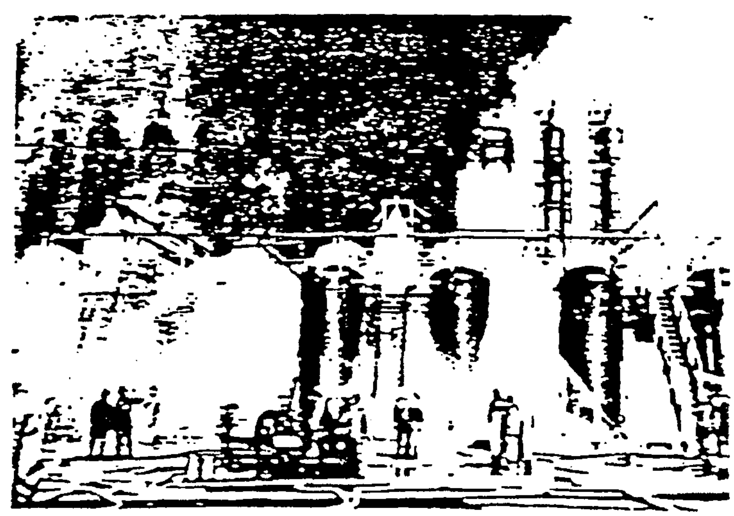
Water resistant magnesia insulation was found by the Pittsburgh Testing Laboratory to be "highly resistant to disintegration under test conditions of continuous steam flow while immersed in boiling water." This insulation was applied to a standard pipe carrying steam up to 140 psig, immersed in boiling water for 7 hours, then dried for 17 hours, and the cycle repeated 30 times. This was followed by an additional 168-hour period of immersion, after which the test results were summarized as follows: "All test pieces were intact. Surfaces were considerably rougher than original insulation. Joints were firm and in good condition. No appreciable shrinkage at joints and no cutting in of bands."

FIRE RESISTANCE

Since 85% Magnesia is entirely mineral, it will neither burn nor support combustion. Tests have shown that even when exposed to a 2000 F flame, the insulation remains intact and provides protection of piping and equipment. In a major fire at a large chemical plant, piping and equipment insulated with 85% Magnesia and subjected to several hours of intense heat and hose streams were virtually undamaged. Similar equipment without insulation was severely damaged.



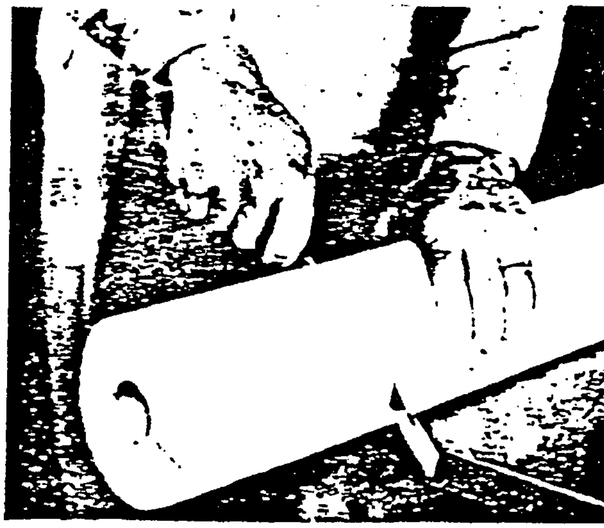
14. Direct impingement of 2,000 F flame produced only small surface cracks in 85% Magnesia, proving fire resistance.



15. Intensely hot fire in chemical plant failed to damage equipment insulated with 85% Magnesia. Uninsulated equipment was destroyed.

EASE OF APPLICATION

85% Magnesia is the preferred insulation of most skilled insulation mechanics. It is easy to cut and fit, very malleable despite its resistance to compression, and offers no hazard to the workman. Its structural strength is sufficient to enable strenuous handling on difficult jobs, and it requires only normal precautions in shipping, storing and handling.



16. Readily cut and fitted, 85% Magnesia is noted for ease of application.

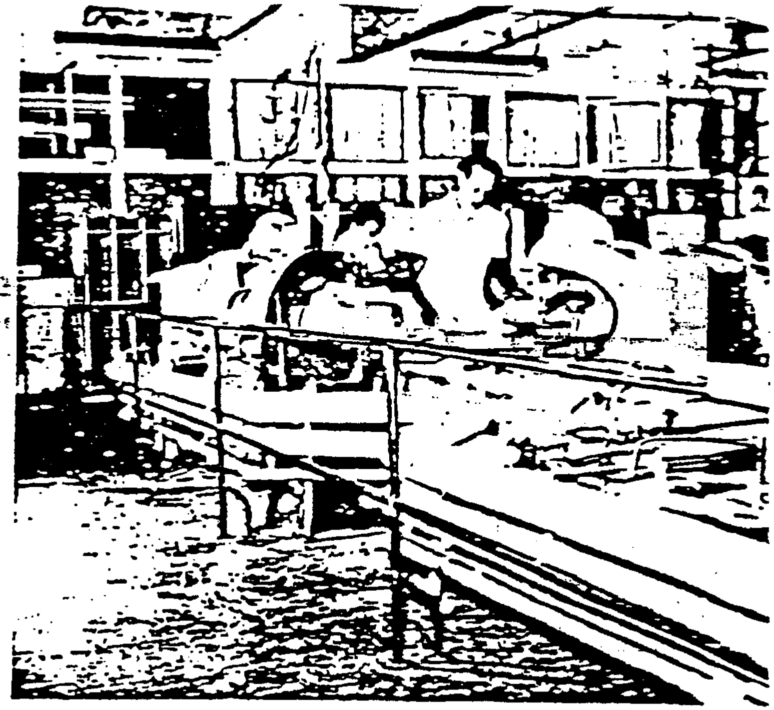
DESIGN CONSIDERATIONS

The primary function of thermal insulation is to conserve heat and save fuel. It is important that careful judgment be exercised in the selection of insulating materials and in the specification of proper thicknesses. It is equally important that sound application methods be employed, and that protection and maintenance be given proper attention.

Insulation serves many purposes other than conserving heat. It is essential to process temperature control; it helps maintain comfortable temperatures in enclosed areas containing hot equipment; it protects personnel from being burned; it protects against fire or fire damage, and it prevents undesirable condensation in hot flues, ducts and other equipment.

These and other purposes of insulation should be considered in the planning and engineering of all types of structures and equipment. Advance consideration of the insulation requirements will simplify construction, and result in a more efficient and longer-lived insulation.

The design and placement of hot piping and



17. In addition to conserving heat, 85% Magnesia has other valuable functions such as helping to maintain comfortable workroom temperatures in this laundry.

equipment should allow sufficient clearance for the application and maintenance of insulation between units of equipment and between the equipment and structural elements of the building.

18. While basic design should place insulated piping away from traffic locations when possible, unavoidable exposures may be protected from mechanical damage by metal jackets.

In cases where supports for insulation, such as angles, will be required, or where anchors for bands and wires securing insulation are indicated, the equipment manufacturer or mechanical contractor should be notified so that they may be added at the most expedient time and place.

If insulated equipment and piping should be located where they can be damaged by material handling equipment such as chain hoists or lift trucks, the insulation should be covered with sheet metal or other protective jackets.

Technical advice and assistance can be obtained from either the producers of 85% Magnesia or from any of the major insulation contractors applying 85% Magnesia insulation. Insulation engineers in the 85% Magnesia industry can assist in preparing specifications, recommending proper thickness, insulating for critical temperature control, or devising application methods for unusual equipment or conditions. Because of their many years of experience with 85% Magnesia, contractors have developed special knowledge and skills in its application.

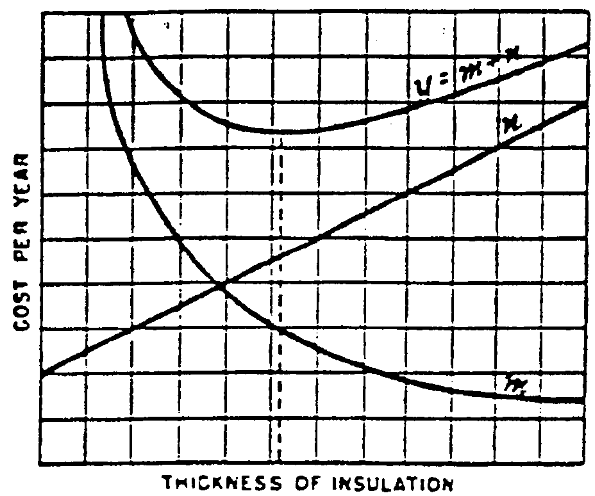
CALCULATING ECONOMICAL THICKNESS

The economical thickness of insulation for a given set of conditions may be calculated exactly, and because it is frequently advisable to do so, the method is explained and illustrated here. In tables of recommended thicknesses, the variables which enter into the calculation have necessarily been averaged to make them valid for relatively wide temperature ranges under average conditions. However, the economical thickness for a given temperature is always a special case. The following information is required:

Annual hours of operation
Rate of insulation amortization
Cost of heat production per million Btu
Rate of heat loss through insulation in Btu per hr
Operating temperature
Applied cost of insulation per linear ft
Pipe size, when applicable

The calculation is carried out in several steps. It applies equally to sectional or block insulation.

It is evident that two factors, the annual cost of the heat lost through the insulation and the annual cost of the insulation itself, will vary with respect to each other as thickness varies. While the annual cost of the insulation increases with thickness, the cost of the heat lost decreases. The economical thickness is therefore found where the value of the sum of the two costs is at a minimum. This is illustrated graphically below.



19. Economical thickness of insulation. From "Heat Transfer Through Insulation in the Moderate and High Temperature Fields," by L. B. McMillan.

In the formula $y = m + n$, y is the sum of m, the annual cost of the heat lost, and n, the annual cost of the insulation. To obtain n, multiply the applied cost of the insulation per linear foot by a percentage for annual fixed charges. To obtain m, multiply the heat loss per linear foot (from Table VIIA, page 56) by the annual hours of operation; then multiply this product by the cost of heat per million Btu. Total yearly cost (y) is the sum of m and n.

A good first approach is to find a trial thickness by the rule of thumb which uses ½ in. of insulation for each 100 degrees F of operating temperature. If y is then determined for several other thicknesses, greater and lesser than the trial thickness, comparative yearly cost figures will be available. The lowest total annual cost (y) indicates the most economic thickness.

The following example using assumed costs of applied insulation illustrates a typical calculation:

EXAMPLE

Determine the economic thickness of pipe insulation to be applied to a 3 in. steam pipe at 400° F. with average air temperature of 80° F. The annual fixed charges are 10%, the annual hours of operation are 8,760 and the cost of steam is $0.40 per million Btu. The insulating material is 85% Magnesia. The following applied insulation costs are assumed (representative costs should be used for a specific case):

1 in. nominal	$0.71 per lin ft
1 ½	1.00
2	1.37
2 ½	1.70
3	2.08

Unit heat transmissions for 85% Magnesia pipe insulation expressed in Btu per linear foot per hour for various temperature differences are listed in Table VII-A in the appendix.

For 1 in. 85% Magnesia:

Step A—Annual cost of heat loss per linear foot of insulated pipe = unit heat transmission (from Table 00, Page) x annual hours of operation x cost of heat = 129 x 8,760 hours per year x $0.40/10^6 = $0.452 per year.

Step B—Annual cost of insulation per linear foot of pipe = applied cost per linear foot of insulation x fixed charges per year = $0.71 x 10% = $0.071 per year.

Step C—Total yearly cost (y = m + n) = $0.452 (annual heat loss cost—obtained in Step A) + $0.071 (annual insulation cost—obtained in Step B) = $0.523 per linear foot.

Similar calculations for the other available thicknesses give the following results:

Nominal Thickness	Btu/lin ft/hr	MM Btu/lin ft/yr	Heat Loss Cost/lin ft/yr—$	Total Ins. Cost/lin ft—$	Ins. Fixed Charge/yr—$	Cost/lin ft/yr H.L. & Ins.—$
1 in.	129	1.13	.452	.71	.071	.523
1 ½	96	.841	.336	1.00	.100	.436
2	80	.701	.280	1.37	.137	.417
2 ½	71	.622	.249	1.70	.170	.419
3	65	.569	.228	2.08	.208	.436

The economic thickness in this example would, of course, be 2 in.

The thickness of insulation for a long steam line will depend upon the quantity and condition of steam required at the delivery end of the line.

Other factors such as process temperature control, preventing excessive temperature rise in working areas, or personnel protection will sometimes take precedence over economic considerations in determining insulation thickness.

APPLICATION PROCEDURES

Maximum heat conservation and durability depend upon the use of proper application procedures. Some contractors and large users of insulation have developed their own application techniques which, though they vary somewhat from those described here, may be preferred for the circumstances involved.

The application procedures discussed here represent more or less standard techniques which have proved satisfactory over a period of many years.

20. Applications of 85% Magnesia pipe insulation are made easily, look neat and clean, last as long as the piping itself.

INSULATION OF PIPING

85% Magnesia and diatomaceous silica pipe insulations are furnished in semi-cylindrical sections or curved segments, 3 ft long, in diameters to fit standard steel or wrought iron pipe and copper tubing.

Single layer sectional insulation is supplied with a factory-applied jacket of light-weight pasted canvas. On double layer insulation, this canvas is supplied on the outer layer only. No factory-applied canvas is supplied on segmental insulation.

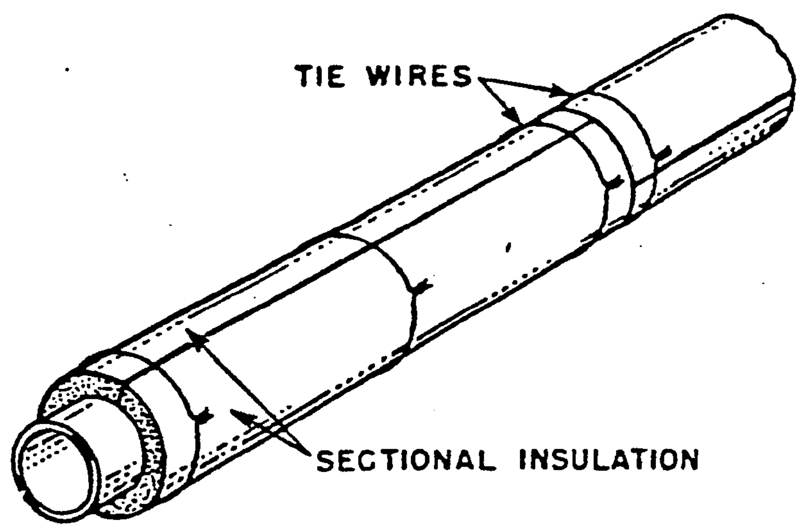
The sections or segments of insulation are carefully fitted to the pipe with side and end joints butted tightly together. If two layers of insulation are used, side and end joints of the outer layer are staggered with respect to those of the inner layer. The insulation is secured by various means and finished as discussed in the section on Finishes.

In the case of exceptionally long vertical lines, where insulation weight is a factor, additional support may be given to the insulation by angles or other means.

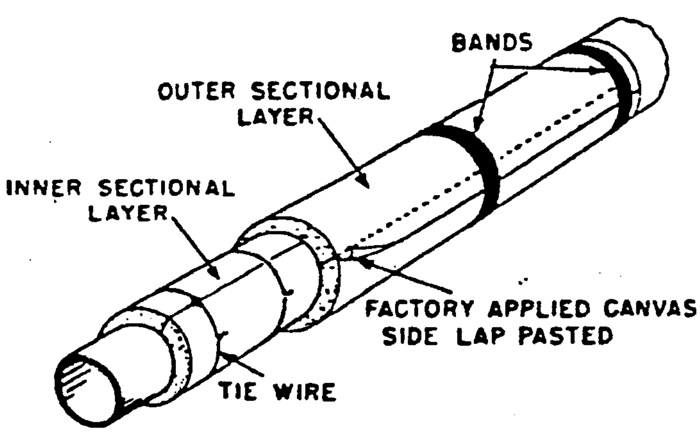
PIPES

Single Layer: When the sections of insulation have been fitted to the pipe, unless a different finish is to be used, the side and end laps of factory-applied canvas are pasted down smoothly and the insulation may be further secured with wires or metal bands.

If the factory-applied canvas is removed, the insulation is secured in place with not less than three loops of annealed iron wire per section. Ends of the wire loops are twisted and pressed into the insulation.



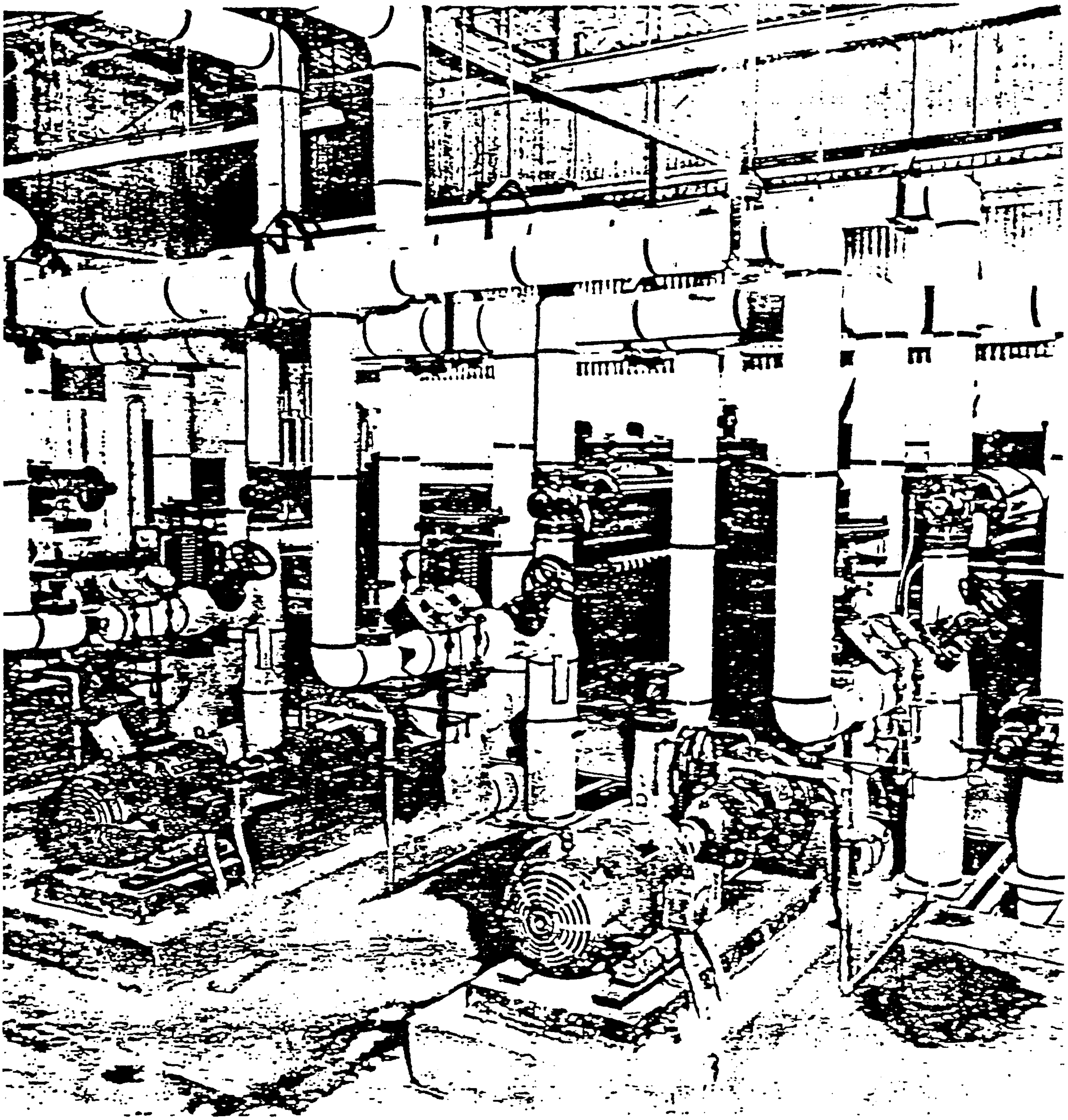
21. Single-layer sectional insulation, with joints staggered, factory-applied canvas removed, and sections wired in place.



22. Double-layer sectional insulation, first layer wired in place, second layer held with factory-applied canvas and metal bands.

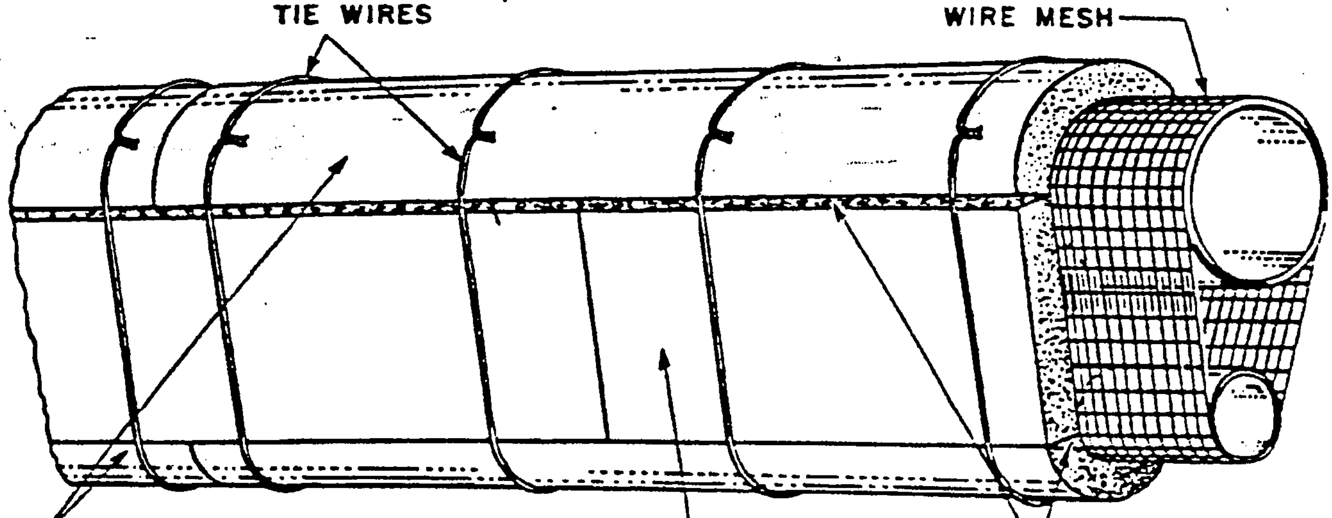
Double Layer: The inner layer (which has no canvas) is secured in place with not less than two loops of annealed iron wire. The outer layer is then applied with joints staggered and held in place with either the factory-applied canvas and metal bands, if desired, or with annealed iron wire. End joints of half sections or segments of a given layer should be in alignment to allow freedom of movement with thermal expansion of the pipe.

23. Typical application of 85% Magnesia pipe insulation.

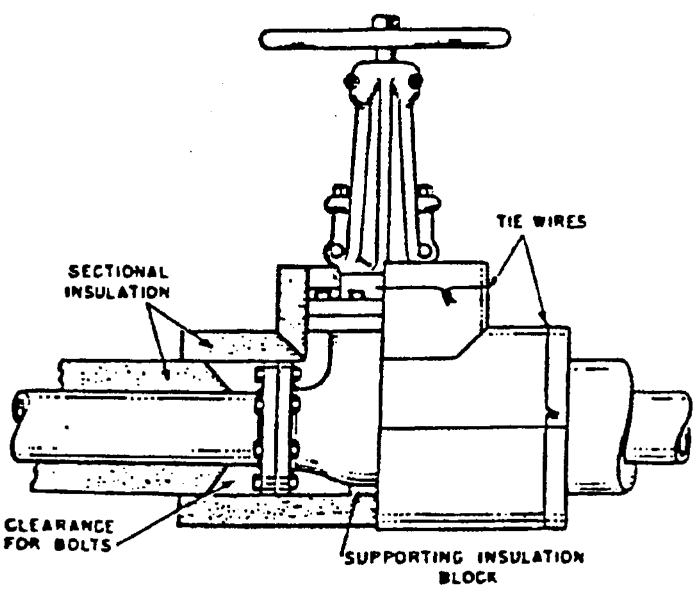


PARALLEL PIPES

Half-sections of pipe insulation are fitted over the outer half circumference of each pipe, the two sections of insulation being of the same thickness. These half-sections of insulation may be held in place temporarily with adhesive. On the two sides, insulating blocks of the same thickness as the pipe insulation are fitted between the edges of the sections of pipe insulation and voids filled with insulating cement. The entire assembly is firmly secured with not less than four loops of annealed iron wire per insulation section. The ends of the loops are twisted tight, bent over, and pressed into the surface of the insulation.



