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PIPING

E3-3.1

ENGINEERING

STANDARD

FITTINGS, GASKETS, and BOLTING MATERIAL SELECTION CHARTS

CELANESE CORPORATION OF AMERICA

Central Engineering

Charlotte Office

000097

Approved June 5, 1962

CELANESE CORPORATION OF AMERICA PIPING FITTINGS, GASKETS, and BOLTING MATERIAL SELECTION CHARTS Sponsor - Chemcel	ENGINEERING STANDARD E3-3.1		
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1. SCOPE

This standard covers selection charts for fittings, gaskets and bolting material intended for use in designing piping systems. Manufacturers' recommendations and ASA Standards should be followed in all cases where other materials not included in this standard are used.

2. GENERAL

The purpose of this standard is to provide the designer and material take-off men with convenient charts to serve as a guide in the selection of fittings, gaskets and bolting materials suitable for service equivalent to the piping specified. The items shown are not ordinarily specified on piping drawings, but their specifications must be clearly set forth on the bills of material for purchasing and stores use and for use of the pipe fabricators and erectors. Use of the charts will expedite the job of material take-off men and serve as an aid in obtaining a more consistent quality of material specified in the design and fabrication of piping systems.

3. FITTING SELECTION

Fittings should be selected from the following chart according to the type of pipe required. For any fittings not included refer to manufacturers' recommendations or ASA Piping Standards.

FITTING SELECTION CHART

Pipe (Code)	Fittings
53 W 53 A 53 B 83 A (1-1/2" & smaller only) 120 W 120 G (3" & larger) 106 A	(1)(4)*WPB Seamless Carbon Steel for use with ASTM A-106 Grade B pipe, ASTM A-234 Marking Symbol "WPB" Schedule No. "Same as Pipe"
120 G (2-1/2" & smaller)	*150# Screwed Malleable Iron Galvanized Crane, Walworth, Vogt, or Grinnel
106 B	(1)(4)*WPB Seamless Carbon Steel for use with ASTM A-106 Grade B pipe, ASTM A-234 Marking Symbol "WPB" Schedule "Same as pipe"
AL 3	(1) Forged 6061 Aluminum Alloy
Cu 42 CU 42 T B 43 B 43 T	Bronze Sweat Fittings 150 PSI at 500 F, Silver Solder Joints - Walworth or equal
304 310 316 317 161 S 165 S SL GL AGL	(1) *ASTM A-312 Type 304 Butt-Weld L.R. (1) ASTM A-312 Type 310 Butt-Weld L.R. (1) *ASTM A-312 Type 316 Butt-Weld L.R. (1) ASTM A-312 Type 317 Butt-Weld L.R. (1) ASTM B-161 Seamless (1) ASTM B-165 Seamless Butt-Weld (1) Saran lined Carbon Steel, any grade flan As recommended by manufacturer As recommended by manufacturer

NOTE: 1) All fittings shall be same schedule as pipe except where pressure ra is specified above.
2) For stainless steel tubing, use mitered fittings when tubing size fi tings are not available.
3) Fittings are not coded on drawings. This standard to be used primar for fitting selection and for material take-off.
4) ASTM A-105-I socket weld fittings may be substituted for 1-1/2" and smaller pipe (Symbol for socket weld fittings to be shown on drawing

*Standard fittings used within the Corporation.

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4. GASKET SELECTION

Gaskets listed in the following chart are recommended for use with flanges of various pressure ratings and facings.

The chart is set up in tabular form with a letter code to indicate the type of gasket. The letter code is applied only for ease in selecting the gaskets from this standard and is not meant to be used as a means of identification on drawings, specifications or warehouse records. Where identification of gaskets is required, it should be spelled out.

The material listed is adequate to cover gasket requirements for general piping installations throughout the Corporation. It is recognized that each plant may have areas where special materials are required. These requirements should be considered "special" and a specification sheet added to the standards by the plant concerned. Gasket materials found satisfactory in some specific problem areas may be found in Engineering Standard E12-2.1.