24. Parallel piping with sectional and block insulation applied over wire mesh wrapped around both lines.

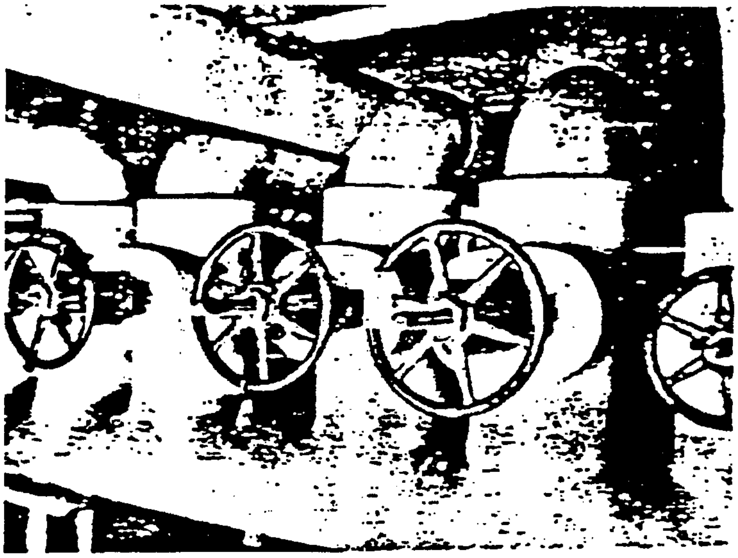


25. Flanged valve body on piping of 4-in. diameter, insulation wired in place.

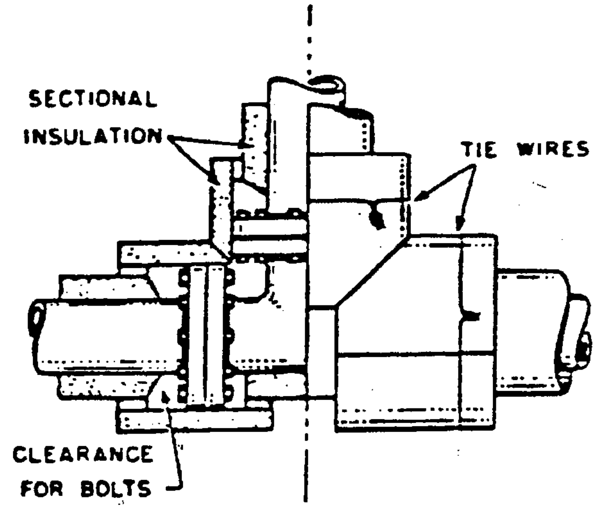
FITTINGS AND VALVES

On Pipe Sizes 3½ in. and Less: Fittings and valves are covered with insulating cement, bringing the total thickness to that of the insulation on the adjacent piping.

On Pipe Sizes 4 in. and Larger: The bodies of flanged fittings and valves, the entire surface of screwed fittings and the entire surface up to the bonnet of screwed valves are insulated with block or pipe insulation of the same material and thickness as the insulation on the adjacent piping. The insulation is carefully fitted and firmly secured in place with annealed iron wire, the wire being looped as many times as necessary to make the blocks secure. When block insulation is used, a finish coat of asbestos cement is applied to create a smooth finish.



26. Large valves insulated with 85% Magnesia.



27. Flanged body of fitting on pipe of 4-in. diameter, insulation wired in place.

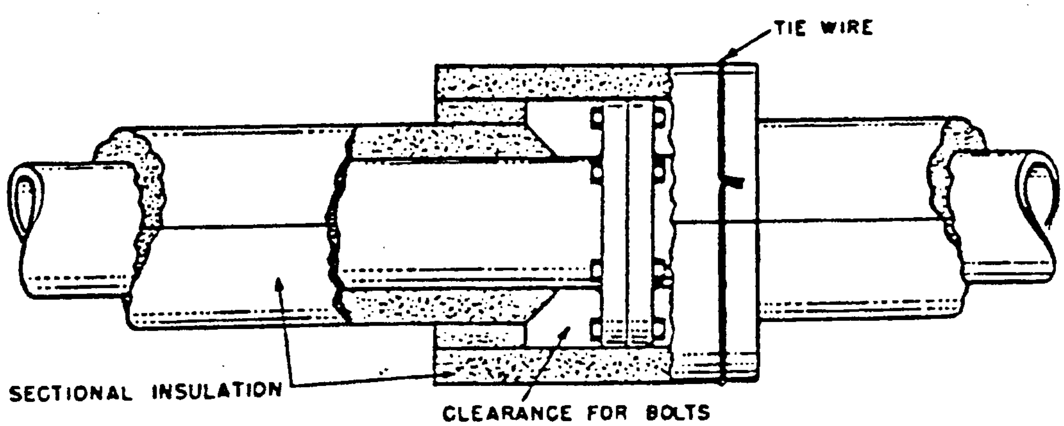
FLANGES

Permanent Type: Flanges are insulated in the manner described above for fittings and valves, under the heading "On Pipe Sizes 4 in. and Larger." The flange insulation should extend not less than 2 in. over the adjacent pipe insulation on each side of the flange. The annular space between pipe and flange insulation is filled with insulating material. Insulation on pipes is stopped short of flanges and beveled off to permit removal of flange bolts when necessary. The flange insulation is applied in such a manner that it may be removed without damage to the adjacent pipe insulation.

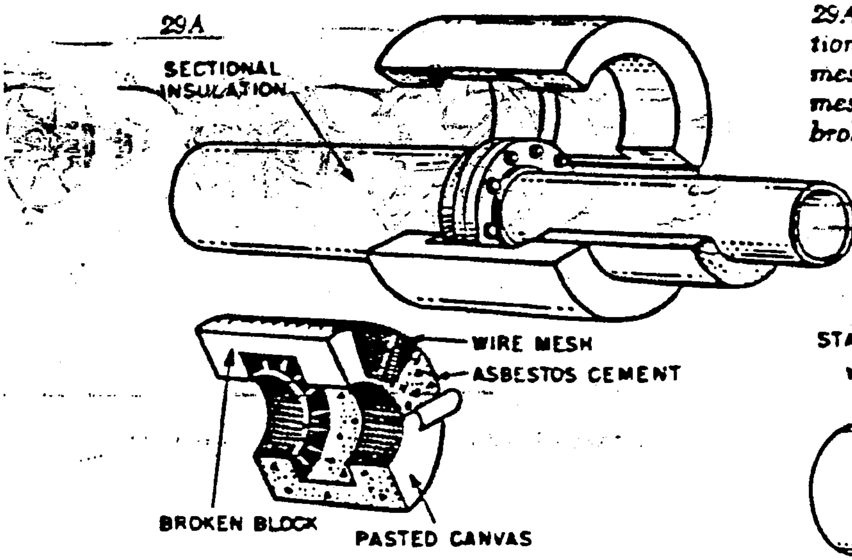
Removable and Replaceable Type: Flange insulation of this type may be either sectional or block. The insulation is made to encircle the flange, long enough to overlap the pipe insulation by at least 2 in. at either side.

When sectional insulation is used, each half-section is wrapped with galvanized wire mesh and covered with a thin layer of asbestos cement. If block insulation is used, a galvanized wire mesh frame, in two halves, is shaped to fit the flange and covered with pieces of block. Wire mesh is then applied to the outside of each half and a layer of asbestos cement is applied over the inside and outside of both halves of the unit.

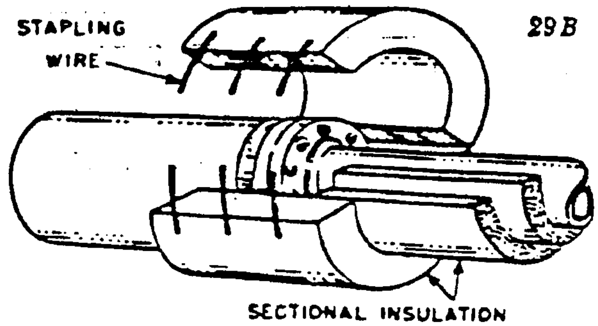
The two halves are then wired in place on the flange. Pipe insulation is stopped short of flanges and beveled off, to permit removal of flange bolts when necessary.



28. Permanent type flange insulation wired in place. Flange insulation may be removed, if necessary, without damage to pipe insulation.



29A & B. Removable and replaceable flange insulation may be made of sections wrapped with wire mesh or of broken block on previously shaped wire mesh frame. Detail shows flange insulation made of broken block.



30. Flanges and valves in condensate return piping insulated with 85% Magnesia.

INSULATION OF EQUIPMENT

Equipment is generally insulated with block insulation. Small, irregularly shaped equipment is insulated with block and cement, in the same manner as valves and fittings.

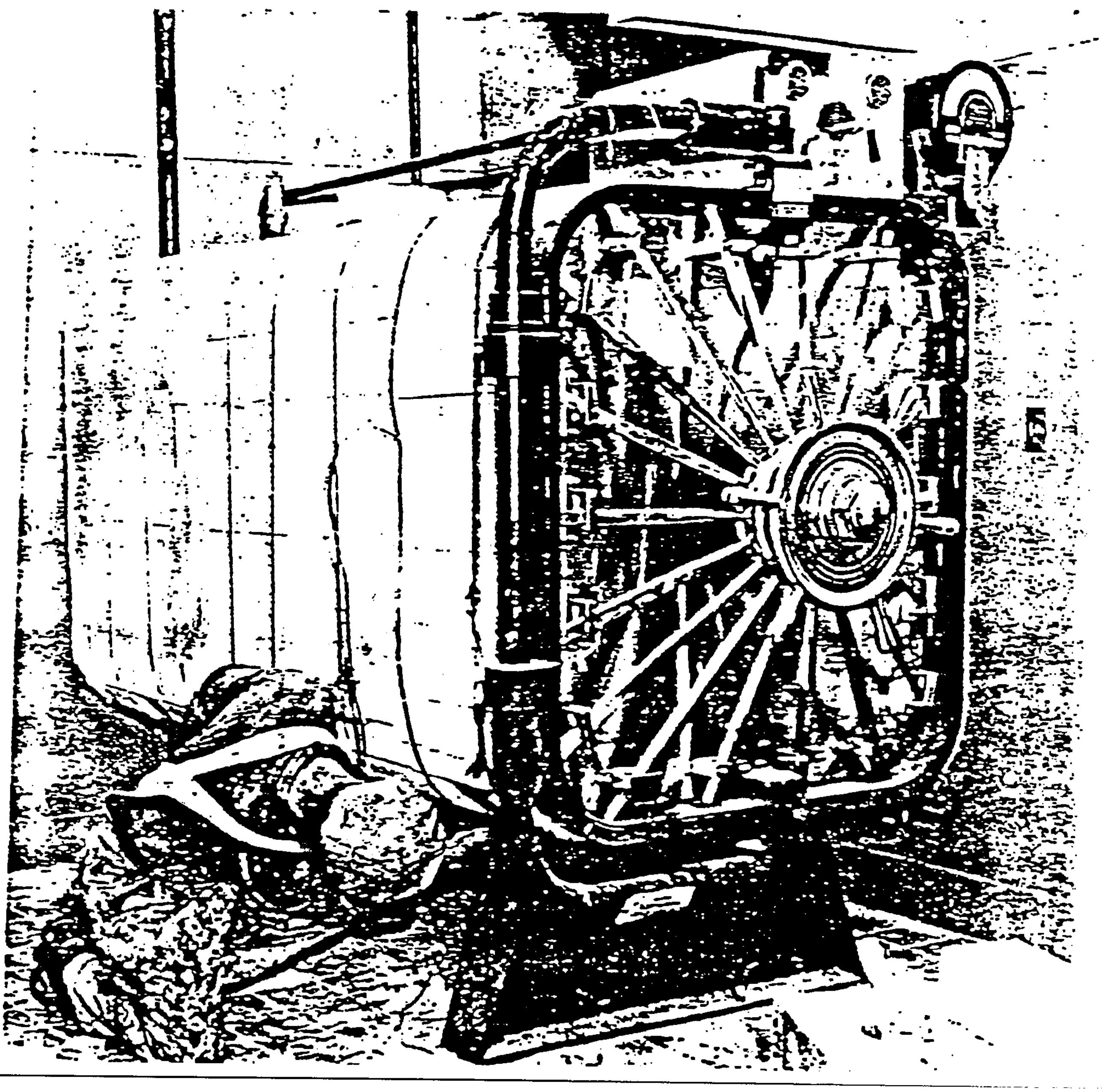
When insulation is applied to the bottom surface of equipment, an adhesive recommended by the insulation manufacturer may be used to hold the blocks in place temporarily during installation.

Where vibration or other movement makes it difficult to hold insulation applied to metal surfaces in place by conventional means, additional support for the insulation may be provided, the method of securement depending upon the particular conditions.

If two or more layers of block are required, the joints of each layer are staggered with those of the preceding layer. The blocks are butted tightly together and all voids are pointed with insulating cement.

For small and irregular surfaces, insulating cement may be used. When the thickness required exceeds ¾ in., more than one coat of cement is used, the first being allowed to dry before the next is applied.

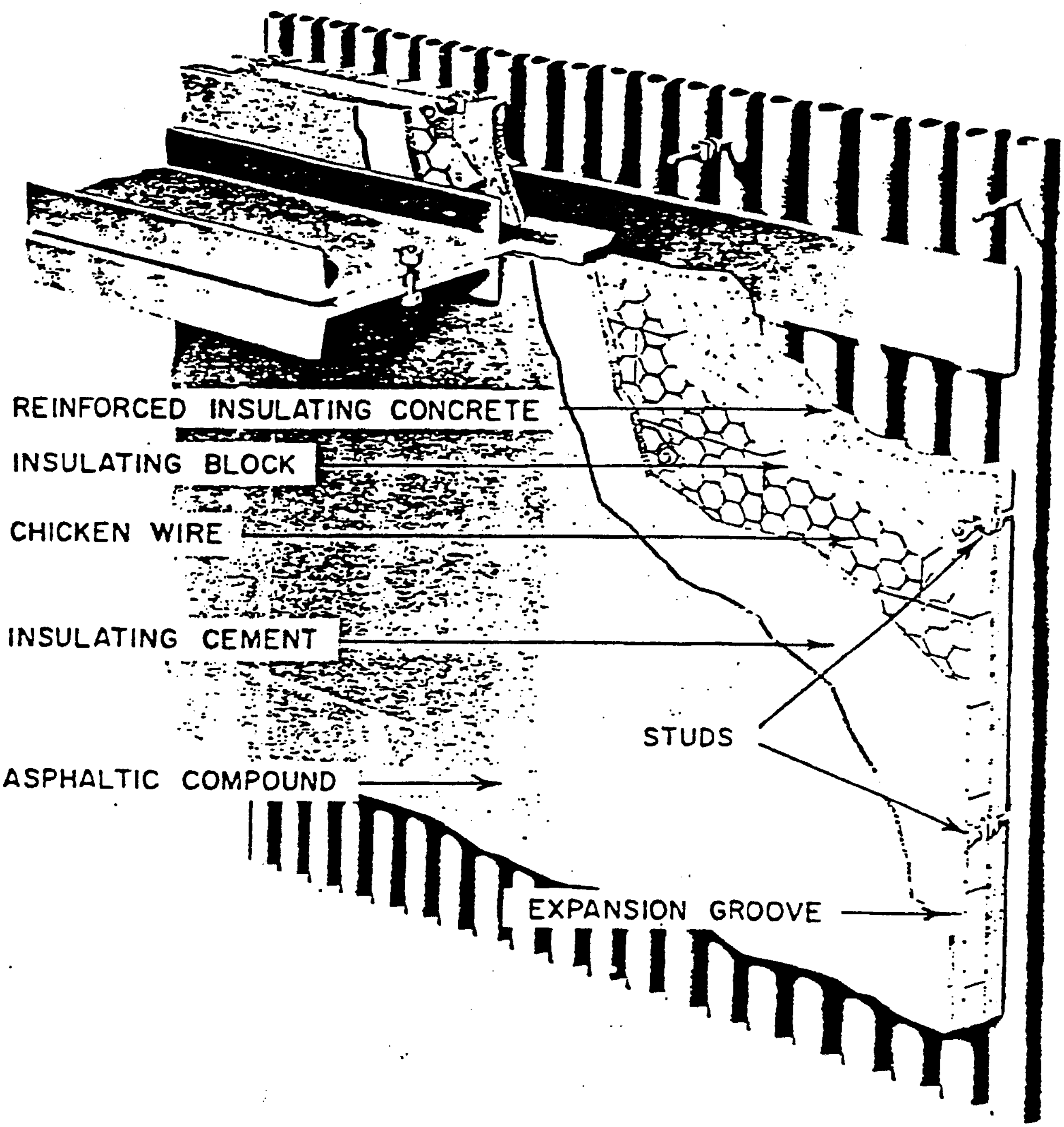
31. Strapping 85% Magnesia blocks to an autoclave in a pharmaceutical research center.



WATER-COOLED FURNACE WALLS

Where tubes, clamps, nuts, bolts or metal projections are exposed on the exterior side of the water tube wall, a filler coat of insulating cement, thick enough to cover the high points, is applied, and troweled to a level surface before the insulating blocks are applied.

If access to water tubes with minimum disturbance to the insulation is desired, the insulating blocks are placed with their longest dimension vertical. The blocks are fastened in place with light wire cables and annealed iron wire lacings. The insulation may be finished with asbestos cement or with removable panel finish. *(See section on Finishes.)*

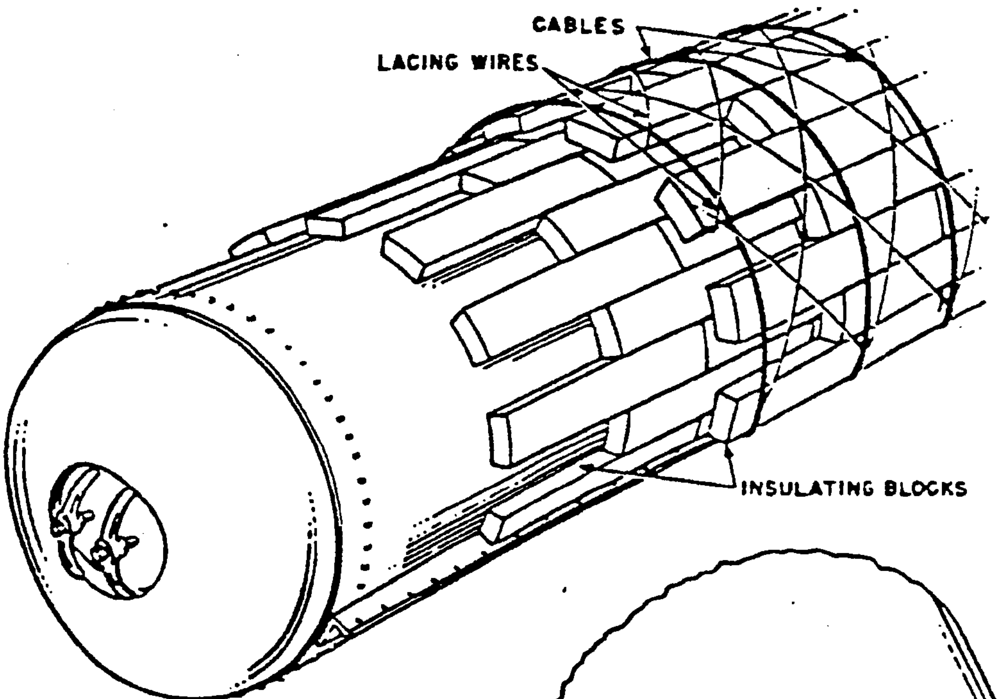


32. Detail of insulation on water-cooled furnace wall.

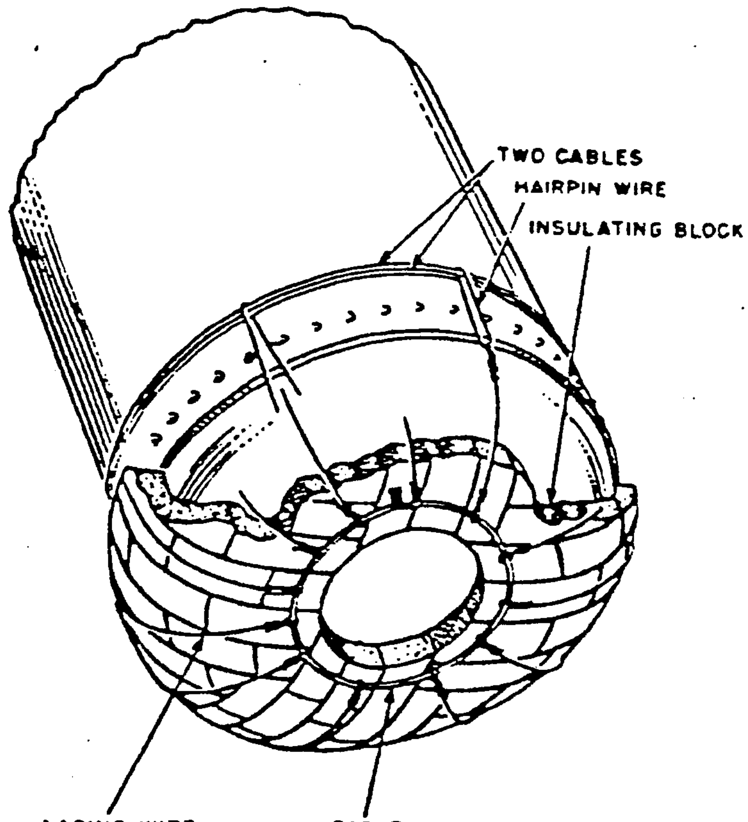
STEAM DRUMS AND DRUM HEADS

Blocks of insulation are carefully fitted and placed against the cylindrical surface of the shell. They are held securely in place with annealed iron wire laced through steel straps, wire or wire cables drawn tightly from previously installed anchorages.

Provision for securing the insulating blocks to drum heads should also be made, preferably before the equipment is installed. Two heavy wires or wire cables are wrapped around the surface of the shell,



33. Cylindrical surface of steam drum with double-layer insulation. Blocks may be fastened in place with wires laced through steel straps, wire or cables anchored to previously affixed angle.

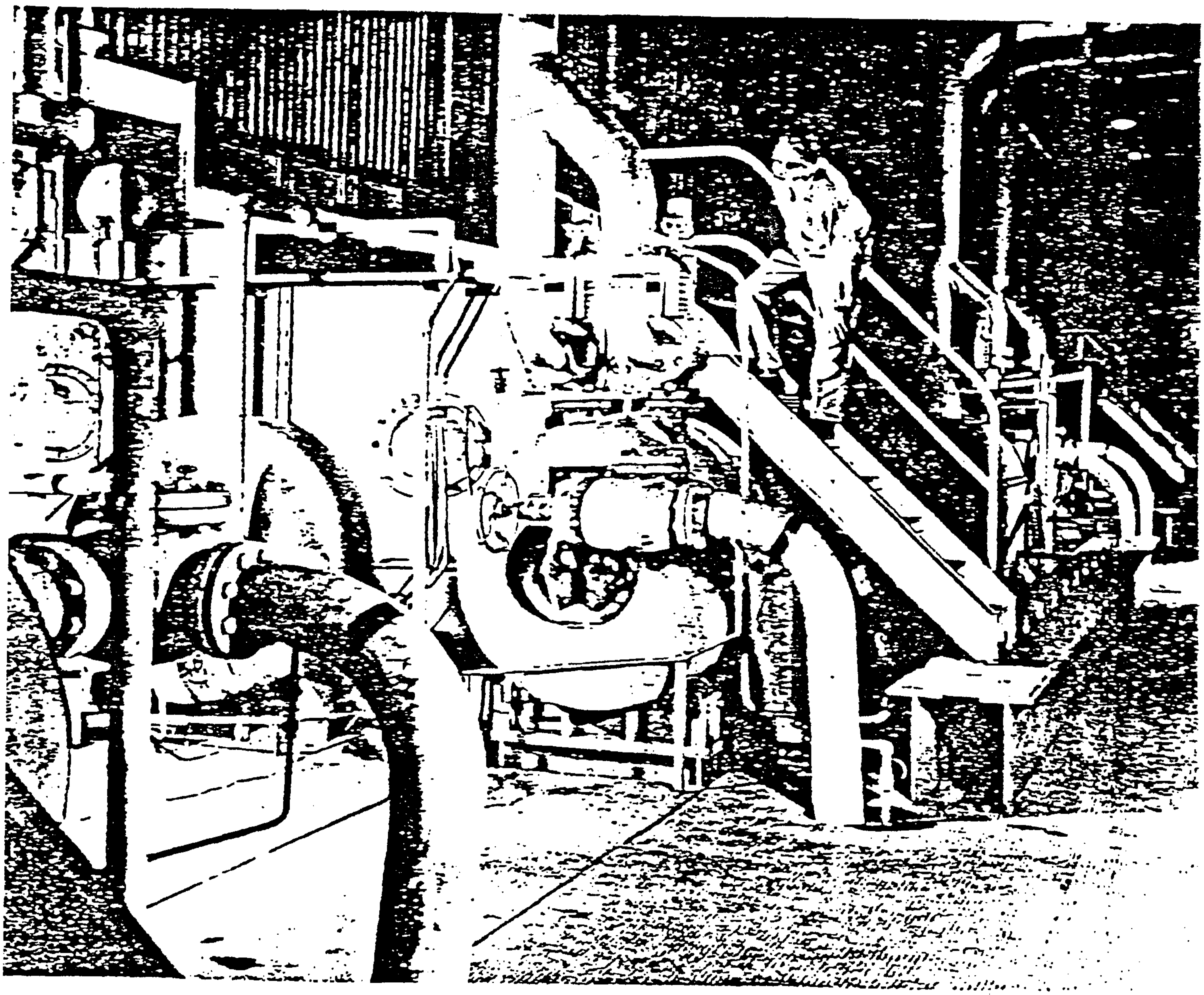


34. Drum head with insulation wired in place. Lacing wires are fastened to cable around manhole and to hairpin wires looped through cables around drum shell.

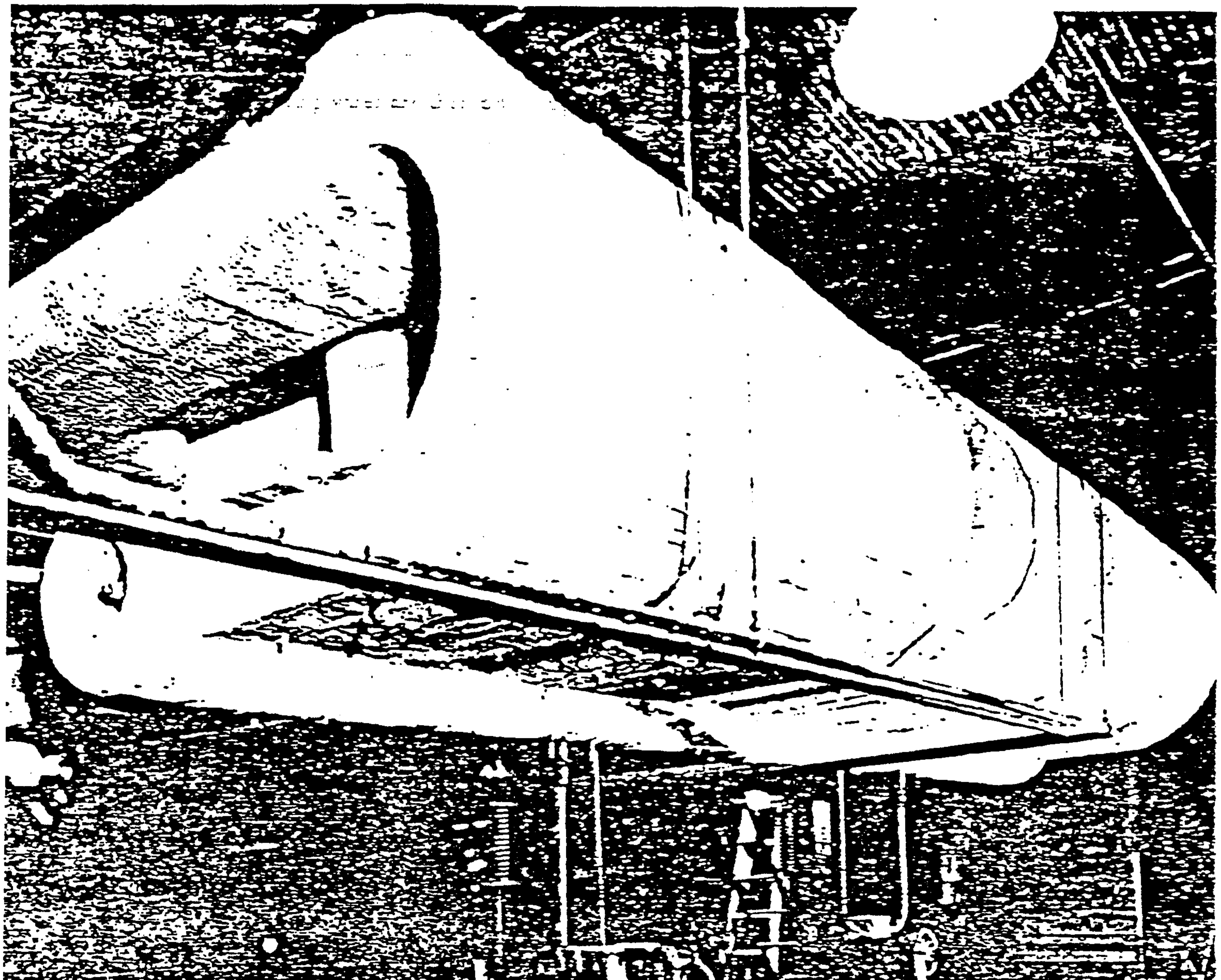
and hairpin wires are looped around the cables at frequent intervals.

When the insulating blocks are being applied, annealed iron lacing wires are attached to the hairpin wires. The iron lacing wires are then drawn tightly to a wire cable looped around the manhole opening. Adhesive may be used to facilitate application of the insulating blocks.

An asbestos cement finish is generally used. (See section on Finishes.)



35. Insulated steam drum heads and related equipment in boiler room of major steel plant.



36. *Insulation of nested tubes in the downtake header of a midwestern utility.*

STEAM HEADERS AND DOWNCOMER TUBES

Steam headers are insulated with sectional or segmental insulation, each layer being secured to the header with either annealed iron wire or soft steel bands which are attached to angle sections welded to the header for that purpose. The insulation may be finished with asbestos cement or covered with a steel casing. *(See section on Finishes.)*

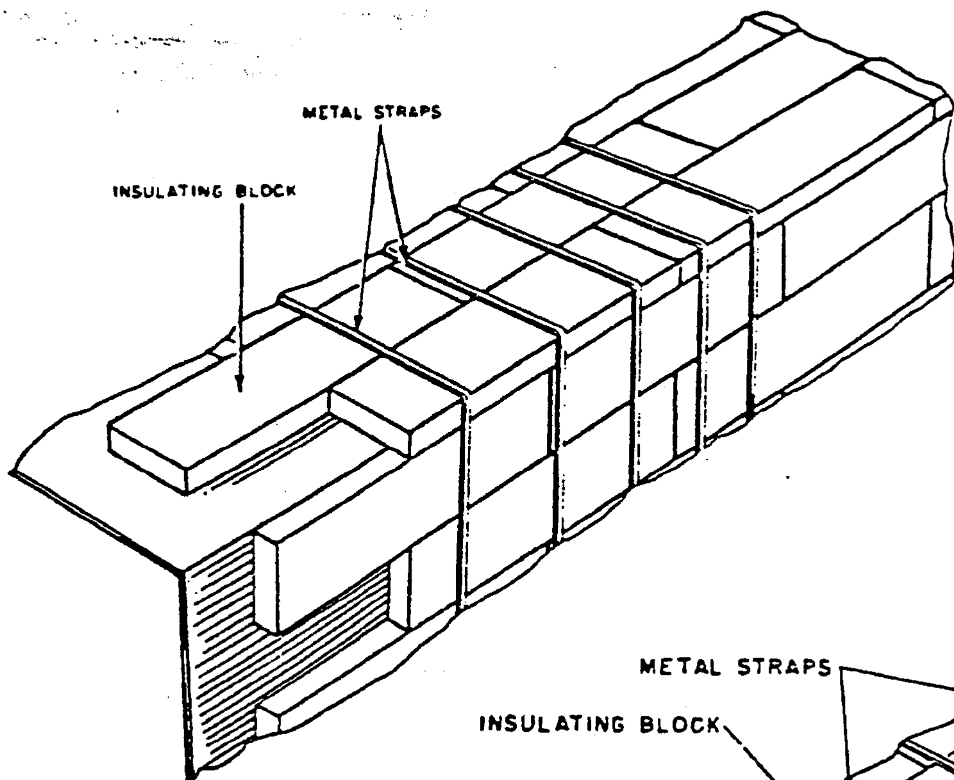
When downcomer tubes are widely spaced, they are insulated individually with sectional insulation. Each layer of insulation is bound in place with annealed wire.

Closely spaced tubes, such as the exposed portion of division wall tubes, are enclosed in one or more layers of insulating block, which is then covered with hexagonal wire mesh and finished with asbestos cement. A removable section of insulation can be provided to allow for periodic inspection of the tube seats without causing damage to the insulation.

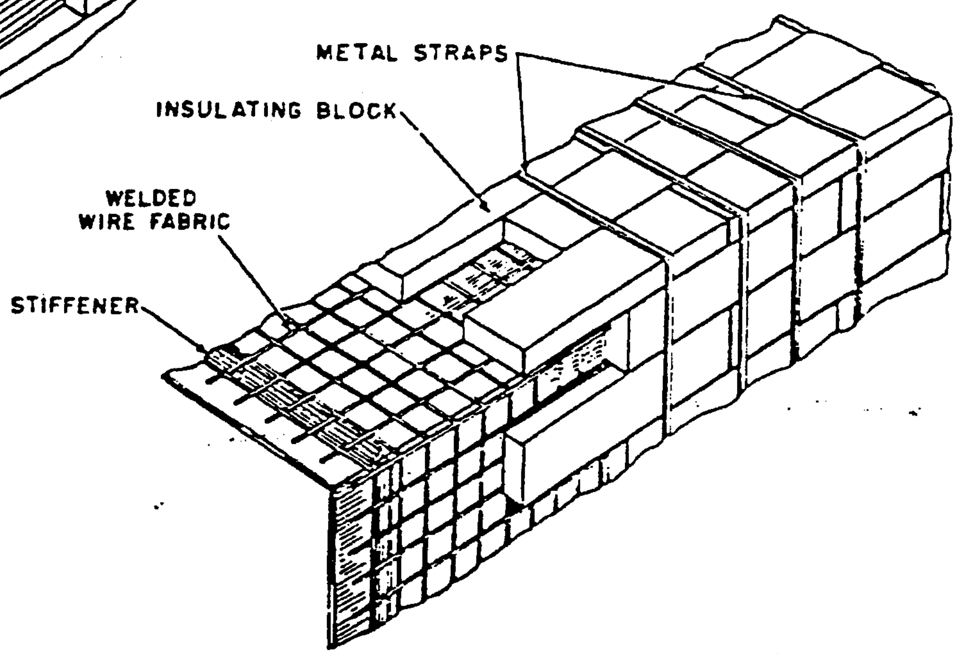
DUCTS, BREECHINGS AND FLUES

When the surface of the duct, breeching or flue has no stiffeners or other projections, and if no provision for expansion and contraction is required, the insulation may be applied directly to the surface, wire cables or metal straps being used to fasten the insulation in place. Beading may be used on the corners to prevent the bindings from cutting into the insulation and to guard against later mechanical damage.

If there are widely spaced stiffeners or other projections, and if expansion and contraction need not be considered, insulation blocks are applied directly to the surface between the stiffeners. If the stiffeners do not project beyond the insulation, the blocks are cut, if necessary, and fitted so that a tight joint between blocks will be made over the stiffener. If the stiffeners protrude beyond the insulation, pipe or block insulation is built up around the projections and wired in place.



37. *Duct without stiffeners, insulation applied to duct surface and held in place with metal straps.*



38. *Insulation applied on duct with stiffeners. Welded wire fabric stretched over stiffeners provides foundation for the insulating blocks.*

Where the stiffeners or other projections are closely spaced or where provision for expansion and contraction is desired, metal strips or heavy iron wire fabric may be stretched over the projections to form a foundation for the insulation. The insulating blocks are fastened over this foundation with wire cables or metal straps.

An asbestos cement finish is generally used. *(See section on Finishes.)*

Where it is necessary to insulate the interior of a duct, breeching or flue in order to protect the metal surface, the particular problem must be studied and the procedure engineered to suit the operating conditions involved.

39. Final stages of insulating ducts in a New England power plant.

TURBINES

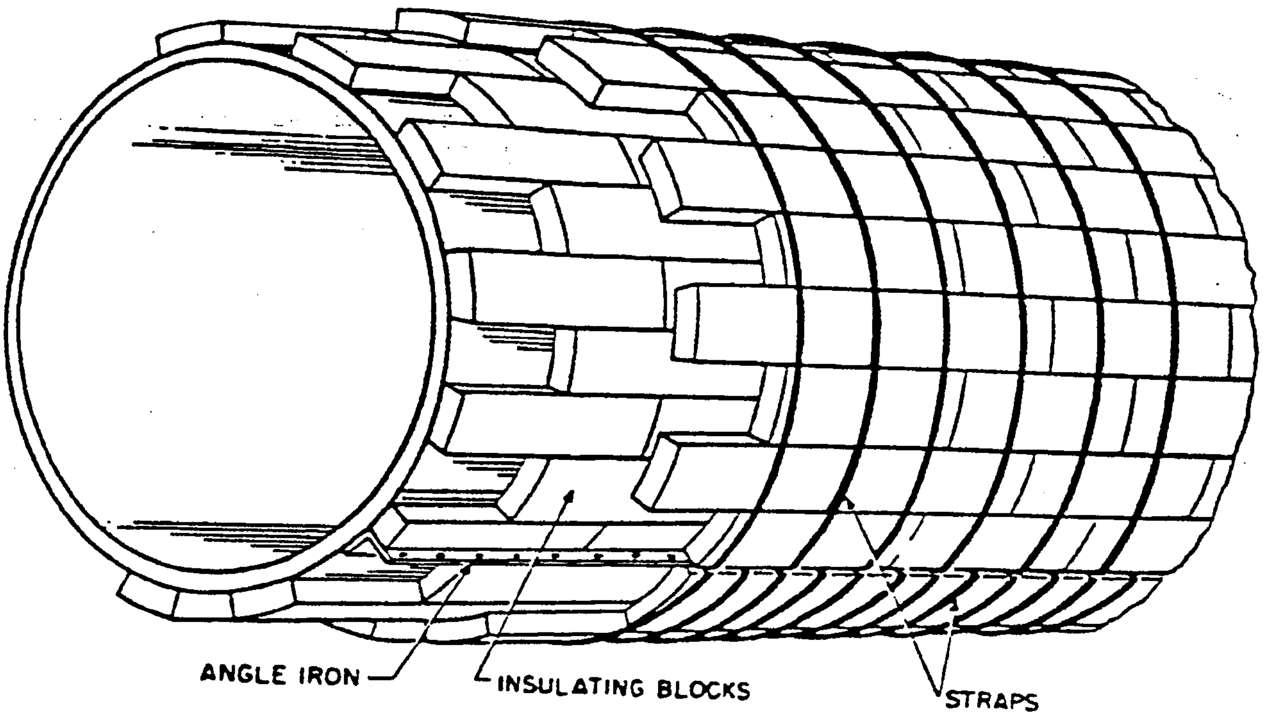
Steel anchors are welded previously to the casing of the turbine on approximately 18-in. centers. All irregularities of the turbine surface are filled and leveled over with either 85% Magnesia or diatomaceous silica cement, depending upon the temperature involved. The insulating blocks are applied over the dry cement surface, and secured with wire cables and annealed iron wire lacings, which are tied to the welded anchors.

For a finish, asbestos cement, asbestos cloth or sheet metal casings may be used. *(See section on Finishes.)*

HEATERS AND EXCHANGERS

Insulation on the cover plate or heads of equipment such as heaters and exchangers is cut back so that the bolts can be removed without disturbing the insulation. The heads of shell and tube bundles which must be opened frequently for cleaning are provided with removable insulation-lined sheet metal covers.

40. Sheet metal cover for heat exchanger head being lined with insulating blocks.



41. Horizontal tank insulation affixed with metal straps anchored to angle irons.

VESSELS

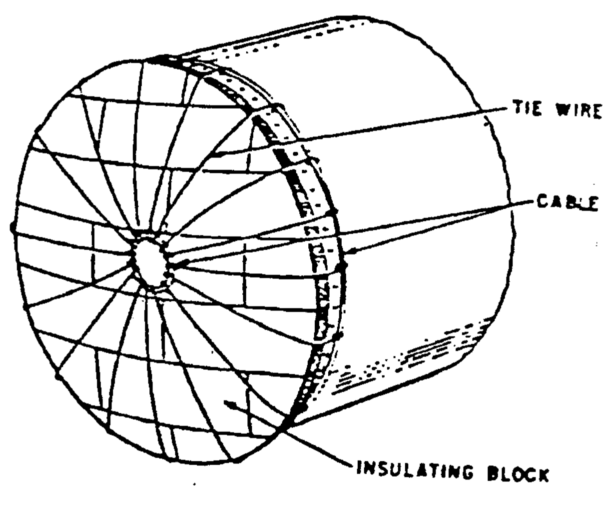
Horizontal Vessels: On the cylindrical body of vessels, the insulation blocks in each layer, if more than one layer is used, are held in place with metal bands or straps, three being used per 3-ft section of block.

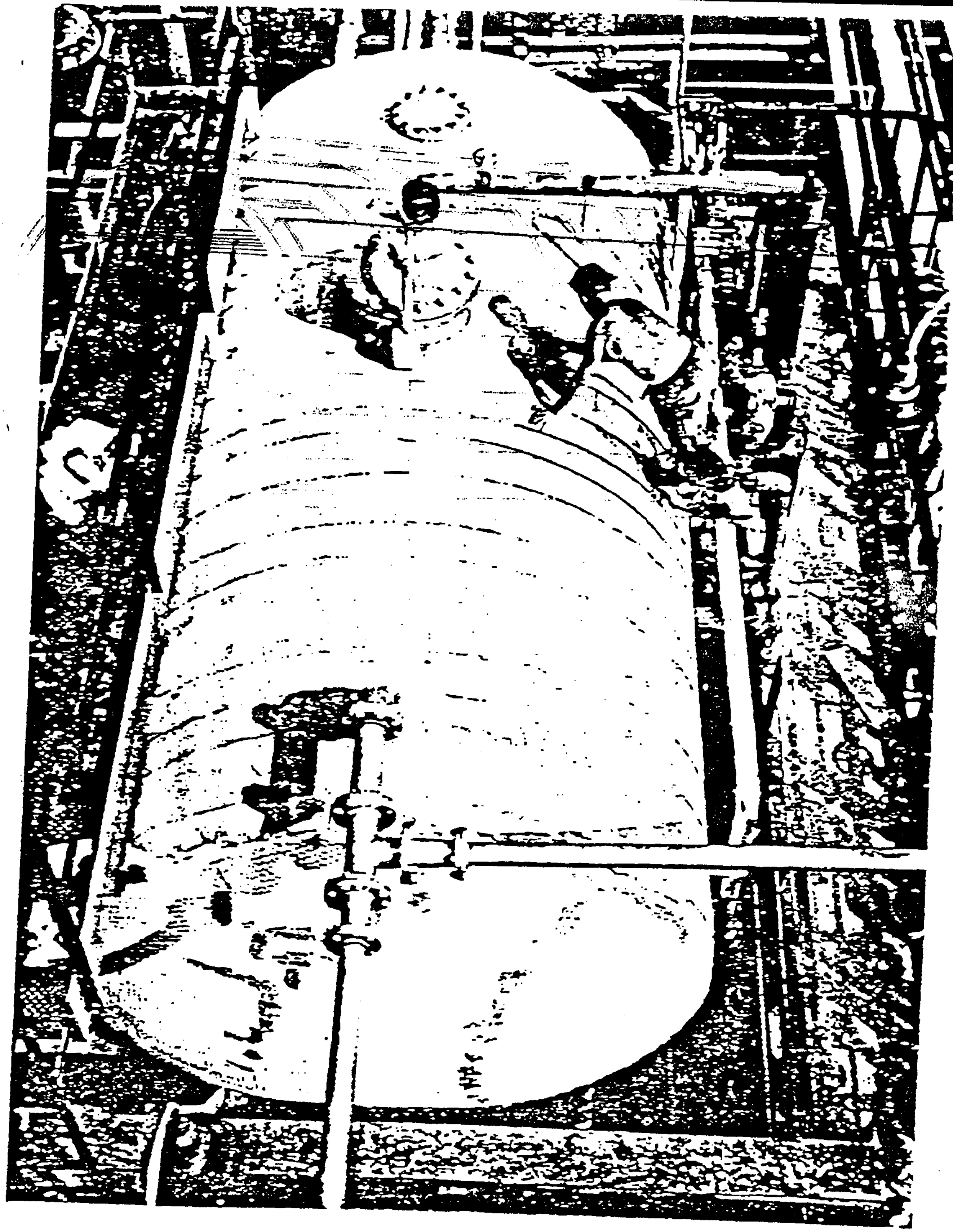
If greater support is desired for insulation on the under side of the vessel, two angle irons of the same length as the vessel may be welded longitudinally to its under side and spaced 120 deg apart, equally distant from the bottom center. The blocks are then applied and held in place by means of bands anchored to the angle irons. Six bands to the block are usually used on the bottom third, and three bands for the rest of the circumference.

On vessel ends, the insulation blocks are held in place with wire laced over the blocks and fastened to a wire cable looped around the circumference of the vessel, piping, or other projections or behind or through angle iron clips previously welded to the circumference of the vessel.

The type of finish depends primarily on whether the vessel is located indoors or outdoors. *(See section on Finishes.)*

42. Horizontal tank end, insulation wired to cable looped behind rivet heads on tank shell and to floating ring at tank center.



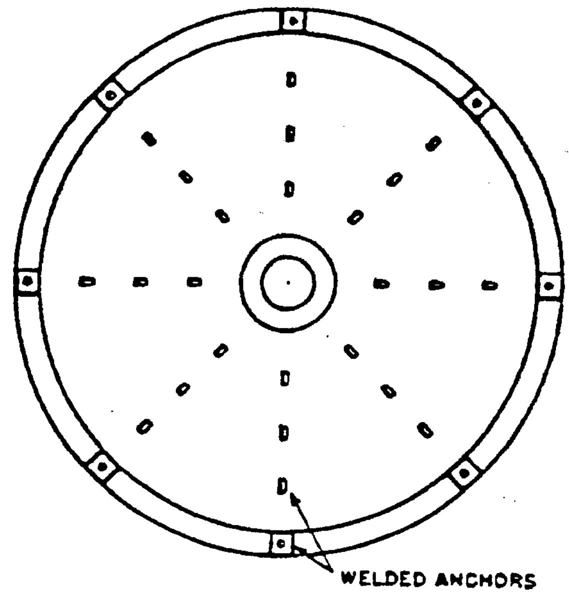


43. 85% Magnesia insulation on horizontal tank receives first cement coat preparatory to final finish.

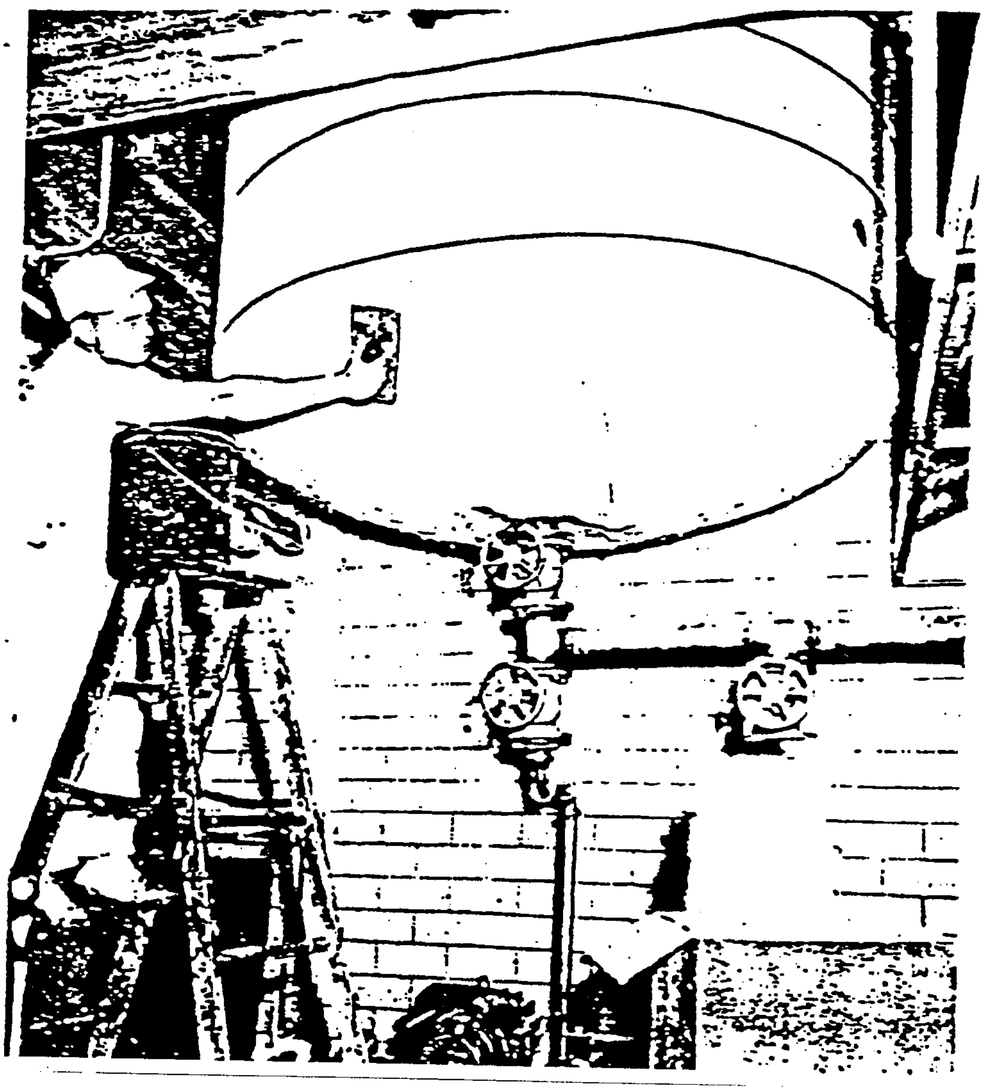
Conical and Convex Bottom Vessels: The cylindrical portions of such vessels are insulated in the same manner as the cylindrical portion of any other vessel.