GASKET SELECTION CHART

Flange or Flanged Valve Description			
Material	Type	Rating, PSI	Gasket Symbol *
Iron	Flat Face	25	B
Iron	Flat Face	125	B
Iron	Raised Face	250	A
Carbon Steel	Flat Face	150	B
Carbon Steel	Raised Face	150, 300, 400	A
Carbon Steel	Raised Face	600	E (1)
Carbon Steel	Raised Face	900, 1500, 2500	E
Carbon Steel	Ring Joint	All	F
Carbon Steel	Small Tongue & Groove	All	G (2)
Stainless Steel	Full Face Corrosion	150	D
Stainless Steel	Std. ASA Raised Face	150, 300	C
Stainless Steel	Raised Face	600	E
Stainless Steel	Lap Joint	150, 300	C
Stainless Steel	Lap Joint	600	E
Nickel	Flat Face	150	B
Monel	Flat Face	150	B
Alloy 20	Flat Face	150	D
Bronze	Flat Face	150, 300	D
Karbate	Raised Face	-	J
Aluminum	Flat Face	150	D
Aluminum	Raised Face	150	C
Glass or Glass Lined	Flat Face	125	H
Porcelain	Raised Face	-	J

*Refer to next page for explanation of gasket symbols AND Notes (1) and (2)

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4.1 Explanation of Gasket Code

Gasket Symbol	Gasket Specification	
A	Ring Type 1/16" Tk	Preferred: Bellmont 585 or Crane 888
B	Full Face 1/16" Tk	
C	Ring Type 1/16" Tk	Acceptable: Garlock 8748 or Anchor 451
D	Full Face 1/16" Tk	
E	Type 304 stainless steel spiral wound, asbestos inserted, .175" thick gasket with .125" thick metal gauge ring, ring shape, Flexitallic Style CG or equal.	
F	Steel rings 4-6% chrome, 1/2" moly, 130 maximum Brinnell hardness, oval or octagonal ASA or API Standard. Cup grease before installation.	
G	Lead - 1/16" thick. Ring type.	
H	Teflon or Teflon jacketed rubber full face	
J	Teflon or Teflon jacketed rubber ring type	

(1) Where 600# flanges or valves are required by service temperatures and pressures, gasket "E" shall be used. Where standard procedure calls for 600# flanges or valves on a service which could use flanges or valves of a lower rating, gasket "A" shall be used.

(2) Small tongue and groove flanges shall be used only for ammonia service.

Should other types of gaskets be required, assign each a code continuing with "K" and add to this sheet for construction standards.

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5. BOLTING SELECTION

Flange bolting material is selected according to the type of flanges and facings. A bolting code is ordinarily not required on piping drawings.

The following table specifies the type of bolting material required for specific flanges and is followed by dimensional sheets for bolts and studs. These sheets will be of considerable value when preparing a material list as well as assuring proper installation in the field.

Minimum bolting requirements shall be in accordance with ASA B16.5 and Paragraph 616 of the ASA Piping Code, B31.1.

5.1 Specifications for Flange Bolting Material. Flanges and flanged valves listed below require carbon steel machine bolts equivalent to ASTM A 307 Grade B, without heat treatment other than stress relief.

1) 250# Raised Face Iron Flanges
2) Any Flat Face Iron Flange Joined with a Raised Face Flange
3) 150# Raised Face Aluminum Flanges
4) Glass, glass lined, porcelain, or porcelain lined valves or flanges
5) Cast iron split flanges for Haveg pipe

All other flanges and flanged valves require heat treated carbon steel (ASTM A 261), or alloy steel (ASTM A 193) bolting material. Stud bolts are required for high temperature services.

BOLT AND NUT SPECIFICATIONS*

Item	Description	Material	Thread	Dimensions
Stud Bolts	Alloy Steel Continuous Thread	ASTM A-193 Grade B-7	ASA B-1.4	ASA B-18.2
Nuts for Stud Bolts	Heavy Hex Semi-finished	ASTM A-194 Grade 2H	ASA B-1.4	ASA B-18.2
Machine Bolts	Regular Square Unfinished	ASTM A-307 Grade B	Coarse ASA B-1.1	ASA B-18.2
Nuts for Machine Bolts	Heavy Hex Semi-finished	ASTM A-307 Grade B	Coarse ASA B-1.1 Class 2 fit	ASA B-18.2

*This chart shows that alloy steel bolt studs and machine bolts are recommended. Substitutions may be made in accordance with ASA B16.5 and ASA B31.1.

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5.2 Stud Bolt Dimensions.

150# F L A N G E D J O I N T S

Nominal Pipe Size	Diameter of Bolt	Number of Bolts	L E N G T H		
			1/16" R.F.	Corr. Std.*	R..
1/2	1/2	4	2-1/2	2	-
3/4	1/2	4	2-1/2	2	-
1	1/2	4	2-1/2	2	3
1-1/2	1/2	4	3	2-1/2	3-
2	5/8	4	3-1/2	2-1/2	4
3	5/8	4	3-1/2	3	4-
4	5/8	8	3-1/2	3	4-
6	3/4	8	4	3-1/2	4-
8	3/4	8	4-1/2	4	5
10	7/8	12	5	4-1/2	5-1
12	7/8	12	5	4-1/2	5-1
14	1	12	5-1/2		6
16	1	16	5-1/2		6
18	1-1/8	16	6		6-1
20	1-1/8	20	6-1/2		7
24	1-1/4	20	7		8