In the case of vessels with a cylindrical portion more than 5 ft high, an angle iron shelf which serves as a support for the insulation on the cylindrical portion is welded to the vessel at the juncture of the cylindrical and conical or convex bottom surfaces. The projecting leg of the angle iron extends outward and the welded leg extends upward.

On the conical or convex section, metal anchors such as punched angle clips, nuts, etc., are welded to the surface and spaced in a pattern of concentric rings, with equal spacing between the anchors in each ring and between the rings. The rings start a few inches below the juncture of the cylindrical and convex or conical sections and extend to the tip of the cone or the end of the convex section. Hairpin wires are attached to each anchor, with the wires projecting outward. The insulation blocks are applied and held in place with wire drawn through the holes in the anchors. The projecting ends of the hairpin wires are used for anchoring cross-lacing wire and metal wire mesh.



46. Pattern of clips, studs, nuts, etc., welded to conical or convex tank bottom as anchors for insulation bindings.

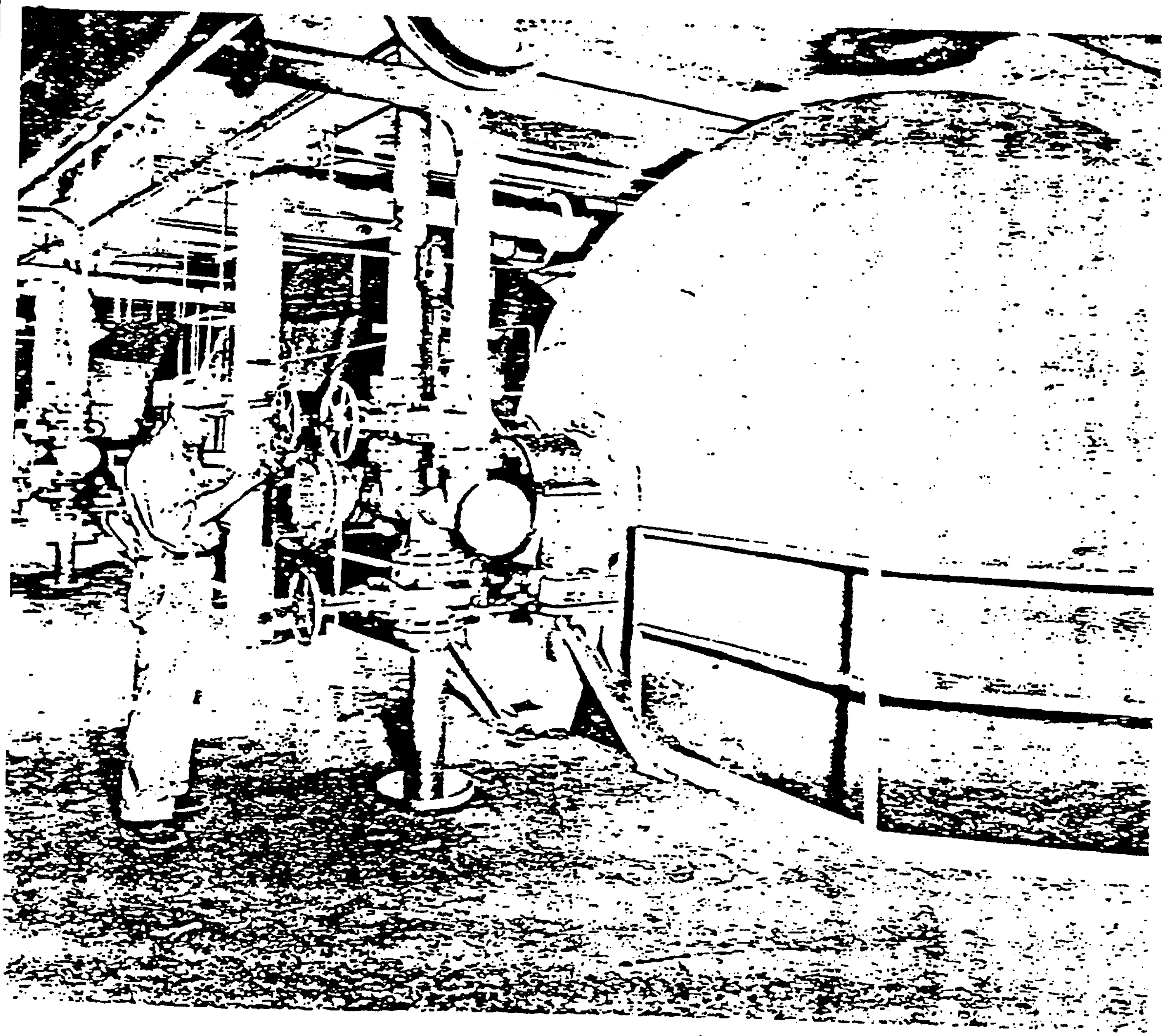


47. 85% Magnesia block insulation on convex bottom of extraction tank.

ROTATING EQUIPMENT AND EQUIPMENT SUBJECT TO SUBSTANTIAL EXPANSION

Each case of equipment of this type must be studied and the application procedure designed by an insulation engineer to suit the operating conditions involved.

48. Rotating corn cob digester in food processing plant is insulated with 85% Magnesia.



INSULATION FINISHES

Insulation is generally covered with a finishing material or jacket when it is installed. The major purpose of this finishing material is protection of the insulation against injury from severe weather conditions, moisture, chemicals or mechanical damage and to improve appearance.

PASTED CANVAS JACKET

The light-weight, factory-applied canvas jacket on sectional insulation, with metal bands if desired, may be used as a finish for many indoor installations. Where greater protection is desired, the light-weight, factory-applied canvas may be removed and a heavier canvas used instead.

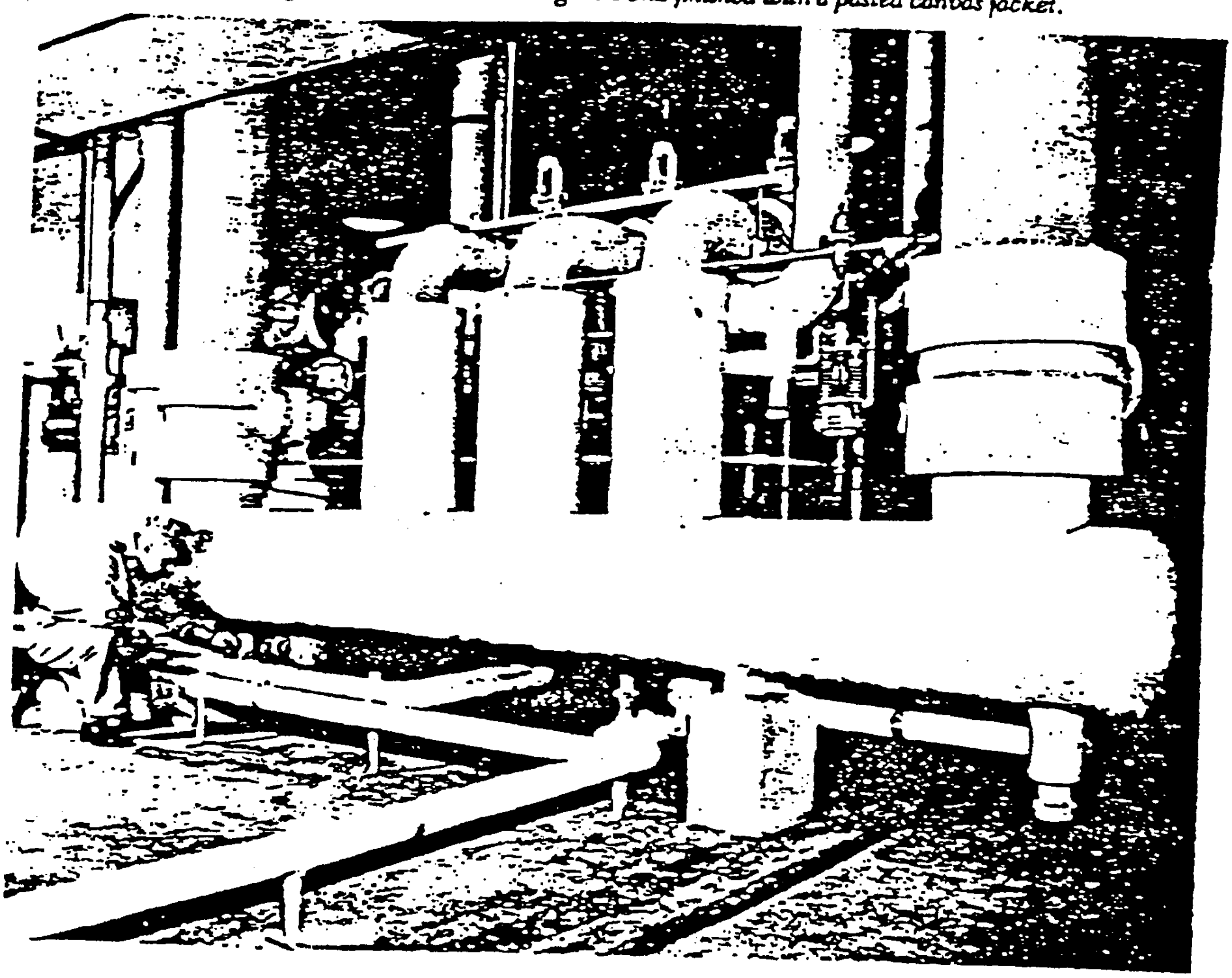
Pasted canvas jackets may also be employed on segmental insulation and on insulation applied to bent piping and small equipment. Asbestos cement is usually applied to provide a smooth surface before the canvas jacket is pasted on.

Adhesive is used to seal the canvas laps, the flap being turned, wherever possible, to the least visible side of the pipe or equipment.

On flanges, valves and fittings, the canvas is cut to lap and pasted down smoothly over the cement coating.

If uninsulated metal is adjacent to the insulation, it is necessary to protect the canvas finish from burning. The canvas is stopped a few inches short of the end of the insulation and the exposed length of insulation is finished with cement or asbestos cloth.

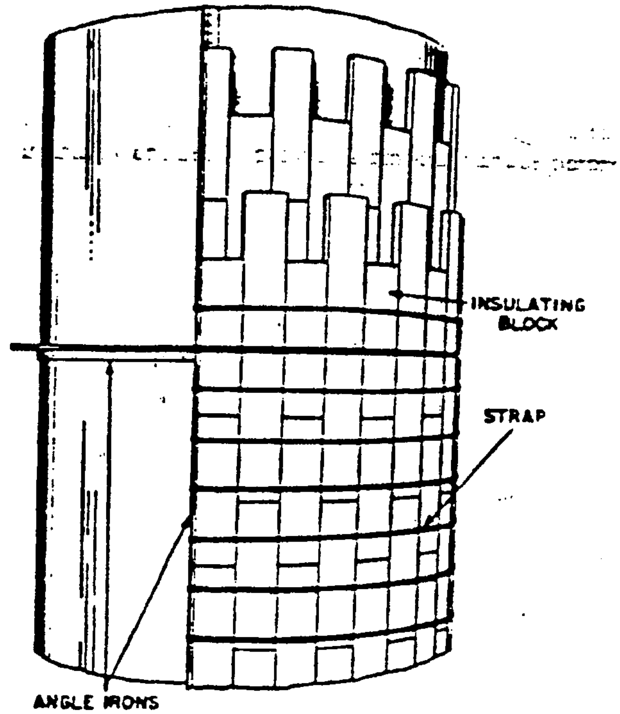
49. Low pressure steam manifold, piping and valves in a life insurance office building insulated with 85% Magnesia and finished with a pasted canvas jacket.



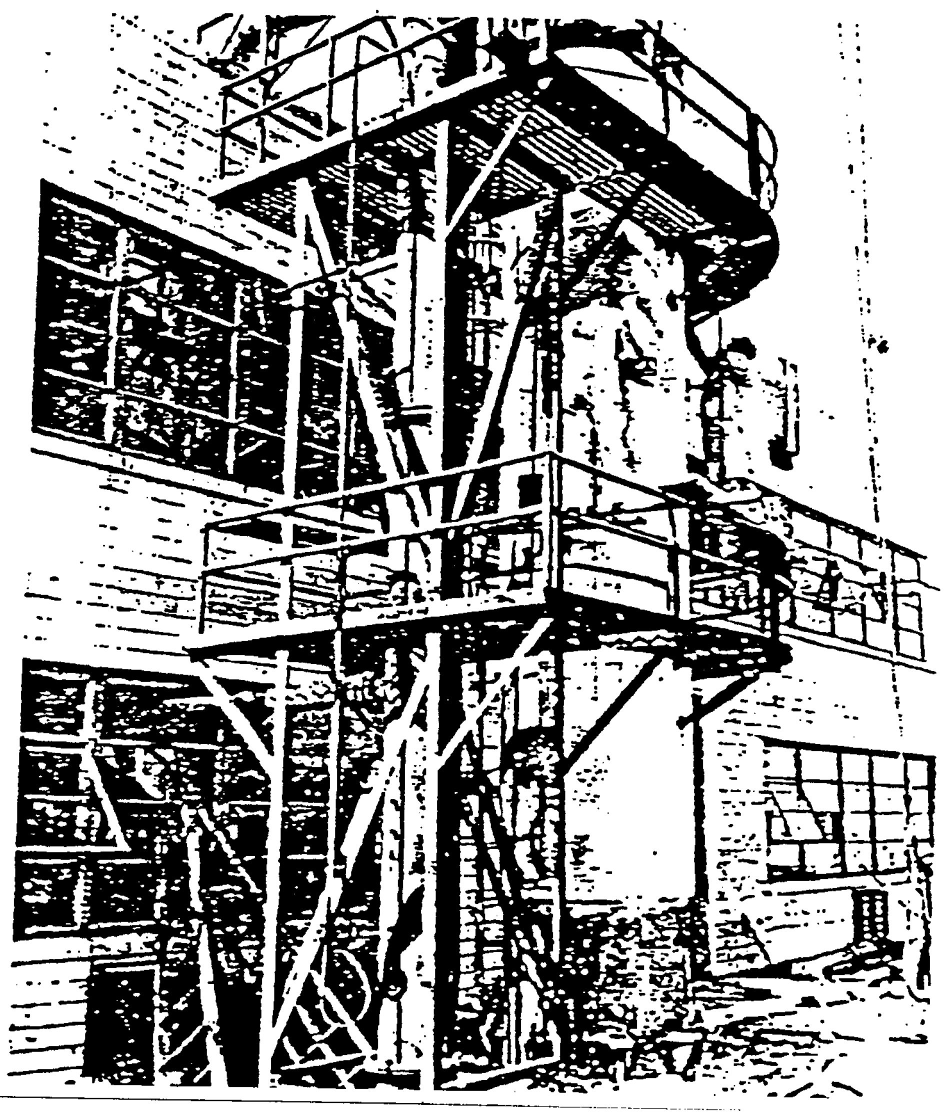
Vertical Vessels: The sides of vertical vessels are insulated with one or more layers of blocks secured in place with metal bands or strapping, three being used per 3-ft section of block. On large vertical vessels, to provide anchorage for the metal strapping or bands, vertical angle irons are welded to the vessel at intervals of approximately 20 ft. The blocks are supported on circumferential angle irons welded to the vessel at regular intervals of approximately 12 ft.

The tops of vertical vessels are insulated with blocks held in place with metal bands or strapping.

As in the case of horizontal vessels, the type of finish depends on whether location is indoors or outdoors.



44. Block insulation on vertical tank. In actual application, blocks would be mitered or pressed over horizontal and vertical angle irons.



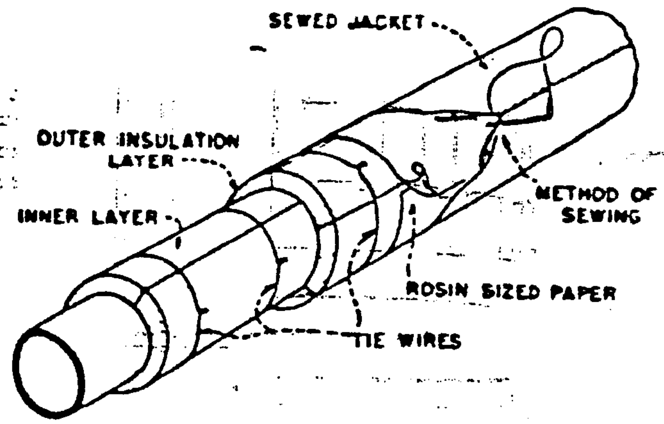
45. Mechanics apply asbestos cement over insulation on vertical vessel at meat packer's by-product plant.

SEWED CANVAS JACKET

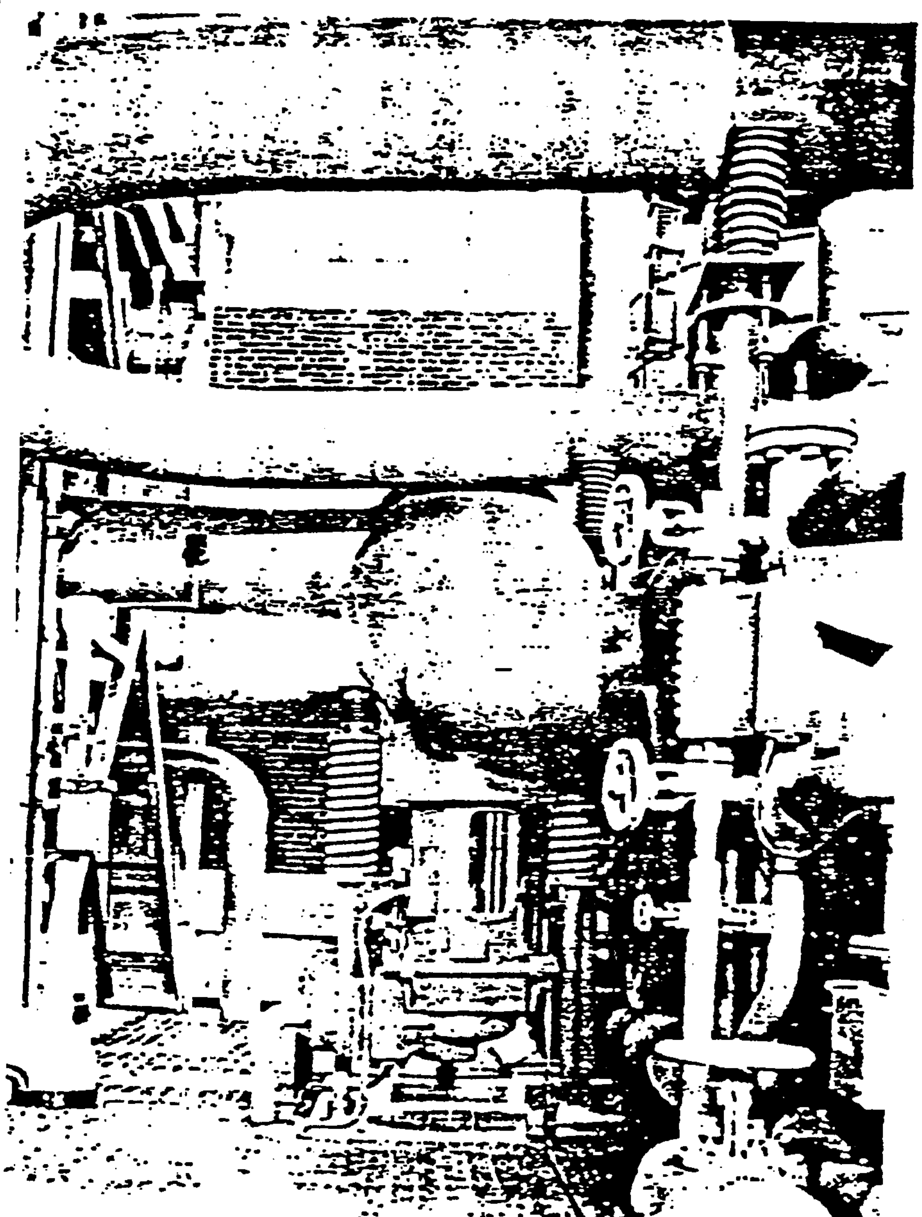
With the development of improved adhesives, pasted jackets are used more frequently than sewed canvas. The latter may be preferred for certain installations.

A layer of rosin-sized or sheathing paper is applied over the insulation (where sectional insulation is used, the factory-applied canvas is removed) and 8-oz canvas is stretched over the paper and sewed in place. The canvas is given a coat of glue sizing and painted as desired.

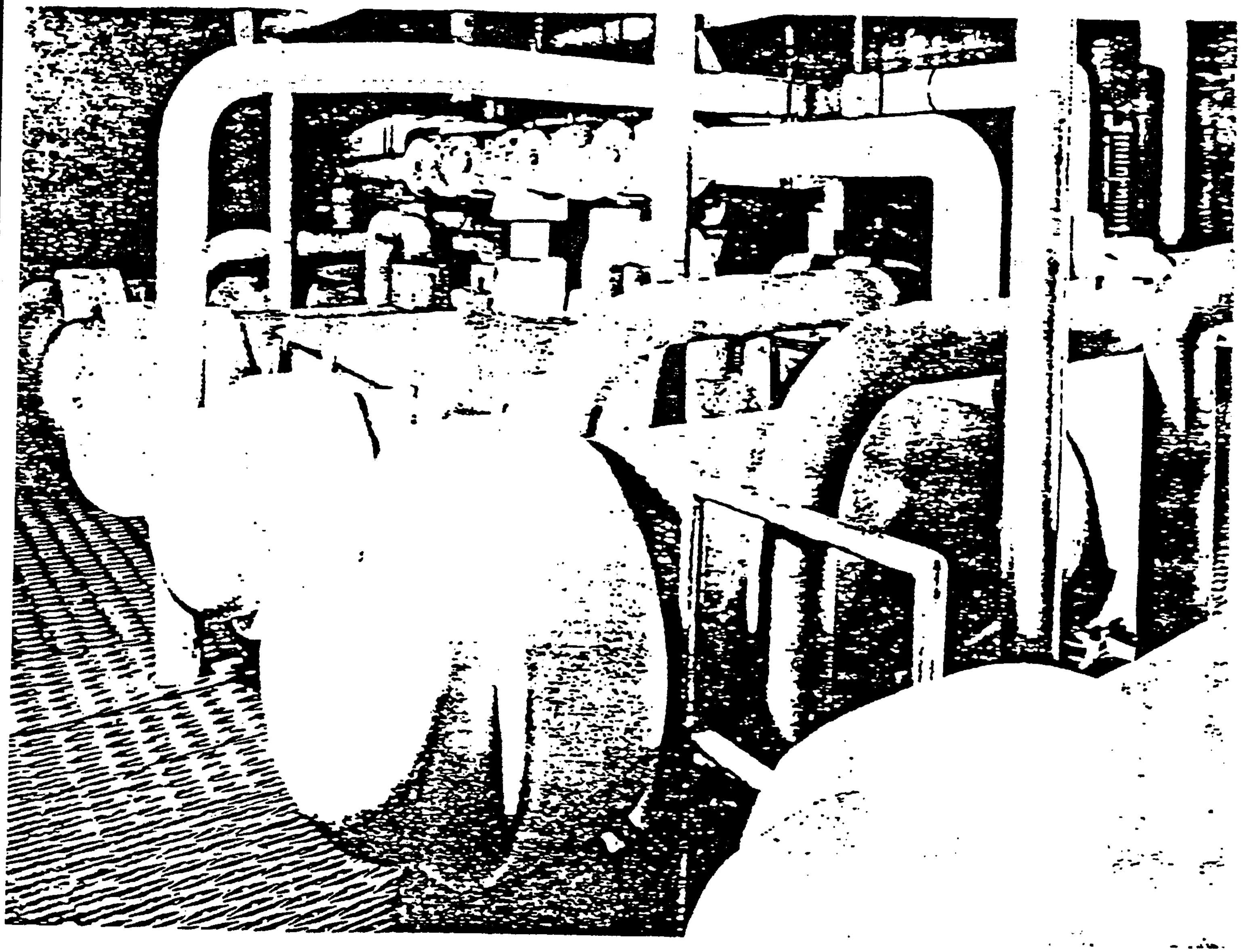
To prevent burning of the canvas finish, where there is adjacent uninsulated metal, the canvas and rosin-sized paper or sheathing are stopped a few inches short of the end of the insulation, and the exposed length of insulation is finished with cement or asbestos cloth.



50. Sewed canvas jacket on double-layer pipe insulation.



51. Sewed canvas jackets on piping in a mercury vapor power plant.



52. Heaters finished with asbestos cement.

ASBESTOS CEMENT FINISH

Where an asbestos cement finish is required, as on small equipment, the cement is applied directly to the insulation surface and troweled to a smooth finish. For a hard finish, portland cement is mixed with the asbestos cement.

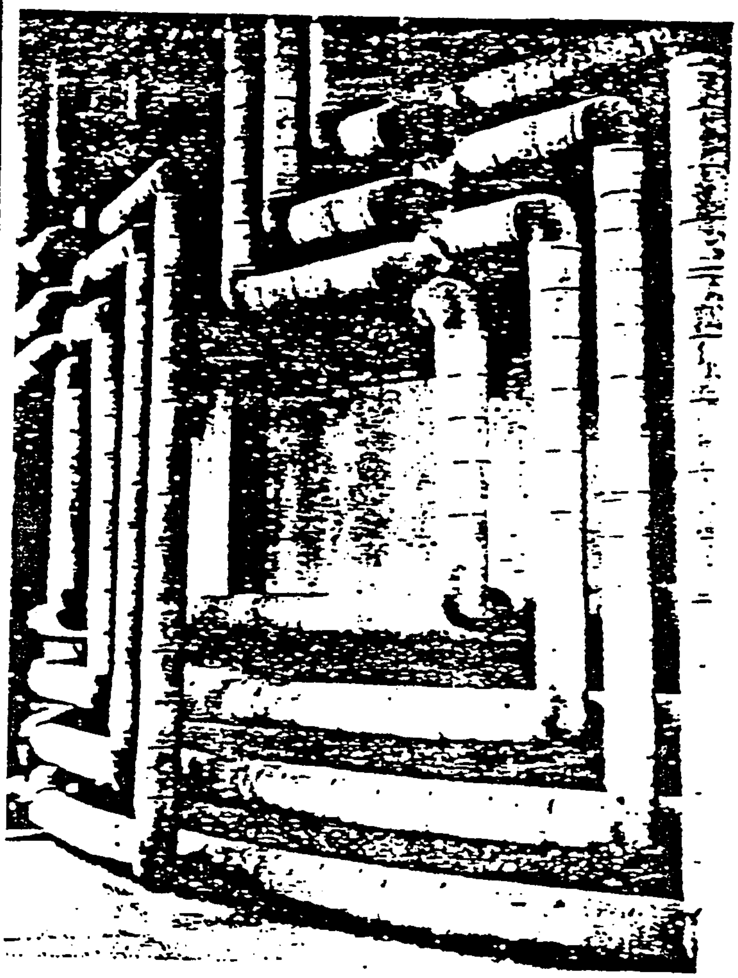
On large equipment, including ducts and breechings, hexagonal wire mesh is drawn tightly over the insulation to provide the reinforcing for the cement finish, which is then applied as described above.

ASPHALT-SATURATED ASBESTOS (ROOFING) FELT

Pipe insulation which requires protection against weathering may be finished with asphalt-saturated and coated asbestos felt.

After the insulation has been wired on, a jacket of heavy asphalt-saturated and coated asbestos felt is applied. Laps of not less than 3 in. are provided at all edges and side laps on vertical piping are sealed with asphalt cement. All horizontal joints in the felt jacket are lapped downward so as to shed water.

As the felt is applied and the laps are sealed, corrosion-resistant straps or wires are fastened around the felt jacket at equal spacings of not more than 6 in. If wire is used, the ends of the wire loops are twisted tight and turned over to avoid projections, care being taken not to puncture the felt.



53. Insulated outdoor steam lines finished with an asphalt saturated and coated asbestos felt jacket; pipe elbows are finished with an asphaltic weatherproof compound.

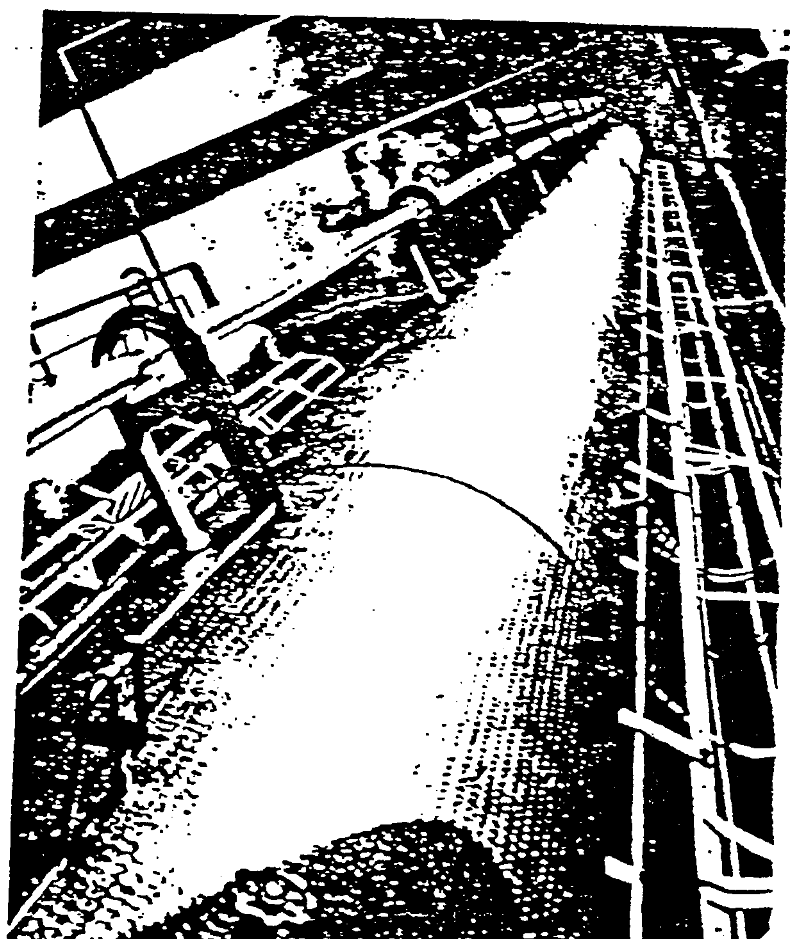
PLASTIC WEATHERPROOFING

For weatherproofing an uneven surface for which a felt finish is impractical, such as insulation on bends, flanges, valves and fittings, a plastic finish consisting of asbestos fiber and an asphalt compound is used. The plastic weatherproofing should be used in the form supplied by the insulation manufacturer, without additives, unless the manufacturer recommends otherwise.

When large equipment is to be finished with plastic weatherproofing, the insulation is given a base coat of asbestos and portland cement and a light-gauge galvanized 1-in. wire mesh is applied over the cement and drawn taut, with all the edges thoroughly tied and wired in place. The weatherproofing plastic is then applied to a thickness of ¼ in. when wet and troweled to a smooth, even surface.

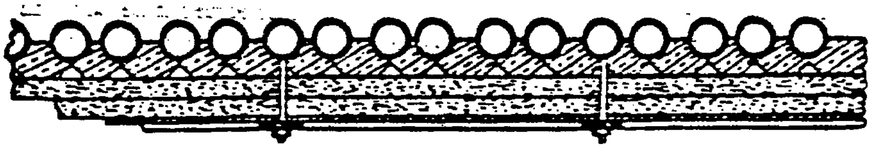
On equipment subject to expansion such as fractionating towers, stills, etc., it is preferable to apply the base coat of asbestos and portland cement and the finish coat of weatherproofing plastic while the vessel is hot. Where there are expansion joints in the insulation, the finishing procedure must be specially planned by the insulation engineers.

54. Tower in oil refinery is insulated with 85% Magnesia and finished with plastic weatherproofing applied over wire mesh.

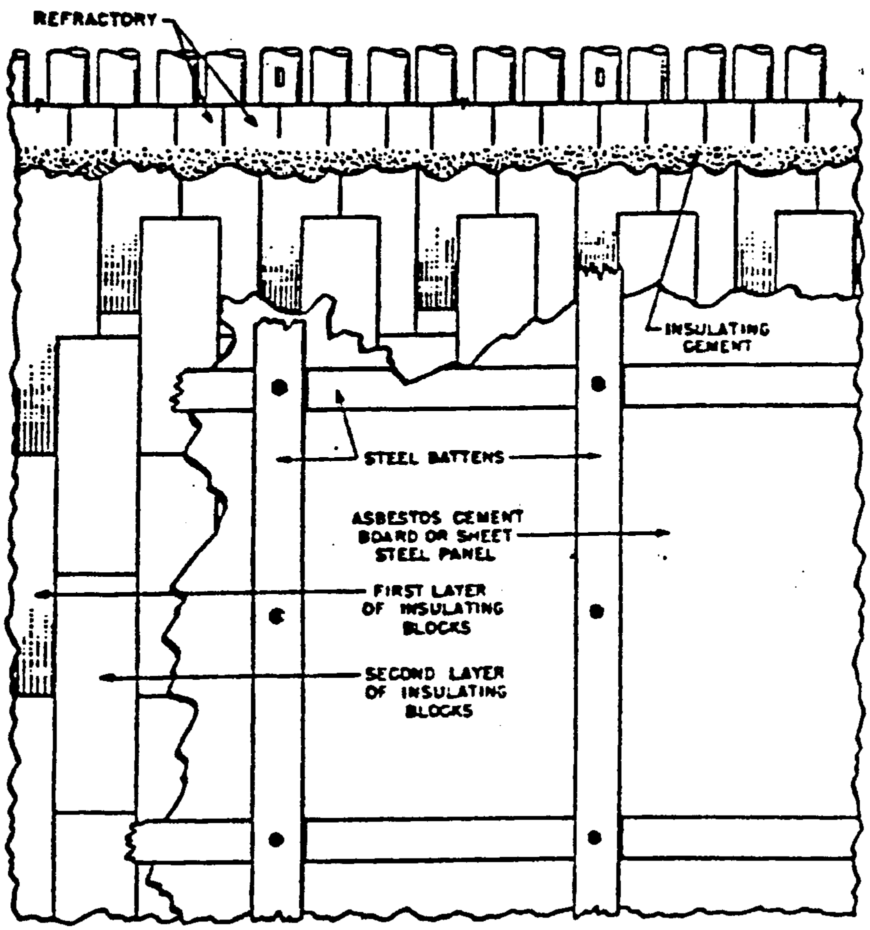


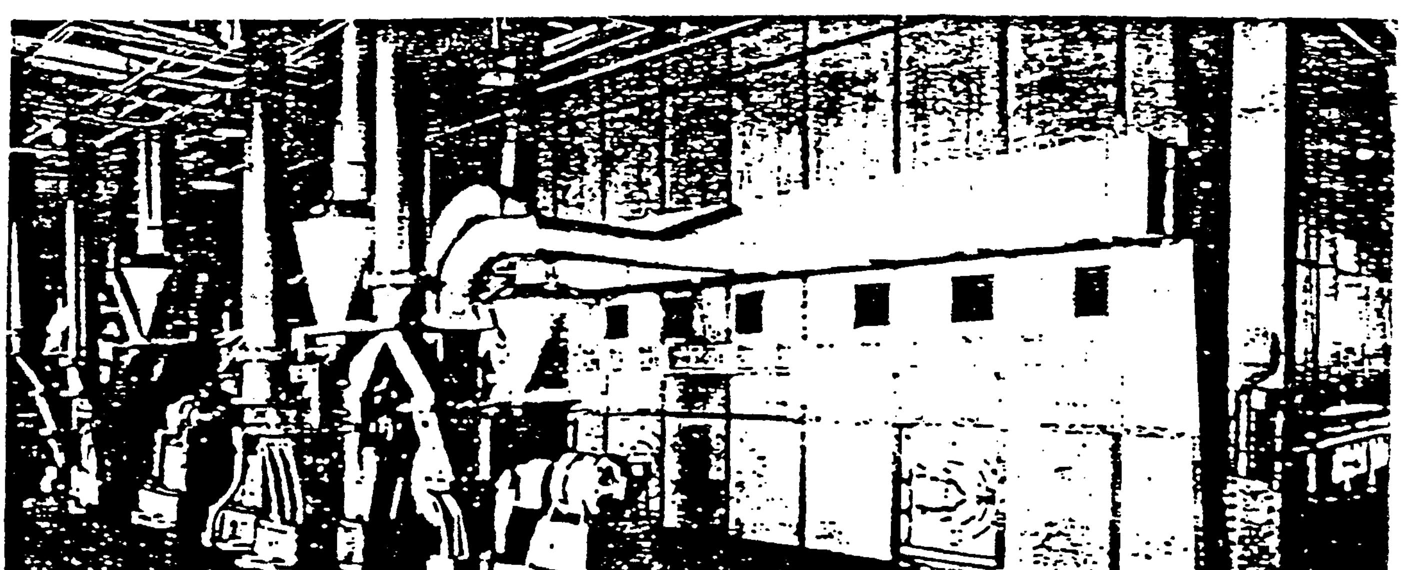
REMOVABLE PANEL FINISH

It is sometimes desirable to have easy access to equipment, such as the water tubes in furnace walls. A removable panel finish may be used in such cases. Panels of asbestos-cement board or sheet steel are applied over the blocks. The panels are held in place by a combination of vertical and horizontal strip steel battens.



55. *Removable panels over water wall insulation held in place with steel battens.*





56. *Removable panel finish on water tube furnace wall. Panels are asbestos-cement board, held in place by strip steel battens.*

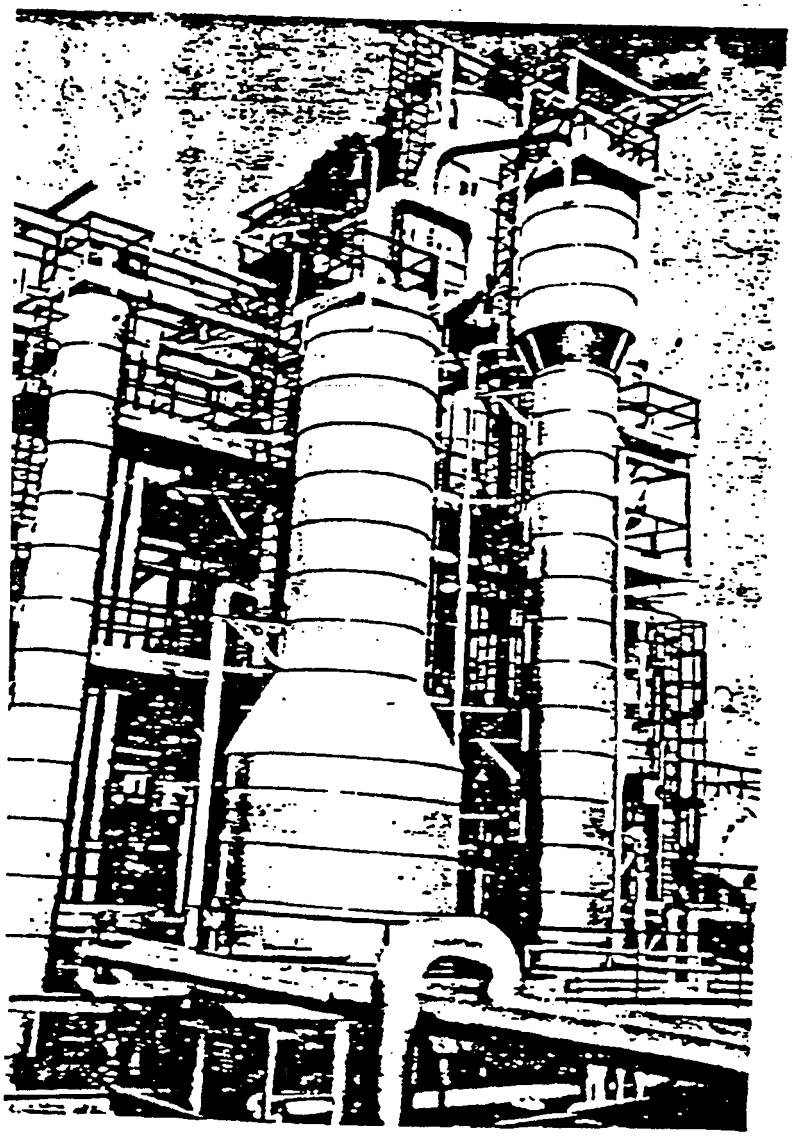
METAL JACKETS

Where there is danger of mechanical damage, sheet-steel jackets designed to fit the equipment may be applied. Expansion joints with spring-loaded bolts may be provided in the steel jacket to compensate for circumferential expansion. Longitudinal expansion of the jacket is permitted by lap seams at intervals of approximately 12 ft.

ASBESTOS CLOTH FINISH

Where a fire-resistant or heat-resistant finish is required, asbestos cloth may be used. The cloth is drawn snugly over the insulation and is held in place by cementing all laps. Or the cloth may be sewed with copper or brass wire. Asbestos cloth is also applied over adjacent flanges. It may be painted with fire-retardant paint.

57. Furfural solvent refining unit insulated with 85% Magnesia and diatomaceous silica and finished with galvanized sheet metal jackets.



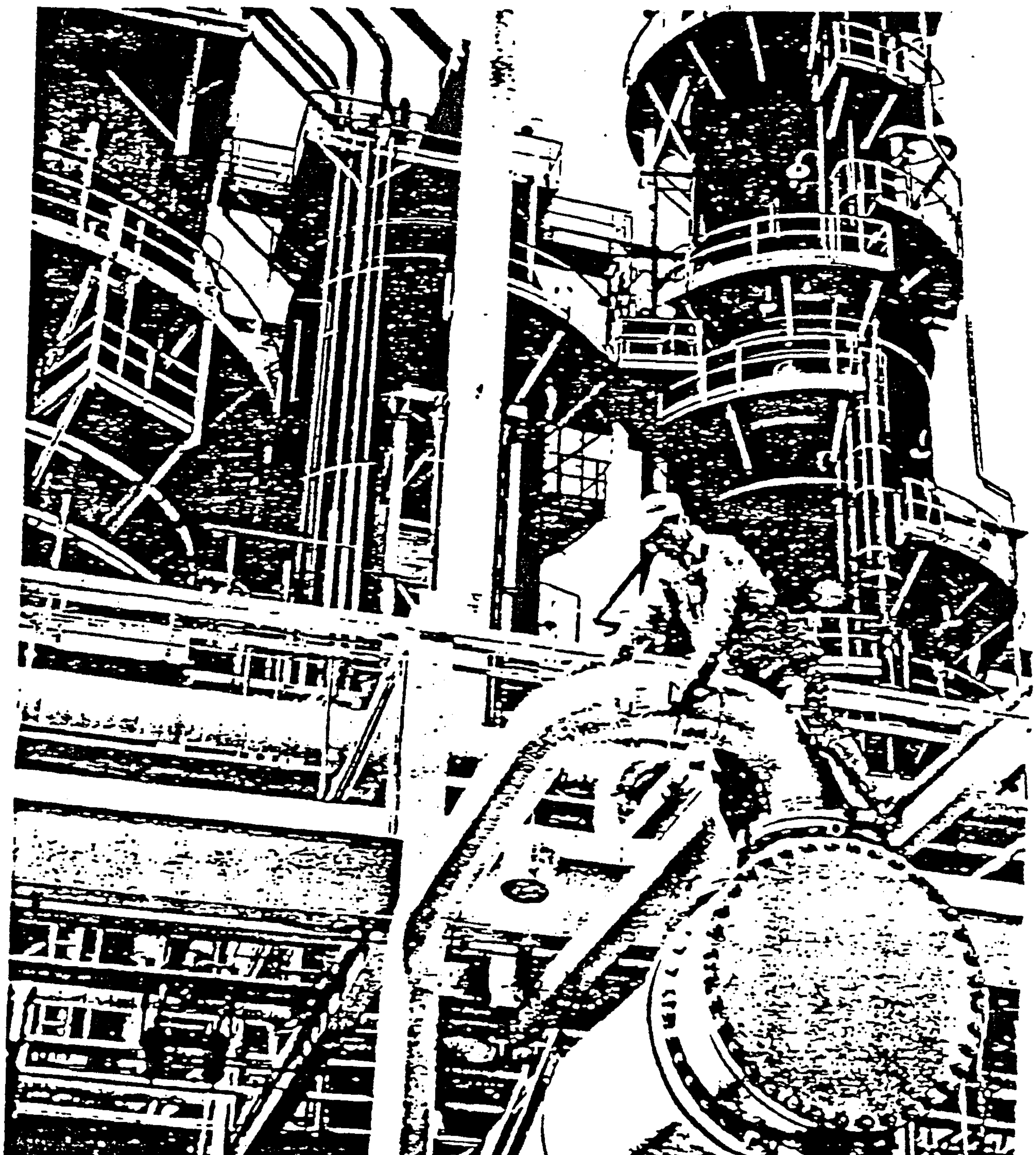
58. Turbine drain pipes with 5-in. combination insulation and finished with an asbestos cloth jacket.

MAINTENANCE

To provide maximum insulating value, all insulation requires regular inspection and routine maintenance. An adequate inspection and maintenance program for average operations can be described in nine steps:

1. All equipment is inspected regularly to see that all sources of heat loss are insulated (for example, new sections of piping).
2. Insulation thickness is periodically evaluated. Changes in operations or costs of fuel may warrant an increase in insulation thickness.

59. Important insulation maintenance step is inspection and repair of weather-proof jacketing. Repainting provides greater water resistance and longer life.



3. Protective jacketing on insulation is regularly surveyed to check for signs of mechanical, chemical or other damage. There may be indications that a different type of jacket—one providing more protection—is required.
4. Scorched spots on jackets are thoroughly investigated since they may indicate a crack or structural damage in the insulation underneath.
5. Weather-resistant jackets are given periodic inspection for holes, torn and loose laps, loose or broken wiring, and deterioration of the jacket due to weathering or mechanical damage.
6. Weather-resistant plastic finish on outdoor fittings, vessels and other equipment is inspected carefully to locate any mechanical damage or cracks which may permit water to seep into the insulation. It is desirable to paint this type of finish every five years or oftener, both to lengthen the life of the protective coating and to seal small, hairline cracks.
7. The insulation is examined for mechanical damage. The damaged insulation is cut out and replaced with the same material and method of securement as used originally. The joints are pointed with insulating cement and the protective finish replaced.
8. The insulation is checked after any change in operations. Operating difficulties, such as leaks, water hammer, etc., may also cause damage to insulation so that a prompt check-up follows such occurrences.
9. If insulation has been saturated with water, as a result of fire fighting or flood, the insulation should be brought up to temperature slowly to prevent damage to the finish due to generation of steam within the insulation.

APPENDIX

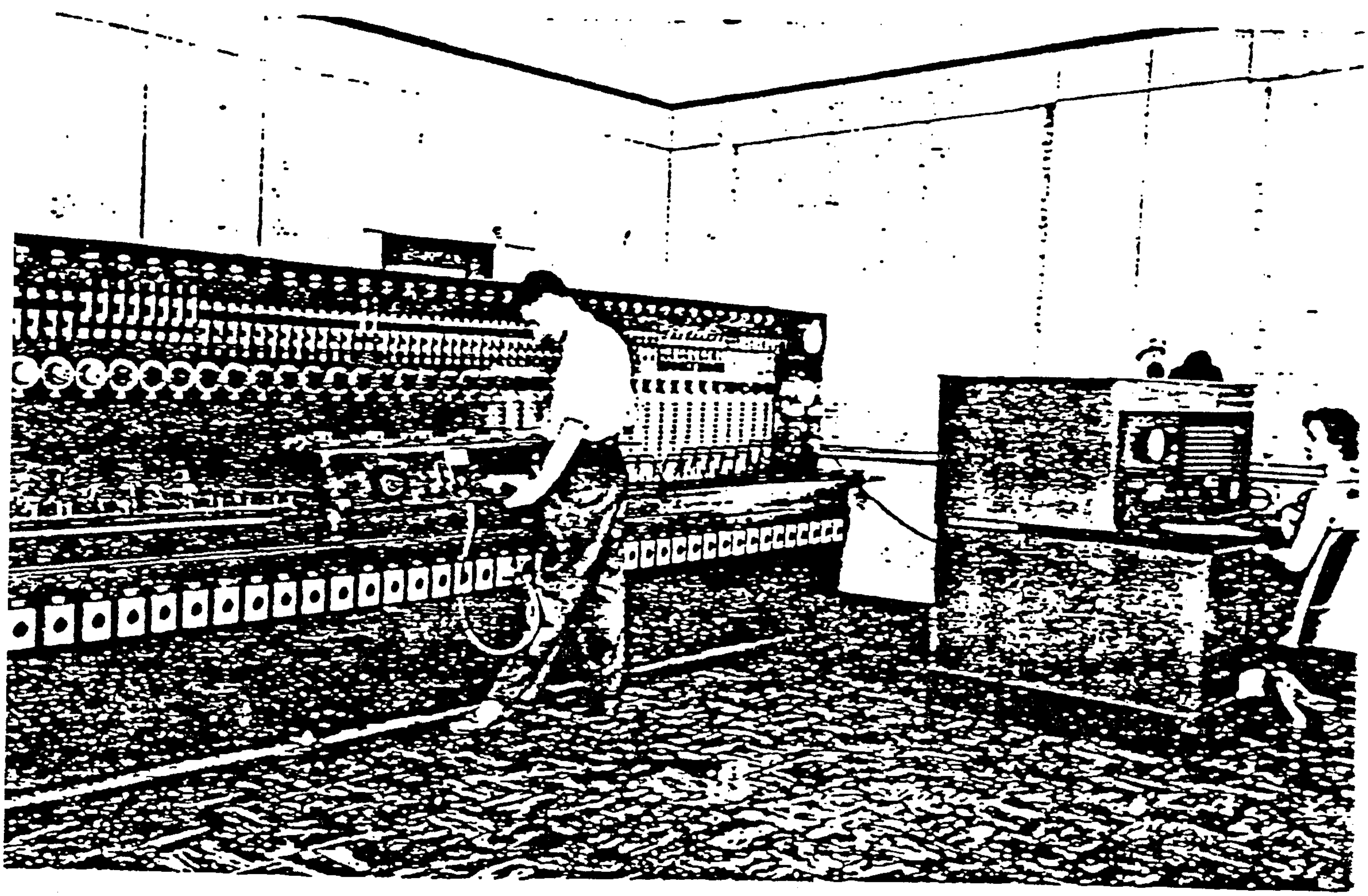
HEAT TRANSMISSION AND INDUSTRIAL INSULATION

Heat is transmitted by radiation, by conduction and by convection. Except in the semi-refractory and refractory fields, where radiation is of great importance, the chief concern in the design of insulation for industrial equipment is with the means of reducing convection and conduction to negligible quantities.