300# F L A N G E D J O I N T S

Nominal Pipe Size	Diameter of Bolt	Number of Bolts	L E N G T H		
			1/16" R.F.	Corr. Std.*	R.J
1/2	1/2	4	2-1/2	-	-
3/4	5/8	4	3	-	-
1	5/8	4	3	-	-
1-1/2	3/4	4	3-1/2	-	-
2	5/8	8	3-1/2	-	4-1
3	3/4	8	4-1/2	-	5
4	3/4	8	4-1/2	-	5-1
6	3/4	12	5	-	6
8	7/8	12	5-1/2	-	6
10	1	16	6	-	7-1
12	1-1/8	16	7	-	7-1
14	1-1/8	20	7	-	8
16	1-1/4	20	7-1/2	-	8-1
18	1-1/4	24	8	-	9
20	1-1/4	24	8-1/2	-	9-1
24	1-1/2	24	9-1/2	-	10-1

NOTES:

* Corrosion standard for use with corrosion standard stainless steel flat faced flanges.

Lengths given do not include height of bolt end crowns.
Lengths include thickness of two nuts.

600# F L A N G E D   J O I N T S

Nominal Pipe Size	Diameter of Bolt	Number of Bolts	L E N G T H		
			1/4" R.F.	T & G	R.J
1/2	1/2	4	3	3	
3/4	5/8	4	3-1/2	3-1/2	3-1
1	5/8	4	3-1/2	3-1/2	3-1
1-1/2	3/4	4	4-1/2	4	4-1
2	5/8	8	4-1/2	4	4-1
3	3/4	8	5	5	5-1
4	7/8	8	6	5-1/2	6
6	1	12	7	6-1/2	7
8	1-1/8	12	8	7-1/2	8
10	1-1/4	16	8-1/2	8-1/2	9
12	1-1/4	20	9	8-1/2	9
14	1-3/8	20	9-1/2	9	9-1/
16	1-1/2	20	10	10	10-1/
18	1-5/8	20	11	10-1/2	11
20	1-5/8	24	11-1/2	11-1/2	12
24	1-7/8	24	13	13	13-1/

900# F L A N G E D   J O I N T S

Nominal Pipe Size	Diameter of Bolt	Number of Bolts	L E N G T H		
			1/4" R.F.	T & G	R.J.
3	7/8	8	6	5-1/2	6
4	1-1/8	8	7	6-1/2	7
6	1-1/8	12	8	7-1/2	8
8	1-3/8	12	9	8-1/2	9
10	1-3/8	16	9-1/2	9	9-1/2
12	1-3/8	20	10	10	10-1/2
14	1-1/2	20	11	10-1/2	11-1/2
16	1-5/8	20	11-1/2	11	12
18	1-7/8	20	13	13	13-1/2
20	2	20	14	13-1/2	14-1/2
24	2-1/2	20	17-1/2	17	18

NOTES:

Lengths given do not include height of bolt end crowns.
Lengths include thickness of two nuts.

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REVISION RECORD
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1, 2, 3, 4, 5, & 6

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DATE	REV. NO.	NO.
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CELANESE PLASTICS COMPANY
BISHOP PLANT

PLANT ENGINEERING MANUAL
REVISION RECORD

INSULATION

BY	DWG.	REVIEWED	APPROVED	ISSUE DATE
				11/14/74

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REV	DATE	BY	APPROVAL	PAGES	REMARKS
0	11/14/74		a.J.D.	79	Issued for Celanex Phase II Expansion
1	12/1/75			88	New Issue

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1. SCOPE

A statement to explain the contents and logic of this section.

2. INSULATING MATERIALS

2.1 CALCIUM SILICATE

2.1.1 Description

Gives type and form of pipe covering desired. Inhibitor is required since calcium silicate is sometimes used on stainless steel piping. Some calcium silicate insulation contains asbestos. CAUTION: Handling of asbestos containing materials may be hazardous to the health of the worker. Precautions are required as per OSHA

2.1.2 Service

2.1.2.1 Temperature Range

Calcium silicate is used for pipe covering above the 450°F limit of most fiberglass coverings. When used for applications above 1200°F consult manufacturer's data for suitability of the product used.

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2.1.2.2 Components Insulated

Used on small diameter equipment due to ease of application. No case of stress corrosion cracking attributable to calcium silicate insulation has been experienced in the drier non-coastal locations; therefore, inhibitied calcium silicate is used at these locations for economy.