If it were practical, the perfect insulation for industrial equipment would be a vacuum, since there would be no material to convect or conduct heat. The next best thing to a vacuum is dead or noncirculating air. In the manufacture of insulating materials, a great number of tiny air spaces or pockets are trapped between the fibers or crystals that make up the body of the insulation. The effectiveness of the insulation results from this great number of small air spaces which reduce the cross-sectional area of the solid material and provide a multitude of surface resistances at the boundaries of the air spaces.

In order to measure their ability to resist the flow of heat, insulating materials are subjected to conductivity tests.

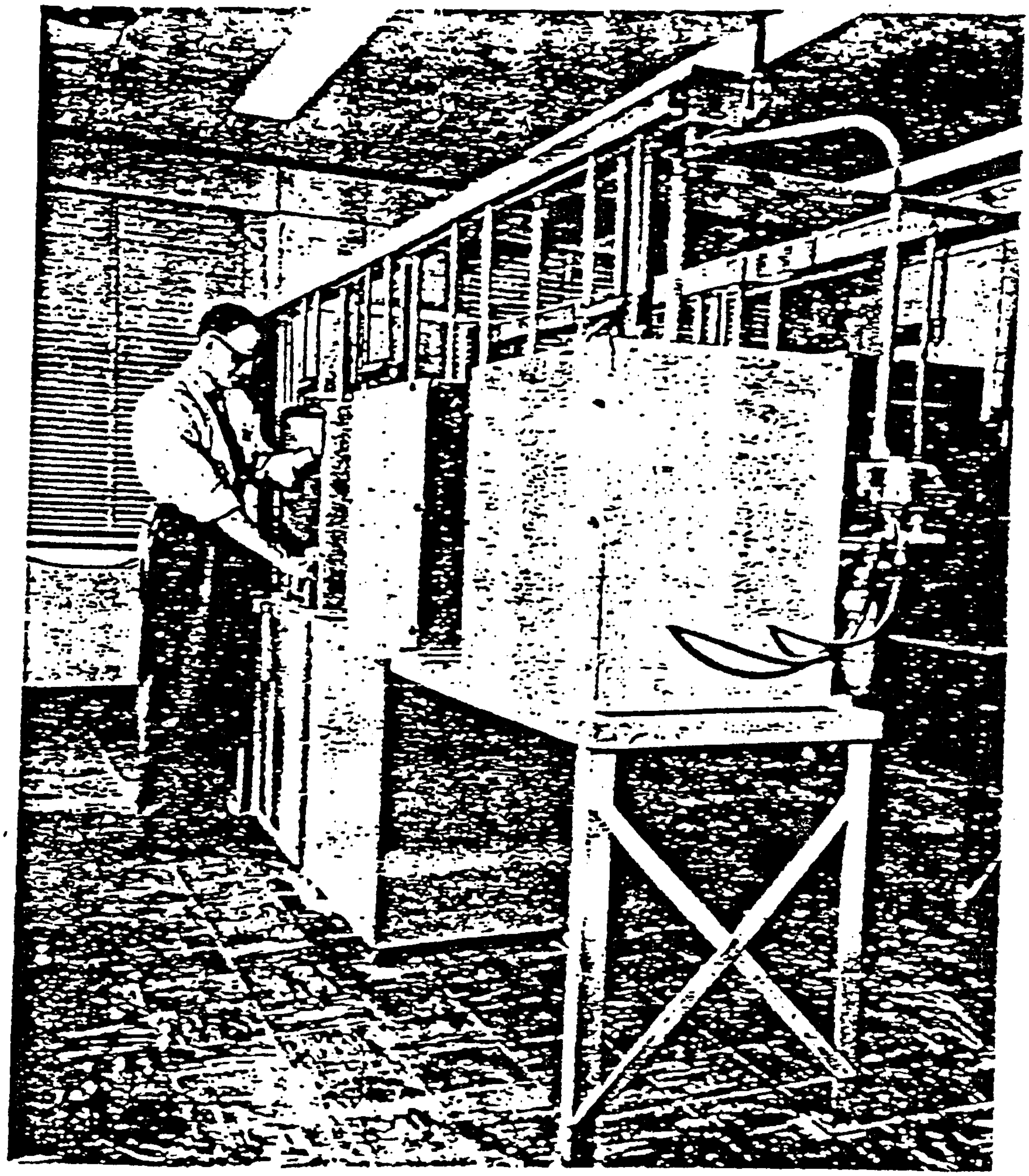
This is done with 85% Magnesia and diatomaceous silica insulation by attaching these materials to a



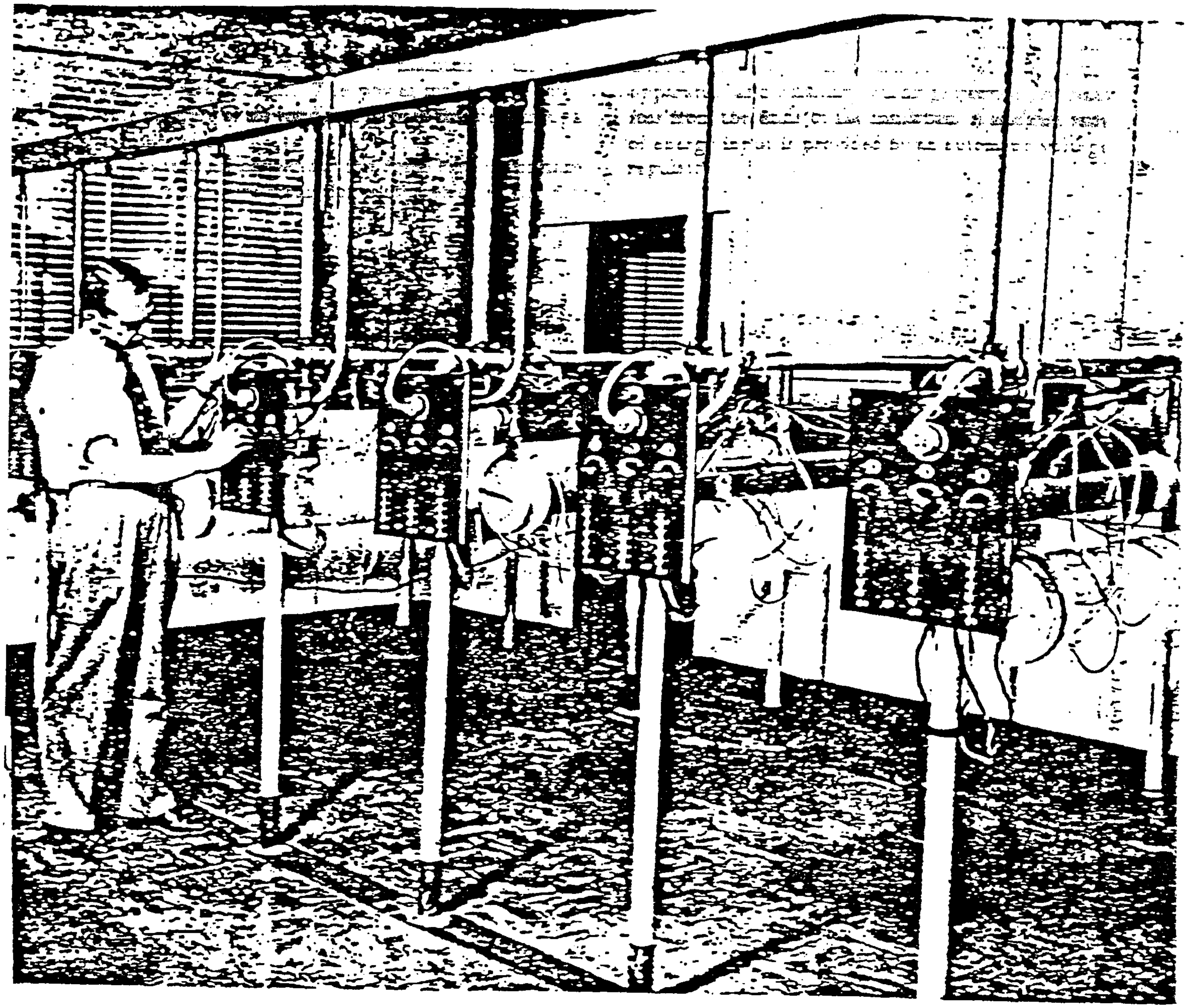
60. Power control board in insulation testing laboratory.

steel surface, applying heat with an electrical heater, and measuring the rate at which electrical energy must be supplied in order to maintain a uniform temperature gradient. The power input is an accurate measure of the total rate of heat transfer through the insulation.

The tests are carried out in a room kept at constant temperature. Pipe insulation is applied on a standard steel pipe equipped with internal heater. Windings of the heater are spaced so as to assure uniform distribution of heat to all points on the surface of the apparatus, and auxiliary windings provide for heat loss from the ends of the insulation. A uniform rate of energy input is provided by an automatic voltage regulator.



61. Guarded hot plate thermal conductivity apparatus.



62. Apparatus for determining thermal conductivity of pipe insulation.

Temperatures at both boundaries of the insulation are determined by copper-constantan thermocouples at the center of each foot of length and distributed around the circumference. Thermocouple potentials are measured with a potentiometer to the nearest one-hundredth of a millivolt.

Blocks are tested in a similar manner, except that they are placed against a flat steel or a refractory surface.

These testing procedures have been standardized and approved by the American Society for Testing Materials.

Certain commonly held ideas concerning insulation, when considered on the basis of heat transmission prove to be fallacious. They are as follows:

a) "*Surface temperature is an accurate method of determining heat loss from insulation.*" Surface temperature alone, measured either by placing the hand on the surface or by means of thermocouples and thermometers, is not a measure of heat loss. Surface temperature depends upon the temperature of the surrounding air, the proximity of other hot and cold objects, the nature of the surface, whether dull, polished, etc., and the velocity of the ambient air. Air motion lowers surface resistance to heat transfer; stated another way, it increases the rate of heat transfer from the surface. This cools the surface to a lower temperature than it would have under still air conditions, so that more heat may actually be lost with the lower than with the higher surface temperature. While the variables mentioned, such as air velocity and type of surface, have little effect on the total heat transmitted by the insulation, they may have marked effects on the surface temperature.

b) "*Air space between a hot surface and the insulation provides effective insulation.*" A series of tests was conducted at an industrial laboratory to determine the value of such air spaces. The results indicated that an air space is of little value as insulation, because circulating air carries heat from the surface to the inner surface of the insulation with but little drop in temperature. Also the air space proved to be of no value as protection against high temperature deteroriation of either the equipment surface or the insulation. It should be understood that air, other than in microscopic pockets such as are present in insulating materials, is never "dead," and will aways convect heat.

c) "*Insulation affects the pressure drop in a steam line.*" Regardless of the fluid, there is always a pressure drop in a line, due to the friction between the fluid and the pipe wall. With superheated steam, as heat is lost the temperature will drop. The pressure remains constant, and no condensation takes place until the saturation temperature is reached for the particular pressure involved. If the temperature drops any further, the pressure will drop as well and a certain amount of condensation will take place. Insulation, by keeping heat losses at a minimum, keeps the superheat in the steam. Under such conditions, any pressure drop is of a frictional nature only and does not reduce the temperature of the steam.

Regardless of the thickness of insulation used, a surprisingly large loss of steam superheat may occur if the piping system is not designed properly. For instance, if a pipe size is too large for the flow conditions involved or, conversely, if the flow rate is too low for the pipe size used, the cost of insulating such a line to prevent large heat losses would be prohibitive.

The table which follows, giving reasonable velocities for steam flow based on average practice, can be used to advantage in designing steam lines. As a general rule, velocities in the lower end of the range given are used for pipe sizes 12 in. and smaller.

†REASONABLE VELOCITIES FOR FLOW OF STEAM THROUGH PIPE

CONDITION OF STEAM	PRESSURE Lb per Sq In.	SERVICE	REASONABLE VELOCITY Ft Per Min
Saturated	0 to 15	Heating (short lines)	4,000 to 6,000
Saturated	50 and up	*Miscellaneous	6,000 to 10,000
Superheated	200 and up	*Miscellaneous	7,000 to 20,000

†Crane Company Technical Paper No. 409, Flow of Fluids.
*The velocity of steam, in the case of boiler leads, should be lower than in large turbine leads because of the stop-check valves which are necessarily installed in these lines. A high velocity through the stop-check valve would cause an excessive pressure drop which may be detrimental to efficient operation.

HEAT: A form of energy which transfers from one system to a second system at lower temperature by virtue of the temperature difference when the two are brought into communication.

INSULATION (HEAT): A material having a relatively high resistance to the flow of heat per unit of thickness.

LATENT HEAT: The heat absorbed or rejected by a substance in changing its state without changing its temperature.

Mb, Mbh: Symbols which represent 1000 Btu and 1000 Btu per hour, respectively.

MEAN TEMPERATURE: The arithmetic mean of inner and outer surface temperatures of the insulation.

POTENTIOMETER: An instrument for measuring or comparing small electromotive forces.

PYROMETER: An instrument for measuring high temperatures, generally above 900 F.

RADIATION: The transmission of heat through space by wave motion.

SATURATION: The condition of coexistence in stable equilibrium of two or more distinct phases such as steam over water from which it is being generated.

SATURATION PRESSURE: The pressure at which vapor and liquid or vapor and solid can coexist in stable equilibrium.

SENSIBLE HEAT: Heat which manifests itself by temperature change.

SPECIFIC HEAT: The number of units of energy required to raise the temperature of a unit mass of a substance through 1 degree, under specified conditions, such as constant pressure, constant volume, etc.

STEAM: Water in the vapor phase. *Dry saturated steam* is steam at the saturation temperature corresponding to the pressure, and containing no water in suspension. *Wet saturated steam* is the same as above except that it contains water particles in suspension. *Superheated steam* is steam at a temperature higher than the saturation temperature corresponding to the pressure.

SURFACE CONDUCTANCE: The amount of heat (Btu) transmitted by radiation, conduction and convection from a surface to the air or liquid surrounding it, or vice versa, in one hour per sq ft of surface for a difference in temperature of 1 degree between the surface and the surrounding air or liquid.

THERM: 100,000 Btu. Used in the gas industry.

THERMAL RESISTANCE: The reciprocal of conductance.

THERMAL RESISTIVITY: The reciprocal of conductivity.

DEFINITIONS OF TECHNICALTERMS

ABSOLUTE PRESSURE: The pressure of a system referred to that of a perfect vacuum. It is the sum of the gauge pressure and barometric pressure.

ABSOLUTE TEMPERATURE: A reading on the absolute temperature scale. Absolute temperature is obtained by adding 459.70 degrees to the Fahrenheit temperature.

ATMOSPHERIC PRESSURE: The pressure indicated by a barometer. Standard atmospheric pressure is a pressure of 76 cm mercury, equivalent to 14.69 lb per sq in. or 29.92 in. of mercury at 32 F.

Btu: The abbreviation for British thermal unit, a unit of energy. It is approximately the quantity of heat required to raise the temperature of 1 lb of water from 63 to 64 F.

CALORIE (MEAN): For practical purposes it may be considered as 1/100 of the heat required to raise the temperature of 1 gram of water from 0 to 100 C. The kilocalorie or large calorie is equal to 1000 gram or small calories.

CONDUCTANCE: The amount of heat (Btu) transmitted from surface to surface in one hour through 1 sq ft of a material, whatever its thickness, when the temperature difference is 1 F between the two surfaces.

CONDUCTION: The transmission of heat through and by means of matter unaccompanied by any obvious motion of the matter.

CONDUCTIVITY: The amount of heat (Btu) transmitted in one hour through 1 sq ft of a homogeneous material 1 in. thick for a difference in temperature of 1 F between the two surfaces of the material.

CONDUCTOR (HEAT): A material capable of readily conducting heat, the opposite of an insulator or insulation.

CONVECTION: The transmission of heat by the circulation of a liquid or gas such as air. Convection may be natural or forced.

DENSITY: Mass per unit volume, generally expressed as weight per unit volume, i.e., lb per cu ft.

EMISSIVITY (TOTAL): The ratio of the total heat radiating power of a surface to that of a black body (ideal or perfect radiator) of the same area and at the same temperature.

GAUGE PRESSURE: Pressure measured from atmospheric pressure as a base, such as steam pressure expressed in lb per sq in. gauge, or psig.

TABLE I

SIMPLIFIED THICKNESSES FOR PIPE INSULATION*

Nominal Pipe Size, Inches	Outside Dia. of Pipe, Inches	Nominal Thickness, Inches: 1		1-1/2		2		2-1/2		3		3-1/2		4	4-1/2	5
		Actual Thickness and Outer Layer Pipe Size, Inches														
		Thickness	Pipe Size	Thickness	Pipe Size	Thickness	Pipe Size	Thickness	Pipe Size	Thickness	Pipe Size	Thickness	Pipe Size	Thickness	Thickness	Thickness
1/2	0.840	1	2 1/2	1 9/16	3 1/2	2 1/16	4 1/2	2 7/8	6	3 11/32	7	3 7/8	8	4 3/8	4 29/32	5 13/32
3/4	1.050	29/32	2 1/2	1 15/32	3 1/2	1 31/32	4 1/2	2 3/4	6	3 1/4	7	3 3/4	8	4 9/32	4 13/16	5 5/16
1	1.315	1 3/32	3	1 19/32	4	2 1/8	5	2 21/32	6	3 5/32	7	3 21/32	8	4 5/32	4 11/16	5 3/16
1 1/4	1.660	29/32	3	1 21/32	4 1/2	1 15/16	5	2 15/32	6	2 31/32	7	3 15/32	8	3 31/32	4 1/2	5
1 1/2	1.900	1 1/32	3 1/2	1 17/32	4 1/2	2 5/16	6	2 27/32	7	3 11/32	8	3 27/32	9	4 3/8	4 7/8	5 3/8
2	2.375	1 1/16	4	1 19/32	5	2 1/8	6	2 5/8	7	3 1/8	8	3 5/8	9	4 5/32	4 21/32	5 5/32
2 1/2	2.875	1 1/16	4 1/2	1 7/8	6	2 11/32	7	2 7/8	8	3 3/8	9	3 29/32	10	4 13/32	4 29/32	5 9/16
3	3.50	1 1/32	5	1 9/16	6	2 1/16	7	2 9/16	8	3 1/16	9	3 19/32	10	4 3/32	4 19/32	5 1/4
3 1/2	4.00	1 9/32	6	1 13/16	7	2 9/32	8	2 25/32	9	3 11/32	10	3 27/32	11	4 5/16	....	4 31/32
4	4.50	1 1/16	6	1 9/16	7	2 1/16	8	2 9/16	9	3 3/32	10	3 19/32	11	4 3/32	4 3/4	5 3/16
4 1/2	5.00	1 9/32	7	1 13/16	8	2 5/16	9	2 13/16	10	3 11/32	11	3 27/32	12	......	4 1/2	4 15/16
5	5.563	1 1/32	7	1 17/32	8	2 1/32	9	2 9/16	10	3 1/16	11	3 9/16	12	4 7/32	4 21/32	5 5/32
6	6.625	1	8	1 1/2	9	2 1/32	10	2 17/32	11	3 1/32	12	3 11/16	14	4 1/8	4 5/8	5 3/16
7	7.625	......	....	1 17/32	10	2 1/32	11	2 17/32	12	3 1/8	14	3 5/8	15	4 1/8	4 5/8	5 1/8
8	8.625	......	....	1 17/32	11	2 1/32	12	2 11/16	14	3 1/8	15	3 5/8	16	4 3/16	4 11/16	5 3/16
9	9.625	......	....	1 17/32	12	2 5/32	14	2 21/32	15	3 1/8	16	3 21/32	17	4 5/32	4 21/32	5 5/32
10	10.75	......	....	1 19/32	14	2 3/32	15	2 19/32	16	3 3/32	17	3 19/32	18	4 3/32	4 19/32	5 3/32
11	11.75	......	....	1 19/32	15	2 3/32	16	2 5/8	17	3 3/32	18	3 19/32	19	4 3/32	4 19/32	5 3/32
12	12.75	......	....	1 19/32	16	2 3/32	17	2 5/8	18	3 3/32	19	3 19/32	20	4 1/8	4 5/8	5 1/8
14	14.00	......	....	1 1/2	17	2	18	2 1/2	19	3	20	3 1/2	21	4	4 1/2	5
16	16.00	......	....	1 1/2	19	2	20	2 1/2	21	3	22	3 1/2	23	4	4 1/2	5
18	18.00	......	....	1 1/2	21	2	22	2 1/2	23	3	24	3 1/2	25	4	4 1/2	5

*Use nominal thickness for given pipe size in specifying and purchasing.

TABLE II

THERMAL EXPANSION OF PIPES*

IN INCHES PER 100 LINEAR FEET

Temp Deg F	Cast Iron Pipe	Steel Pipe	Wrought Iron Pipe	Copper Pipe	Temp Deg F	Cast Iron Pipe	Steel Pipe	Wrought Iron Pipe	Copper Pipe
−20	0	0	0	0	500	3.847	4.296	4.477	6.110
0	0.127	0.145	0.152	0.204	520	4.020	4.487	4.677	6.352
20	0.255	0.293	0.306	0.442	540	4.190	4.670	4.866	6.614
40	0.390	0.430	0.465	0.655	560	4.365	4.860	5.057	6.850
60	0.518	0.593	0.620	0.888	580	4.541	5.051	5.268	7.123
80	0.649	0.725	0.780	1.100	600	4.725	5.247	5.455	7.388
100	0.787	0.898	0.939	1.338	620	4.896	5.437	5.660	7.636
120	0.926	1.055	1.110	1.570	640	5.082	5.627	5.850	7.893
140	1.051	1.209	1.265	1.794	660	5.260	5.831	6.067	8.153
160	1.200	1.368	1.427	2.008	680	5.442	6.020	6.260	8.400
180	1.345	1.528	1.597	2.255	700	5.629	6.229	6.481	8.676
200	1.495	1.691	1.778	2.500	720	5.808	6.425	6.673	8.912
220	1.634	1.852	1.936	2.720	740	6.006	6.635	6.899	9.203
240	1.780	2.020	2.110	2.960	760	6.200	6.833	7.100	9.460
260	1.931	2.183	2.279	3.189	780	6.389	7.046	7.314	9.736
280	2.085	2.350	2.465	3.422	800	6.587	7.250	7.508	9.992
300	2.233	2.519	2.630	3.665	820	6.779	7.464	7.757	10.272
320	2.395	2.690	2.800	3.900	840	6.970	7.662	7.952	10.512
340	2.543	2.862	2.988	4.145	860	7.176	7.888	8.195	10.814
360	2.700	3.029	3.175	4.380	880	7.375	8.098	8.400	11.175
380	2.859	3.211	3.350	4.628	900	7.579	8.313	8.639	11.360
400	3.008	3.375	3.521	4.870	920	7.795	8.545	8.867	11.625
420	3.182	3.566	3.720	5.118	940	7.989	8.755	9.089	11.911
440	3.345	3.740	3.900	5.358	960	8.200	8.975	9.300	12.180
460	3.511	3.929	4.096	5.612	980	8.406	9.196	9.547	12.473
480	3.683	4.100	4.280	5.855	1000	8.617	9.421	9.776	12.747

To obtain the amount of expansion between any two temperatures, take the proportionate difference between the values given for those temperatures.

*From PIPING HANDBOOK, 4th Edition by Sabin Crocker, 1945. Courtesy of McGraw-Hill Book Co.

TABLE III

NOMINAL WEIGHTS OF WELDED AND SEAMLESS STEEL PIPE*

Nominal Pipe Size (In.)	Sched 10	Sched 20	Schedule 30		Schedule 40		Sched 60	Sched 80	Sched 100	Sched 120	Sched 140	Sched 160
	Plain Ends	Plain Ends	Plain Ends	Threads[2] and Couplings	Plain Ends	Threads[2] and Couplings	Plain Ends	Plain Ends	Plain Ends	Plain Ends	Plain Ends	Plain Ends
1/8	...	...	...	...	0.25	0.25	...	0.32	...	...	...	...
1/4	...	...	...	...	0.43	0.43	...	0.54	...	...	...	...
3/8	...	...	...	...	0.57	0.57	...	0.74	...	...	...	...
1/2	...	...	...	...	0.86	0.86	...	1.09	...	...	...	1.31
3/4	...	...	...	...	1.14	1.14	...	1.48	...	...	...	1.94
1	...	...	...	...	1.68	1.69	...	2.18	...	...	...	2.85
1¼	...	...	...	...	2.28	2.29	...	3.00	...	...	...	3.77
1½	...	...	...	...	2.72	2.74	...	3.64	...	...	...	4.86
2	...	...	...	...	3.66	3.68	...	5.03	...	...	...	7.45
2½	...	...	...	...	5.80	5.82	...	7.67	...	...	...	10.0
3	...	...	...	...	7.58	7.62	...	10.3	...	...	...	14.3
3½	...	...	...	...	9.11	9.21	...	12.5	...	...	...	...
4	...	...	...	...	10.8	10.9	...	15.0	...	19.0	...	22.6
5	...	...	...	...	14.7	14.9	...	20.8	...	27.1	...	33.0
6	...	...	...	...	19.0	19.2	...	28.6	...	36.4	...	45.3
8	...	22.4	24.7	25.0	28.6	28.8	35.7	43.4	50.9	60.7	67.8	74.7
10	...	28.1	34.3	35.0	40.5	41.2	54.8	64.4	77.0	89.2	105	116
12	...	33.4	43.8	45.0	53.6	55.0	73.2	88.6	108	126	140	161
14 OD	36.8	45.7	54.6	...	63.3	...	85.0	107	131	147	171	190
16 OD	42.1	52.3	62.6	...	82.8	...	108	137	165	193	224	241
18 OD	47.4	59.0	82.0	...	105	...	133	171	208	239	275	304
20 OD	52.8	78.6	105	...	123	...	167	209	251	297	342	374
24 OD	63.5	94.7	141	...	171	...	231	297	361	416	484	536
30 OD	99.0	158	197	...	...	...	...	...	...	...	...	...

*ASA—B36.10—1939

[1] Weights are given in pounds per linear foot and are for pipe with plain ends except for sizes which are commercially available with threads and couplings for which both weights are listed.

[2] The weights for line pipe with couplings are slightly greater than shown in Schedules 30 and 40 and may be found in A.P.I. Specification 5-L.

Weights shown in italics in Schedules 30 and 40 are identical with weights for "standard weight" pipe; those in Schedules 60 and 80 are identical with weights for "extra strong" pipe.

The Schedule Numbers indicate approximate values of the expression 1000 × P/S.

TABLE IV

AREAS OF FLANGED FITTINGS AND EQUIVALENT PIPE LENGTHS

Figures in columns under "Area" give surface areas in square feet. Figures in columns under "Pipe Lengths" give the number of feet of pipe which has an area equivalent to the area of the fittings.

Nominal Pipe Size, In.	STANDARD FLANGED FITTINGS, INCLUDING ACCOMPANYING FLANGES									
	Flanged Coupling		90 Deg Ell		Long Radius Ell		Tee		Cross	
	Area	Pipe Lengths	Area	Pipe Lengths	Area	Pipe Lengths	Area	Pipe Lengths	Area	Pipe Lengths
1	.320	.93	.795	2.31	.892	2.59	1.235	3.59	1.622	4.72
1¼	.383	.88	.957	2.20	1.084	2.49	1.481	3.40	1.943	4.47
1½	.477	.95	1.174	2.35	1.337	2.68	1.815	3.64	2.38	4.78
2	.672	1.08	1.65	2.65	1.84	2.96	2.54	4.08	3.32	5.34
2½	.841	1.12	2.09	2.78	2.32	3.08	3.21	4.26	4.19	5.56
3	.945	1.03	2.38	2.60	2.68	2.93	3.66	3.99	4.77	5.70
3½	1.122	1.07	2.98	2.85	3.28	3.13	4.48	4.28	5.83	5.56
4	1.344	1.14	3.53	2.90	3.96	3.36	5.41	4.59	7.03	5.97
4½	1.474	1.13	3.95	3.01	4.43	3.38	6.07	4.63	7.87	6.01
5	1.622	1.11	4.44	3.049	5.00	3.43	6.81	4.67	8.82	6.06
6	1.82	1.049	5.13	2.95	5.99	3.45	7.84	4.53	10.08	5.81
7	2.17	1.097	6.17	3.09	7.38	3.697	9.37	4.69	12.00	6.01
8	2.41	1.067	6.98	3.09	8.56	3.79	10.55	4.67	13.44	5.96
9	3.00	1.19	8.71	3.457	10.57	4.20	13.18	5.23	16.78	6.66
10	3.43	1.22	10.18	3.61	12.35	4.38	15.41	4.47	19.58	6.95
12	4.41	1.32	13.08	3.92	16.35	4.90	19.67	5.89	24.87	7.45
14 OD	5.39	1.465	16.38	4.47	20.17	5.47	24.81	6.78	31.48	8.60
15 OD	6.18	1.572	18.50	4.72	22.92	5.83	27.91	7.10	35.48	9.04
16 OD	6.69	1.60	20.17	4.82	25.41	6.07	30.32	7.23	38.34	9.15

Nominal Pipe Size, In.	EXTRA HEAVY FLANGED FITTINGS, INCLUDING ACCOMPANYING FLANGES									
	Flanged Coupling		90 Deg Ell		Long Radius Ell		Tee		Cross	
	Area	Pipe Lengths	Area	Pipe Lengths	Area	Pipe Lengths	Area	Pipe Lengths	Area	Pipe Lengths
1	.438	1.273	1.015	2.95	1.083	3.148	1.575	4.578	2.07	6.02
1¼	.510	1.172	1.098	2.524	1.340	3.08	1.925	4.425	2.53	5.816
1½	.727	1.459	1.332	2.674	1.874	3.762	2.68	5.381	3.54	7.108
2	.848	1.363	2.01	3.23	2.16	3.473	3.09	4.968	4.06	6.528
2½	1.107	1.463	2.57	3.41	2.76	3.665	4.05	5.378	5.17	6.865
3	1.484	1.619	3.49	3.807	3.74	4.08	5.33	5.815	6.95	7.582
3½	1.644	1.57	3.96	3.782	4.28	4.087	6.04	5.768	7.89	7.535
4	1.914	1.624	4.64	3.938	4.99	4.236	7.07	6.001	9.24	7.843
4½	2.04	1.558	5.02	3.834	5.46	4.170	7.72	5.897	10.07	7.692
5	2.18	1.497	5.47	3.756	6.02	4.134	8.52	5.851	10.97	7.534
6	2.78	1.603	6.99	4.031	7.76	4.475	10.64	6.136	13.75	7.929
7	3.46	1.733	8.62	4.318	9.73	4.874	12.33	6.177	16.83	8.431
8	3.77	1.670	9.76	4.324	11.09	4.913	14.74	6.531	18.97	8.405
9	4.44	1.762	11.44	4.541	13.17	5.228	17.23	6.84	22.10	8.773
10	5.20	1.846	13.58	4.82	15.60	5.538	20.41	7.245	26.26	9.322
12	6.71	2.01	17.73	5.31	18.76	5.622	26.65	7.987	34.11	10.222
14 OD	8.30	2.26	22.31	6.08	25.70	7.02	33.63	9.18	43.15	11.75
15 OD	9.52	2.43	25.28	6.43	29.34	7.47	38.04	9.68	48.79	12.4
16 OD	10.05	2.4	27.18	6.475	31.73	7.575	40.94	9.775	52.35	12.5

TABLE V-A

STANDARD PIPE SIZES OF RED-BRASS AND COPPER PIPE*

Nominal Size, In.	Actual Dimensions, In.			Lb per Ft	
	OD	ID	Wall	Red-Brass	Copper
1/8	.405	.281	.062	.253	.259
1/4	.540	.376	.082	.447	.457
3/8	.675	.495	.090	.627	.641
1/2	.840	.626	.107	.934	.955
3/4	1.050	.822	.114	1.27	1.30
1	1.315	1.063	.126	1.78	1.82
1 1/4	1.660	1.368	.146	2.63	2.69
1 1/2	1.900	1.600	.150	3.13	3.20
2	2.375	2.063	.156	4.12	4.22
2 1/2	2.875	2.501	.187	5.99	6.12
3	3.500	3.063	.219	8.56	8.75
3 1/2	4.000	3.500	.250	11.2	11.4
4	4.500	4.000	.250	12.7	12.9
4 1/2	5.000	4.500	.250	14.1	14.5
5	5.563	5.063	.250	15.8	16.2
6	6.625	6.125	.250	19.0	19.4
7	7.625	7.063	.281	24.6	25.1
8	8.625	8.001	.312	30.9	31.6
9	9.625	8.937	.344	38.0	38.9
10	10.750	10.020	.365	45.2	46.2
11	11.750	11.000	.375	50.8	51.9
12	12.750	12.000	.375	55.3	56.5

*From "Revere Tube and Pipe" 1949.

TABLE V-B

DIMENSIONS AND WEIGHTS OF COPPER WATER TUBES*

TYPE	Size, In.		Wall Thickness In.	ID, In.	ID Area Sq. In.	Weight Lb per Ft
	Nominal Size	Actual OD				
K	3/8	.500	.049	.402	.127	.269
	1/2	.625	.049	.527	.218	.344
	5/8	.750	.049	.652	.333	.418
	3/4	.875	.065	.745	.436	.641
	1	1.125	.065	.995	.778	.839
	1¼	1.375	.065	1.245	1.217	1.04
	1½	1.625	.072	1.481	1.723	1.36
	2	2.125	.083	1.959	3.014	2.06
	2½	2.625	.095	2.435	4.657	2.93
	3	3.125	.109	2.907	6.637	4.00
	3½	3.625	.120	3.385	8.999	5.12
	4	4.125	.134	3.857	11.684	6.51
	5	5.125	.160	4.805	18.133	9.67
	6	6.125	.192	5.741	25.886	13.9
	8	8.125	.271	7.583	45.162	25.9
	10	10.125	.338	9.449	70.123	40.3
	12	12.125	.405	11.315	100.554	57.8
L	3/8	.500	.035	.430	.145	.198
	1/2	.625	.040	.545	.233	.285
	5/8	.750	.042	.666	.348	.362
	3/4	.875	.045	.785	.484	.455
	1	1.125	.050	1.025	.825	.655
	1¼	1.375	.055	1.265	1.257	.884
	1½	1.625	.060	1.505	1.779	1.14
	2	2.125	.070	1.985	3.095	1.75
	2½	2.625	.080	2.465	4.772	2.48
	3	3.125	.090	2.945	6.812	3.33
	3½	3.625	.100	3.425	9.213	4.29
	4	4.125	.110	3.905	11.977	5.38
	5	5.125	.125	4.875	18.666	7.61
	6	6.125	.140	5.845	26.832	10.2
	8	8.125	.200	7.725	46.869	19.3
	10	10.125	.250	9.625	72.760	30.1
	12	12.125	.280	11.565	105.047	40.4
M	2½	2.625	.065	2.495	4.889	2.03
	3	3.125	.072	2.981	6.979	2.68
	3½	3.625	.083	3.459	9.397	3.58
	4	4.125	.095	3.935	12.161	4.66
	5	5.125	.109	4.907	18.911	6.66
	6	6.125	.122	5.881	27.164	8.92
	8	8.125	.170	7.785	47.600	16.5
	10	10.125	.212	9.701	73.914	25.6
	12	12.125	.254	11.617	105.993	36.7

*From "Revere Tube and Pipe" 1949.

TABLE VI

HEAT LOSSES FROM HORIZONTAL BARE STEEL PIPES AND FLAT SURFACES

IN BTU PER SQUARE FOOT OF PIPE SURFACE PER HOUR PER DEGREE FAHRENHEIT TEMPERATURE DIFFERENCE BETWEEN PIPE AND AIR

Pipe Size, In.	Lin Ft Factor*	Temp Difference Deg F Between Pipe Surface and Surrounding Air. Air at 80																							
		50	100	150	200	250	300	350	400	450	500	550	600	650	700	750	800	850	900	950	1000	1050	1100	1150	1200
½	.220	2.12	2.48	2.76	3.10	3.41	3.75	4.10	4.47	4.86	5.30	5.75	6.21	6.70	7.25	7.81	8.40	9.02	9.73	10.42	11.20	11.98	12.81	13.70	14.65
¾	.275	2.07	2.43	2.70	3.08	3.35	3.68	4.03	4.40	4.79	5.23	5.67	6.14	6.61	7.18	7.73	8.32	8.94	9.67	10.34	11.12	11.90	12.73	13.62	14.55
1	.344	2.03	2.38	2.65	2.98	3.29	3.62	3.96	4.33	4.72	5.16	5.60	6.07	6.56	7.11	7.64	8.25	8.87	9.57	10.26	11.04	11.83	12.65	13.53	14.48
1¼	.435	2.00	2.34	2.61	2.94	3.24	3.57	3.91	4.28	4.67	5.10	5.54	6.01	6.50	7.05	7.59	8.19	8.81	9.51	10.18	10.96	11.75	12.57	13.[illegible]	14.40
1½	.498	1.97	2.31	2.57	2.90	3.20	3.52	3.87	4.23	4.62	5.05	5.49	5.96	6.44	6.99	7.54	8.13	8.75	9.45	10.14	10.92	11.70	12.53	13.40	14.36
2	.622	1.93	2.27	2.52	2.85	3.14	3.47	3.81	4.18	4.56	4.99	5.43	5.89	6.38	6.92	7.48	8.07	8.68	9.38	10.07	10.85	11.63	12.46	13.35	14.28
2½	.753	1.90	2.23	2.48	2.81	3.10	3.42	3.76	4.13	4.51	4.94	5.38	5.84	6.32	6.86	7.42	8.01	8.62	9.32	10.01	10.79	11.57	12.40	13.29	14.22
3	.917	1.88	2.20	2.45	2.77	3.06	3.38	3.72	4.08	4.46	4.89	5.33	5.79	6.27	6.81	7.37	7.96	8.57	9.27	9.96	10.73	11.52	12.35	13.23	14.16
3½	1.047	1.86	2.18	2.43	2.74	3.03	3.35	3.69	4.05	4.43	4.86	5.29	5.75	6.24	6.78	7.33	7.92	8.53	9.24	9.92	10.69	11.49	12.31	13.19	14.12
4	1.179	1.84	2.16	2.41	2.72	3.01	3.33	3.66	4.02	4.40	4.83	5.26	5.72	6.21	6.75	7.30	7.89	8.50	9.21	9.89	10.66	11.44	12.27	13.15	14.09
4½	1.310	1.82	2.14	2.38	2.70	2.98	3.31	3.64	4.00	4.37	4.80	5.23	5.69	6.18	6.72	7.27	7.86	8.47	9.18	9.86	10.63	11.42	12.24	13.[illegible]	14.06
5	1.458	1.81	2.12	2.36	2.68	2.96	3.29	3.62	3.98	4.35	4.78	5.21	5.67	6.15	6.70	7.25	7.83	8.45	9.15	9.83	10.60	11.40	12.22	13.08	14.03
6	1.736	1.79	2.10	2.33	2.65	2.93	3.25	3.58	3.94	4.31	4.74	5.18	5.63	6.12	6.66	7.21	7.79	8.42	9.11	9.79	10.56	11.36	12.17	13.05	13.99
7	2.000	1.78	2.08	2.31	2.62	2.91	3.22	3.55	3.91	4.28	4.71	5.15	5.60	6.09	6.63	7.17	7.76	8.39	9.08	9.76	10.53	11.32	12.13	13.03	13.96
8	2.262	1.76	2.06	2.29	2.60	2.89	3.20	3.53	3.88	4.26	4.68	5.12	5.57	6.06	6.60	7.14	7.73	8.35	9.05	9.73	10.50	11.29	12.10	12.99	13.93
9	2.525	1.74	2.04	2.27	2.58	2.87	3.18	3.51	3.86	4.24	4.66	5.09	5.55	6.03	6.57	7.12	7.70	8.31	9.02	9.70	10.47	11.26	12.08	12.96	13.90
10	2.817	1.73	2.03	2.26	2.56	2.85	3.16	3.49	3.84	4.22	4.64	5.07	5.53	6.01	6.55	7.10	7.68	8.29	8.99	9.67	10.45	11.23	12.06	12.93	13.87
12	3.344	1.71	2.01	2.24	2.54	2.82	3.13	3.46	3.83	4.19	4.61	5.04	5.50	5.98	6.52	7.07	7.65	8.26	8.96	9.64	10.42	11.20	12.03	12.90	13.84
14	3.663	1.70	1.99	2.22	2.52	2.80	3.11	3.44	3.79	4.17	4.58	5.02	5.47	5.96	6.49	7.04	7.62	8.23	8.94	9.62	10.39	11.17	12.00	12.88	13.82
16	4.184	1.69	1.97	2.20	2.50	2.78	3.09	3.42	3.77	4.13	4.56	5.00	5.45	5.93	6.47	7.02	7.60	8.21	8.91	9.59	10.36	11.15	11.97	12.85	13.79
18	4.717	1.68	1.96	2.19	2.49	2.76	3.07	3.40	3.75	4.11	4.54	4.98	5.43	5.91	6.45	7.00	7.58	8.19	8.89	9.57	10.34	11.13	11.94	12.82	13.76
20	5.238	1.66	1.95	2.17	2.47	2.74	3.06	3.38	3.73	4.10	4.52	4.96	5.41	5.88	6.42	6.97	7.55	8.17	8.86	9.55	10.32	11.10	11.93	12.80	13.74
24	6.286	1.64	1.93	2.15	2.45	2.72	3.03	3.35	3.70	4.08	4.98	4.93	5.37	5.84	6.39	6.94	7.52	8.02	8.83	9.51	10.28	11.06	11.90	12.77	13.70
Vertical Surface		1.82	2.13	2.40	2.70	2.99	3.30	3.64	4.00	4.39	4.79	5.25	5.70	6.21	6.72	7.28	7.86	8.49	9.18	9.86	10.64	11.42	12.25	13.[illegible]	14.06
Horizontal Surface Facing Upward		2.00	2.35	2.65	2.97	3.26	3.59	3.94	4.31	4.71	5.12	5.57	6.04	6.55	7.07	7.63	8.21	8.83	9.54	10.23	11.01	11.80	12.63	13.50	14.45
Horizontal Surface Facing Downward		1.58	1.85	2.09	2.36	2.63	2.93	3.25	3.61	3.98	4.38	4.82	5.27	5.77	6.27	6.83	7.40	8.01	8.71	9.39	10.16	10.93	11.76	12.64	13.57

Values are for Flat Surfaces four square feet or more in area.
*To secure losses per linear foot, multiply square foot losses in table by this factor. The losses per square foot of pipe surface for pipes larger than 24 inches can be considered the same as the losses for the 24-inch pipe.

Heat savings for various insulating materials cannot be compared unless the same heat transmission data for bare surfaces are used as a basis. The table listed above was calculated on the basis of the method presented by R. H. Heilman, in his paper on "Surface Heat Transmission." (See bibliography.) This method is of a very general nature and allows the calculation of the rate of heat transfer under still air conditions for practically any shape or type of surface.

The actual equations used for calculating the listed values are as follows:

$$q_c = C \left(\frac{1}{D}\right)^{0.2} \left(\frac{1}{T\ avg.}\right)^{0.181} \Delta t^{1.266}$$

$$q_r = 17.4 \times 10^{-10} \times e\,(T_1^4 - T_2^4)$$

where q_c - heat transfer by free convection in Btu per sq ft per hr

C - a constant depending upon the shape of the surface

(C = 1.016 for horizontal cylinders, = 1.235 for long vertical cylinders, = 1.394 for vertical plates, = 1.79 for horizontal plates facing upward, and = 0.89 for horizontal plates facing downward. The constants for the horizontal plates facing downward are reversed when the plates are cooler than the surrounding air.)

D - cylinder diameter in in. or height of vertical plane in in. (The effect of diameter or height becomes constant at a value of approximately 24 in.)

T avg. = 460 plus the average of cylinder or plate surface and surrounding air temp in deg F

Δt = temp difference (deg F) between surface and air

q_r = heat transfer by radiation in Btu per sq ft per hr

e = emissivity of surface (A value of 0.9 can be assumed as the emissivity of most industrial surfaces, such as brick, stone, glass, canvas, asphalt roofing and various colored flat paints at temp below 400 deg F. For highly polished metals "e" may be as low as 0.02.)

T_1 = temp of the hotter surface, deg F + 460

T_2 = temp of surrounding objects, deg F + 460

TABLE VII-A

HEAT LOSS FOR 85% MAGNESIA PIPE INSULATION FOR NOMINAL PIPE SIZES ½ INCH THROUGH 18 INCH*

HEAT LOSS EXPRESSED IN BTU PER LINEAR FOOT PER HOUR FOR INDICATED PIPE TEMPERATURE

Nominal Pipe Size, In.	Nominal Insulation Thickness, In.	Temp of Pipe, Deg F (Temperature of Surrounding Still Air, 80 F)									
		150	200	250	300	350	400	450	500	550	600
		Temp Diff Between Pipe and Surrounding Still Air, Deg F									
		70	120	270	220	270	320	370	420	470	520
½	1	9	17	25	33	41	49	58	68	77	87
	1½	8	14	20	27	34	41	48	56	64	72
	2	6	12	18	24	30	37	43	49	56	62
	2½	6	10	16	21	26	32	37	42	49	57
	3	3	9	15	19	24	30	35	41	46	52
¾	1	11	20	29	39	49	59	70	81	94	105
	1½	8	16	24	33	40	47	57	68	75	82
	2	8	14	20	27	34	40	48	55	62	72
	2½	5	12	17	23	29	35	42	48	54	62
	3	5	11	16	32	27	34	39	45	50	58
1	1	12	22	32	42	52	63	74	85	97	110
	1½	9	17	25	34	43	52	61	70	80	90
	2	8	15	22	29	36	44	52	61	69	78
	2½	7	13	19	26	33	40	47	54	61	69
	3	6	12	18	24	28	36	43	50	57	65
1¼	1	17	29	41	53	61	69	89	110	125	141
	1½	10	18	27	36	46	57	66	75	85	95
	2	9	18	26	35	45	55	63	72	83	93
	2½	8	15	22	30	41	53	58	64	72	81
	3	7	14	21	28	35	43	50	58	66	75
1½	1	16	28	40	53	66	81	92	104	124	144
	1½	16	22	27	43	54	65	76	88	100	113
	2	9	17	25	34	42	51	60	70	80	90
	2½	9	15	22	30	39	48	56	64	73	82
	3	7	14	21	28	35	43	51	59	70	80
2	1	17	32	47	62	78	94	112	130	147	164
	1½	12	24	36	49	61	74	87	100	113	127
	2	9	20	31	42	52	62	73	85	96	108
	2½	9	18	27	36	45	55	67	80	88	96
	3		14	23	33	41	50	59	68	76	87

*See Table I for actual thicknesses of insulation.

TABLE VII-A (Cont'd.)

HEAT LOSS FOR 85% MAGNESIA PIPE INSULATION FOR NOMINAL PIPE SIZES ½ INCH THROUGH 18 INCH

Nominal Pipe Size, In.	Nominal Insulation Thickness, In.	Temp of Pipe, Deg F (Temperature of Surrounding Still Air, 80 F) 150	200	250	300	350	400	450	500	550	600
		Temp Diff Between Pipe and Surrounding Still Air, Deg F 70	120	270	220	270	320	370	420	470	520
2½	1	18	36	54	73	88	104	126	145	166	202
	1½	16	29	42	56	74	113	113	114	129	145
	2	14	24	34	45	57	70	82	95	108	121
	2½	10	19	26	38	47	57	68	80	90	101
	3	9	17	25	34	44	54	63	73	83	94
3	1	24	44	64	85	107	129	152	176	201	226
	1½	21	35	49	63	79	96	113	131	149	167
	2	14	27	40	53	66	80	94	109	125	142
	2½	11	23	35	47	59	71	84	97	110	123
	3	10	21	32	44	54	65	80	96	104	113
3½	1	24	43	62	81	100	119	141	164	189	213
	1½	17	33	49	65	81	97	114	132	151	170
	2	15	29	42	56	71	87	104	121	137	154
	2½	14	25	35	45	59	74	98	102	114	126
	3	12	22	32	42	53	65	77	90	102	115
4	1	28	52	76	100	126	153	179	210	239	269
	1½	20	39	58	77	96	115	135	156	191	226
	2	18	33	48	64	81	98	114	131	145	170
	2½	13	27	41	55	77	90	101	113	129	146
	3	13	25	37	49	62	75	87	98	114	130
4½	1	29	50	71	93	120	148	174	200	228	257
	1½	21	38	55	73	93	114	138	163	181	200
	2	17	32	47	62	79	97	114	132	150	169
	2½	16	28	40	53	68	83	99	115	131	147
	3	13	26	39	52	65	79	94	109	124	140
5	1	43	64	85	107	135	163	193	223	255	287
	1½	26	48	70	92	115	139	166	193	220	247
	2	21	39	57	76	95	115	136	157	179	202
	2½	14	31	48	65	81	97	99	102	137	173
	3	12	24	36	48	59	71	84	98	111	124
6	1	37	73	109	145	181	218	258	299	345	392
	1½	30	56	82	108	135	163	193	224	255	286
	2	22	43	64	85	106	128	152	176	200	244
	2½	19	37	55	74	93	113	133	153	175	197
	3	16	32	48	65	82	110	117	134	153	173

TABLE VII-A (Cont'd.)