2.1.3 Thickness

Method of calculating thickness is given because rapidly changing economic conditions make a standard thickness specification impractical. Temperatures above 600°F require multi-layer insulation to protect the weather-proofing and prevent excessive heat loss at the joints.

2.2 MINERAL WOOL

2.2.1 Description

Gives type of covering desired. This may be altered to fit services as required by the Project Engineer. It is a non-asbestos containing material conforming to the requirements of the OSHA rulings.

2.2.2 Service

2.2.2.1 Temperature Range

Mineral wool may be used up to 1200°F depending on manufacturer and binder material.

2.2.2.2 Components Insulated

Mineral wool does not contain chlorides which would prohibit use on stainless steel.

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2.2.3 Thickness

Method of calculating thickness is given because rapidly changing economic conditions make a standard thickness specification impractical. Temperatures above 600°F require multi-layer insulation to protect the weather-proofing and prevent excessive heat loss at the joints.

2.3 CELLULAR GLASS

2.3.1 Description

Gives the acceptable material type and forms. The acceptable form will depend on the application, local insulator preference, and installed cost.

2.3.2 Service

2.3.2.1 Temperature Range

800°F is the upper limit for cellular glass insulation. 16°F is the lowest temperature normally encountered in our work; however, cellular glass can be used at much lower temperatures.

2.3.2.2 Components Insulated

Cellular glass insulation is used for low temperature service because it is imprevious to moisture. It is used on equipment because it is durable and light weight. Some coastal locations have experienced stress-corrosion cracking of stainless piping when insulated with inhibited calcium silicate and therefore cellular glass may be specified over stainless steel in coastal locations or where humidity levels are normally high.

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2.3.3.1 Thickness

Method of calculating thickness is given because rapidly changing economic conditions make a standard thickness specification impractical. Temperatures above 600°F require multi-layer insulation to protect the weather-proofing and prevent excessive heat loss at the joints.

2.4 FIBERGLASS

2.4.1 Description

Gives the form of covering desired.

2.4.2 Service

2.4.2.1 Temperature Range

Most fiberglass materials are limited to about 450°F due to the binders. Certainteed 850 is usable to 850°F.

2.4.2.2 Components Insulated

Used for economy and eas of application wherever it can be used.

2.4.3 Thickness

Method of calculating thickness is given because rapidly changing economic conditions make a standard thickness specification impractical. Temperatures above 600°F require multi-layer insulation to protect the weather-proofing and prevent excessive heat loss at the joints.

2.5 INSULATING CEMENT

2.5.1 Description

Gives the type and some acceptable brands which have been tested and found to mix well, adhere to the insulated surface, produce a smooth finish, and hold up well in service.

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2.5.2 Service

2.5.2.1 Temperature Range

Mineral wool insulating cement is not used in low temperature service and the upper limit varies with the product used.

2.5.2.2 Components Insulated

Used where rigid forms are impractical and to produce a smooth surface free of voids where mastic weatherproofing is used over calcium silicate, fiberglass, or cellular glass insulation.

2.5.3 Thickness

Gives the thickness when used as the insulating material.

2.6 CORK-FILLED MASTIC

2.6.1 Description

Gives the type of product and an acceptable brand which has been successfully used.

2.6.2 Service

2.6.2.1 Temperature Range

Temperatures above and below this range justify materials with greater insulating values.

2.6.2.2 Components Insulated

Used for ease of application and economy where a minimum of insulation is required.

2.6.3 Thickness

Thickness will depend upon the severity of service conditions. Consult manufacturer's data.

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2. INSULATING MATERIALS (Continued)

2.6 CORK-FILLED MASTIC (Continued)

2.6.2 Service

2.6.2.1 Temperature Range

Temperatures above and below this range justify materials with greater insulating values.

2.6.2.2 Components Insulated

Used for ease of application and economy where a minimum of insulation is required.

2.6.3 Thickness

Thickness will depend upon the severity of service conditions. Consult manufacturer's data.

2.7 ASBESTOS TAPE

2.7.1 Description

Type and form desired to give good coverage and not be too wide to be applied around tubing bends.

2.7.2 Service

2.7.2.1 Temperature Range

Below 180°F use foamed plastic because it is easier to apply.

2.7.2.2 Components Insulated

Can be easily applied around tight bends and wrapped around valves and fittings.

2.7.3 Thickness

Thickness required for personnel protection and conservation of heat.

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2. INSULATING MATERIALS (Continued)

2.8 FOAMED PLASTIC

2.8.1 Description

Gives type and form desired.

2.8.2 Service

2.8.2.1 Temperature Range

Upper temperature limit is 180°F. Is economical to apply since no weather-barrier is required.