HEAT LOSS FOR 85% MAGNESIA PIPE INSULATION FOR NOMINAL PIPE SIZES ½ INCH THROUGH 18 INCH

Nominal Pipe Size, In.	Nominal Insulation Thickness, In.	Temp of Pipe, Deg F (Temperature of Surrounding Still Air, 80 F)									
		150	200	250	300	350	400	450	500	550	600
		Temp Diff Between Pipe and Surrounding Still Air, Deg F									
		70	120	270	220	270	320	370	420	470	520
7	1	34	61	88	116	146	177	210	243	278	313
	2	25	48	71	95	119	143	169	196	225	253
	3	18	35	52	70	89	109	128	147	168	189
8	1½	34	62	90	119	150	182	216	250	285	320
	2	29	54	79	105	132	159	187	216	248	281
	2½	21	43	65	87	106	129	153	178	204	231
	3	19	38	56	75	97	119	139	159	181	204
9	1½	40	74	108	142	180	218	257	296	339	382
	2	29	55	81	107	136	165	195	226	257	288
	2½	24	47	70	94	118	143	169	195	222	250
	3	21	42	63	84	108	132	154	176	195	215
10	1½	41	78	115	152	191	230	271	315	338	408
	2	33	63	93	123	154	186	220	254	300	347
	2½	26	53	80	107	133	160	190	220	249	279
	3	23	37	51	76	94	112	132	153	173	193
12	1½	49	91	133	175	219	263	313	364	426	485
	2	38	73	108	134	172	210	248	286	328	370
	2½	26	57	88	120	149	178	211	244	278	312
	3	23	51	79	107	133	159	180	222	252	282
14	1½	55	102	149	196	247	298	362	407	460	523
	2	44	82	120	158	194	230	278	327	373	420
	2½	35	68	101	134	178	203	245	287	321	355
	3	28	58	88	118	146	175	199	223	267	312
16	1½	61	116	171	224	279	332	400	469	535	601
	2	51	92	133	175	224	274	338	402	442	482
	2½	40	77	114	151	184	228	271	314	358	403
	3	33	66	99	132	166	200	237	274	313	352
18	1½	71	132	193	254	321	388	459	530	604	679
	2	56	104	152	201	253	305	375	445	491	537
	2½	46	85	124	164	207	251	297	344	392	440
	3	37	73	109	146	179	215	258	301	330	386

TABLE VII-B

HEAT LOSS FOR 85% MAGNESIA AND DIATOMACEOUS SILICA COMBINATION PIPE INSULATION FOR NOMINAL PIPE SIZES ½ INCH THROUGH 18 INCH

HEAT LOSS EXPRESSED IN BTU PER LINEAR FOOT PER HOUR AT INDICATED PIPE TEMPERATURE

Nominal Pipe Size, In.	Nominal Insulation Thickness: Inner Layer, In.	Nominal Insulation Thickness: Outer Layer, In.	Temp of Pipe, Deg F (Temperature of Surrounding Still Air, 80 F) 600 / Temp Diff Between Pipe and Surrounding Still Air, Deg F 520	700 / 620	800 / 720	900 / 820	1000 / 920	1100 / 1020	1200 / 1120
½	2	None	81	100	119	139	161	183	207
¾	2	None	90	111	132	155	179	204	230
1	2	None	101	123	148	173	200	227	258
1¼	2	None	115	141	168	197	227	259	292
1½	2	None	123	142	181	212	245	280	316
2	1½	1	116	142	168	196	225	...	...
	1½	1½	106	130	158	182	210	...	...
	1½	2	97	118	141	165	...	...	...
	1½	2½	89	109	130	152	...	...	...
	1½	3	83	102	122	...	...	...	...
	2	1½	...	...	...	...	...	213	240
	2	2	...	...	...	...	...	197	223
	2½	1½	...	...	...	...	...	203	228
	2½	2	...	...	...	...	...	190	213
	2½	2½	...	...	...	...	...	179	200
3	1½	1½	128	156	186	218	251	...	...
	1½	2	115	141	168	197	...	...	...
	1½	2½	106	130	155	181	...	...	...
	1½	3	98	120	144	169	...	...	...
	2	1½	...	...	...	203	233	264	297
	2	2	...	...	...	186	214	...	...
	2	2½	...	...	...	173	199	...	...
	2	3	...	...	...	163	188	...	...
	2½	1½	...	...	...	...	...	252	284
	2½	2	...	...	...	...	...	233	262
	3	1½	...	...	...	...	...	238	267
	3	2	...	...	...	...	...	224	251
	3	2½	...	...	...	...	...	210	237

TABLE VII-B (Cont'd.)

HEAT LOSS FOR 85% MAGNESIA AND DIATOMACEOUS SILICA COMBINATION PIPE INSULATION FOR NOMINAL PIPE SIZES ½ INCH THROUGH 18 INCH

Nominal Pipe Size, In.	Nominal Insulation Thickness: Inner Layer, In.	Nominal Insulation Thickness: Outer Layer, In.	Temp of Pipe, Deg F (Temperature of Surrounding Still Air, 80 F) 600 / Temp Diff Between Pipe and Surrounding Still Air, Deg F 520	700 / 620	800 / 720	900 / 820	1000 / 920	1100 / 1020	1200 / 1120
4	1½	1½	148	182	217	254	292	...	...
	1½	2	133	164	197	231	...	...	...
	1½	2½	124	151	180	210	...	...	...
	1½	3	110	137	164	...	...	...	...
	2	1½	...	...	...	236	271	308	346
	2	2	...	...	...	214	247	283	...
	2	2½	...	...	...	199	229	...	...
	2	3	...	...	...	185	...	...	...
	2½	1½	...	...	...	...	...	292	329
	2½	2	...	...	...	...	...	269	300
	3	1½	...	...	...	...	...	274	309
	3	2	...	...	...	...	...	257	287
	3	2½	...	...	...	...	...	240	270
5	1½	1½	173	211	252	295	340	...	...
	1½	2	153	189	224	262	...	...	...
	1½	2½	140	171	205	...	...	...	...
	1½	3	129	157	189	...	...	...	...
	2	1½	...	...	...	272	313	...	...
	2	2	...	...	...	249	286	...	...
	2	2½	...	...	...	227	...	...	...
	2	3	...	...	...	198	...	...	...
	2½	1½	...	...	...	...	...	332	373
	2½	2	...	...	...	233	268	305	343
	2½	2½	...	...	...	217	251	...	...
	2½	3	...	...	...	204	234	...	...
	3	1½	...	...	...	...	...	312	351
	3	2	...	...	...	...	...	290	329
	3	2½	...	...	...	...	...	272	305
6	1½	1½	189	231	277	322	...	...	...
	1½	2	172	211	253	297	...	...	...
	1½	2½	157	191	229	...	...	...	...
	1½	3	144	177	211	...	...	...	...
	2	1½	...	...	...	311	358	...	...
	2	2	...	...	...	283	324	...	...
	2	2½	...	...	...	257	...	...	...
	2	3	...	...	...	240	...	...	...
	2½	1½	...	...	...	...	...	372	419
	2½	2	...	...	...	263	301	...	...
	2½	2½	...	...	...	242	281	...	...

TABLE VII-B (Cont'd.)

HEAT LOSS FOR 85% MAGNESIA AND DIATOMACEOUS SILICA COMBINATION PIPE INSULATION FOR NOMINAL PIPE SIZES ½ INCH THROUGH 18 INCH

Nominal Pipe Size, In.	Nominal Insulation Thickness		Temp of Pipe, Deg F (Temperature of Surrounding Still Air, 80 F)						
	Inner Layer, In.	Outer Layer, In.	600	700	800	900	1000	1100	1200
			Temp Diff Between Pipe and Surrounding Still Air, Deg F						
			520	620	720	820	920	1020	1120
	2½	3	...	...	...	226	261	...	...
	3	1½	...	...	...	...	...	352	397
	3	2	...	...	...	...	...	322	363
	3½	1½	...	...	...	...	...	332	375
	3½	2	...	...	...	...	...	308	348
8	1½	1½	235	293	350	409	...	...	...
	1½	2	209	257	305	358	...	...	...
	1½	2½	188	230	276	...	...	...	...
	1½	3	171	210	251	...	...	...	...
	2	1½	...	...	315	369	425	...	...
	2	2	...	...	284	331	382	...	...
	2	2½	...	...	262	307	...	...	...
	2	3	...	...	239	280	...	...	...
	2½	1½	...	...	...	...	...	445	502
	2½	2	...	...	...	313	358	...	...
	2½	2½	...	...	...	287	335	...	...
	2½	3	...	...	...	274	313	...	...
	3	1½	...	...	...	...	...	418	471
	3	2	...	...	...	...	...	383	431
	3½	1½	...	...	...	...	...	395	443
	3½	2	...	...	...	...	...	364	410
	3½	2½	...	...	...	...	...	354	399
10	1½	1½	275	338	403	472	...	...	...
	1½	2	242	297	356	...	...	...	...
	1½	2½	216	270	322	...	...	...	...
	1½	3	198	244	291	...	...	...	...
	2	1½	...	...	363	425	489	...	...
	2	2	...	...	326	382	440	...	...
	2	2½	...	...	297	349	...	...	...
	2	3	...	...	275	322	...	...	...
	2½	1½	...	...	...	...	...	524	591
	2½	2	...	...	...	363	415	...	...
	2½	2½	...	...	...	334	383	...	...
	2½	3	...	...	...	309	356	...	...
	3	1½	...	...	...	...	...	491	550
	3	2	...	...	...	...	...	445	502
	3½	1½	...	...	...	...	...	458	518
	3½	2	...	...	...	...	...	424	475
	3½	2½	...	...	...	...	...	391	441

TABLE VII-B (Cont'd.)

HEAT LOSS FOR 85% MAGNESIA AND DIATOMACEOUS SILICA COMBINATION PIPE INSULATION FOR NOMINAL PIPE SIZES ½ INCH THROUGH 18 INCH

Nominal Pipe Size, In.	Nominal Insulation Thickness: Inner Layer, In.	Nominal Insulation Thickness: Outer Layer, In.	Temp of Pipe, Deg F (Temperature of Surrounding Still Air, 80 F): 600 / Temp Diff Between Pipe and Surrounding Still Air, Deg F: 520	700 / 620	800 / 720	900 / 820	1000 / 920	1100 / 1020	1200 / 1120
12	1½	1½	315	386	453	541	...	...	...
	1½	2	276	339	405	...	...	...	...
	1½	2½	247	303	361	...	...	...	...
	1½	3	231	284	339	...	...	...	...
	2	1½	...	...	414	485	556	...	...
	2	2	...	...	368	431	505	...	...
	2	2½	...	...	339	397	...	...	...
	2	3	...	...	302	...	...	...	...
	2½	1½	...	...	...	...	...	592	667
	2½	2	...	...	...	...	475	...	...
	3	1½	...	...	...	...	...	553	625
	3	2	...	...	...	384	445	503	567
	3	2½	...	...	...	356	411	...	...
	3	3	...	...	...	333	384	...	...
	3½	1½	...	...	...	...	...	521	588
	3½	2	...	...	...	...	...	477	538
14	1½	1½	341	418	499	584	...	...	...
	1½	2	301	370	442	...	...	...	...
	1½	2½	269	330	394	...	...	...	...
	1½	3	243	298	...	...	...	...	...
	2	1½	...	...	458	534	615	...	...
	2	2	...	...	405	475	...	...	...
	2	2½	...	...	366	429	...	...	...
	2	3	...	...	339	...	...	...	...
	2½	1½	...	...	...	490	564	640	717
	2½	2	...	...	...	440	506	...	...
	2½	2½	...	...	...	407	...	...	...
	2½	3	...	...	...	373	...	...	...
	3	1½	...	...	...	...	...	594	668
	3	2	...	...	...	410	475	541	...
	3	2½	...	...	...	378	438	...	...
	3	3	...	...	...	354	408	...	...
	3½	1½	...	...	...	...	...	557	629
	3½	2	...	...	...	...	...	509	573
16	1½	1½	383	471	563	659	...	...	...
	1½	2	338	414	493	...	...	...	...
	1½	2½	301	370	441	...	...	...	...

TABLE VII-B (Cont'd.)

HEAT LOSS FOR 85% MAGNESIA AND DIATOMACEOUS SILICA COMBINATION PIPE INSULATION FOR NOMINAL PIPE SIZES ½ INCH THROUGH 18 INCH

Nominal Pipe Size, In.	Nominal Insulation Thickness: Inner Layer, In.	Nominal Insulation Thickness: Outer Layer, In.	Temp of Pipe, Deg F (Temperature of Surrounding Still Air, 80 F) 600 / Temp Diff Between Pipe and Surrounding Still Air, Deg F 520	700 / 620	800 / 720	900 / 820	1000 / 920	1100 / 1020	1200 / 1120
	1½	3	274	336	...	...	...	...	...
	2	1½	...	...	505	591	680	...	...
	2	2	...	...	452	527	...	...	...
	2	2½	...	...	410	477	...	...	...
	2	3	...	...	371	...	...	...	...
	2½	1½	...	...	...	545	626	...	...
	2½	2	...	...	...	486	557	...	...
	2½	2½	...	...	...	445	...	...	...
	2½	3	...	...	...	414	...	...	...
	3	1½	...	...	...	...	...	659	742
	3	2	...	...	...	457	529	604	...
	3	2½	...	...	...	421	486	...	...
	3	3	...	...	...	392	452	...	...
	3½	1½	...	...	...	...	...	614	692
	3½	2	...	...	...	...	...	559	631
	4	1½	...	...	...	...	...	561	6[illegible]
	4	2	...	...	...	...	...	536	6[illegible]
18	1½	1½	423	519	620	727	...	...	...
	1½	2	368	453	545	...	...	...	...
	1½	2½	328	404	483	...	...	...	...
	1½	3	298	366	...	...	...	...	...
	2	1½	...	...	558	652	750	...	...
	2	2	...	...	495	570	...	...	...
	2	2½	...	...	448	...	...	...	...
	2	3	...	...	409	...	...	...	...
	2½	1½	...	...	...	599	689	...	...
	2½	2	...	...	...	538	619	...	...
	2½	2½	...	...	...	491	...	...	...
	2½	3	...	...	...	436	...	...	...
	3	1½	...	...	...	...	...	730	821
	3	2	...	...	...	500	577	660	...
	3	2½	...	...	...	461	532	...	...
	3	3	...	...	...	429	494	...	...
	3½	1½	...	...	...	...	...	671	755
	3½	2	...	...	...	...	...	618	691
	4	1½	...	...	...	...	...	629	709
	4	2	...	...	...	...	...	586	654

TABLE VIII-A

HEAT LOSS FOR 85% MAGNESIA BLOCK INSULATION. VERTICAL POSITION

HEAT LOSS EXPRESSED IN BTU PER SQUARE FOOT PER HOUR AT HOT SURFACE TEMPERATURE

Insulation Thickness, In.	Surface Temp, Deg F (Temperature of Surrounding Still Air, 80 F)										
	100	150	200	250	300	350	400	450	500	550	600
	Temp Diff Between Surface and Surrounding Still Air, Deg F										
	20	70	120	170	220	270	320	370	420	470	520
1	6	21	40	50	70	89	108	127	146	. . .	. . .
1½	5	15	26	38	50	62	75	88	103	119	135
2	3	11	20	29	38	48	62	68	80	91	103
2½	2	9	16	23	31	39	47	56	65	75	84
3	. . .	5	13	19	26	33	40	47	55	63	71
3½	. . .	4	11	17	23	29	35	41	48	54	61
4	. . .	. . .	11	16	20	25	31	36	42	47	54

TABLE VIII-8

HEAT LOSS FOR 85% MAGNESIA AND DIATOMACEOUS SILICA COMBINATION BLOCK INSULATION. VERTICAL POSITION

HEAT LOSS EXPRESSED IN BTU PER SQUARE FOOT PER HOUR AT HOT SURFACE TEMPERATURE

Insulation Thickness		Surface Temp, Deg F (Temperature of Surrounding Still Air, 80 F)						
Inner Layer, In.	Outer Layer, In.	600	700	800	900	1000	1100	1200
		Temp Diff Between Surface and Surrounding Still Air, Deg F						
		520	620	720	820	920	1020	1120
1½	1½	73.4	90.0	108.0	...	...	...	...
	2	62.3	77.2	92.1	...	...	...	...
	2½	54.2	66.7	...	...	...	...	...
	3	48.1	58.3	...	...	...	...	...
2	1½	...	...	94.6	111.0	...	...	...
	2	...	...	82.2	96.3	...	...	...
	2½	...	...	72.6	...	...	...	...
	3	...	...	65.0	...	...	...	...
2½	1½	...	...	84.7	98.8	114.0	...	...
	2	...	...	74.3	87.2	100.0	...	...
	2½	...	...	66.4	...	...	...	...
	3	...	...	60.1	...	...	...	...
3	1½	...	...	...	...	...	117.0	132.0
	2	...	...	...	79.8	92.1	105.0	...
	2½	...	...	...	71.8	82.6	...	...
	3	...	...	...	65.6	75.5	...	...
3½	1½	...	...	...	...	...	107.0	121.0
4	1½	...	...	...	...	...	97.9	110.0
	2	...	...	...	...	...	88.8	99.6
4½	1½	...	...	...	...	...	90.5	102.0
	2	...	...	...	...	...	83.8	93.0

TRADE NAMES OF 85% MAGNESIA AND DIATOMACEOUS SILICA INSULATION

	TRADE NAME*	MANUFACTURER*
85% MAGNESIA INSULATION	Superlite	The Philip Carey Manufacturing Company
	Thermalite	Ehret Magnesia Manufacturing Company
	J-M 85% Magnesia	Johns-Manville Sales Corporation
	Featherweight	Keasbey & Mattison Company
	Custom Molded	Mundet Cork Corporation
	Precision Molded	Pabco Products Incorporated
DIATOMACEOUS SILICA INSULATION	Hi-Temp	The Philip Carey Manufacturing Company
	Temp-Chek	The Philip Carey Manufacturing Company
	Enduro	Ehret Magnesia Manufacturing Company
	Superex	Johns-Manville Sales Corporation
	Hy-Temp	Keasbey & Mattison Company
	Type M	Mundet Cork Corporation
	Type 3 19	Mundet Cork Corporation
	Prasco 15C	Pabco Products Incorporated
	Prasco 19C	Pabco Products Incorporated

*Trade names registered or copyrighted by manufacturers.

SYMBOLS OF SUPERIOR INSULATIONS

SAVE HEAT WITH EHRET INSULATIONS

JOHNS-MANVILLE JM PRODUCTS

MUNDET

K&M best in asbestos

Carey

PABCO PRECISION MOLDED INSULATIONS

GLOSSARY OF TRADE TERMS

ASBESTOS: Asbestos products such as asbestos cloth jackets, asbestos tape, asbestos paper, and asbestos cement, all made of mined asbestos fiber, are used as finishing materials where high heat resistance combined with nonflammability is desired.

BANDS: Metal strips, sometimes called strapping, made of steel finished in black or gold lacquer, aluminum, brass, galvanized steel, stainless steel, zinc, bronze, and monel metal. They are used as fastening on insulation finished with pasted canvas jackets and for securing block insulation to equipment such as tanks, etc., the particular material of which the bands are made depending upon the requirements of the installation.

BLOCKING IN: The process of applying insulation blocks to irregular surfaces such as fittings, valves, ribbed equipment, etc.

BREAKING THE JOINT, BROKEN JOINT: In double-layer construction, staggering the joints in the outer layer with respect to the joints in the inner layer.

CABLE: Steel cable, usually ⅛ in. in diameter, used to fasten insulation to equipment surfaces.

CANVAS: Cotton cloth used as jacketing for pipe and equipment insulation. Canvas jacketing is used in weights ranging from 2 to 8 oz per square yard. Sewed canvas jacketing is generally an 8-oz canvas.

CEMENT: Finish Cement (soft). This is a fibered asbestos cement mixed with a heat-resistant binder. It may be given a hard surface by troweling and is used where there is little likelihood of wetting.

Finish Cement (hard). This is a mixture of soft cement and portland cement, generally in the ratio of 1 of portland to 2 or 3 of asbestos by weight. It produces a harder finish and is resistant to occasional wetting.

Insulating Cement. 85% Magnesia and diatomaceous silica in crushed form. It is mixed with water and troweled in place.

Lagging Cement. Prepared from a polyvinyl acetate plastic emulsion and used to cement jacketing material such as canvas to insulation.

Asphalt (Lap) Cement. An asphaltic sealing compound used to cement or seal asphalt-saturated weatherproof jackets.

CLIPS: Small pieces of metal which are welded to a surface prior to insulation application, to secure wires or bands holding the insulation.

FIBROUS ADHESIVE: A thick, gummy, silicate-cement base material, having some asbestos fiber mixed with it, and used where necessary to aid in applying insulation.

LAGGING: Any type of jacketing material such as canvas, asbestos, etc. Insulation blocks used on steam locomotive boilers are sometimes called lagging.

MESH WIRE NETTING: Also called netting, chicken wire, hex mesh, etc. It is zinc-coated iron or steel hexagonal wire mesh, mesh size used depending upon the particular installation involved. Most commonly used are 1-in. and 2-in. mesh.

MITERING: Cutting insulation blocks and sections to fit pipe bends and other sharply curved surfaces. Mitering can be done with either a knife or a saw, or simply by shaping the molded insulation by hand.

PASTE: A cold water paste made from organic materials and furnished in dry powder form. Also used in reference to a liquid silicate of soda paste, which is heat-resistant.

PIPE PROTECTOR: Metal cap, made of 20-gauge aluminum, and fastened with a tongue clasp. Applied over exposed ends of pipe insulation.

PLASTIC WEATHERPROOFING: An asphalt emulsion mixed with asbestos fiber of troweling consistency that is resistant to fire and weather.

POINTING UP: Filling in of voids, depressions, etc., in insulation with cement.

REMOVABLE INSULATION: Sometimes called "portable insulation." Consists of molded insulation, either block or pipe insulation, and a wire form constructed so that it can be removed and replaced quickly and easily, as often as necessary, with minimum damage to itself or to the adjacent insulation.

ROSIN PAPER: Sometimes called building paper. A rosin-sized sheathing paper weighing about 40 lb per roll of 500 sq ft.

SHEET METAL JACKET: A jacket made of galvanized iron, equipped with circumferential and longitudinal expansion joints when necessary. Light metals are also used in some cases.

STAPLES: Short iron staples applied with a stapling machine or hammered in with a hammer.

STRAPPING: Signode, Acme or similar metal strapping that can be pulled tight with tensioning tools.

WEATHERPROOFING FELT: An asbestos felt jacketing, impregnated or "saturated" with asphalt. Also available coated with asphalt, in addition to being impregnated. Another type consists of an impregnated felt layer with an outer unsaturated layer, for greater fire resistance.

WIRE: Annealed iron, copper, galvanized steel, copperweld, and monel wire, the gauge used depending upon the requirements of the particular installation.

SELECTED BIBLIOGRAPHY

1. W. H. McAdams: HEAT TRANSMISSION. *McGraw-Hill Book Company*, 3rd edition, 1954.

2. Keenan and Keyes: THERMODYNAMIC PROPERTIES OF STEAM. *John Wiley & Sons, Inc.*, 1936.

3. HEATING, VENTILATING, AIR CONDITIONING GUIDE. *American Society of Heating and Ventilating Engineers*, Annual.

4. L. B. McMillan: HEAT TRANSFER THROUGH INSULATION IN THE MODERATE AND HIGH TEMPERATURE FIELDS—A STATEMENT OF THE EXISTING DATA. *ASME Transactions*, Vol. 48, 1926.

5. R. H. Heilman: TRANSMISSION OF HEAT THROUGH INSULATION. *Mechanical Engineering*, July, 1930, Vol. 52.

6. Marks, MECHANICAL ENGINEERS' HANDBOOK. *McGraw-Hill Book Company*, 5th Edition, 1951.

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