2.8.2.2 Components Insulated

Can be easily applied around bends.

2.8.3 Thickness

Thickness necessary to prevent condensation in cold service is required.

2.9 URETHANE

2.9.1 Description

Gives the forms of covering desired.

2.9.2 Service

2.9.2.1 Temperature Range

A preferred material for low temperature. Above 225°F, it will degrade and release harmful vapors.

2.9.2.2 Chemical Resistance

Urethane will be dissolved or degraded by the listed chemicals.

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2. INSULATING MATERIALS (Continued)

2.9 URETHANE (Continued)

2.9.2.3 Other Limitations

Sunlight will degrade urethane and cause loss of adhesion and insulating properties. Moisture will react with and degrade it. Urethane will burn and release smoke and combustible gases. Degradation from any cause can release harmful gases which can accumulate to dangerous levels in confined spaces.

2.9.2.4 Components Insulated

Spray urethane is generally economical only on large surface area vessels.

2.9.3 Thickness

Method of calculating thickness is given because rapidly changing economic conditions make a standard thickness specification impractical. Normal tolerance for spray is -0, +25%. Above 3" thick spray adhesion to metal would be questionable, and 3" is adequate to prevent condensate in cold service at the minimum temperature and to give negligible heat loss in hot service at the maximum temperature.

3. WEATHER-BARRIER MATERIALS

3.1 ALUMINUM

3.1.1 Description

These alloys are easily obtainable and are easy to work with. These are the minimum thickness of material that can be easily handled without damage due to wrinkling.

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3. WEATHER-BARRIER MATERIALS (Continued)

3.1.2 Service

3.1.2.1 Moisture Barrier

To prevent corrosive attack to the aluminum due to high humidity.

3.1.2.2 Components Jacketed

Type of aluminum used on straight run piping is largely plant preference. The use of aluminum elbow, valve, tee, and flange jackets will depend on economics. Jacketing of vessels and heat exchanger shells is a matter of plant preference. Corrugated aluminum is not used on horizontal vessels and heat exchangers because on a large diameter shell the corrugations would allow water to stand and seep into the insulation at circumferential laps.

3.2 MASTIC

3.2.1 Description

These mastics have been used at the various plants and are preferred.

3.2.2 Service

All insulation not jacketed with aluminum or pvc must be covered with a mastic weather-barrier to protect the insulation.

3.3 POLYVINYL CHLORIDE (PVC)

3.3.1 Description

Describes types of material available. Ultraviolet light will imbrittle non-UV stabilized formulations. Test methods used to describe burning properties of plastics are being revised.

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3. WEATHER-BARRIER MATERIALS (Continued)

3.3 POLYVINYL CHLORIDE (PVC) (Continued)

3.3.2 Service (Continued)

3.3.2.1 Temperature Range

Above 150°F, PVC will lose dimensional stability.

3.3.2.2 Chemical Resistance

Chemicals listed will dissolve or swell PVC.

3.3.2.3 Components Jacketed

Lists pipe and fittings for which jacketing is available, and sheet stock for equipment.

3.4 OTHER MATERIALS

Stainless steel should be used in environments corrosive to aluminum or in which PVC or mastic are not desired.

4. ACCESSORIES

4.1 JOINT SEALER

4.1.1 Description

These joint sealers have proven economical and satisfactory in service.

4.1.2 Service

To completely seal the insulation to prevent moisture vapor from entering and condensing or freezing which would damage the insulation or reduce its effectiveness.

4.2 GLASS CLOTH

4.2.1 Description

These materials are easy to work and have been proven acceptable in use.

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4. ACCESSORIES (Continued)

4.2 GLASS CLOTH (Continued)

4.2.2 Service

Asphalt impregnated glass cloth produces a better bond when used with solvent cutback mastics.

4.3 WIRE NETTING

4.3.1 Description

Common company practice to use corrosion resistant material.

4.3.2 Service

To prevent excessive cracking of the insulation.

4.4 BANDS

4.4.1 Description

Stainless steel used for strength and corrosion resistance.

4.4.2 Service

4.4.2.1 Aluminum Jacketing

Use of bands in place of screws is plant preference.

4.4.2.2 Pipe insulation

Due to size wire would cut the insulation and may break.

4.4.2.3 Vessel Insulation

To prevent cutting into the insulation.

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4. ACCESSORIES (Continued)

4.5 WIRE

4.5.1 Description

Experience proven materials.

4.5.2 Service

Plant preference due to differing atmospheric corrosion potential.

4.6 SCREWS

4.6.1 Description

Screw type used for ease of installation.

4.6.2 Service

Use of screws in place of bands is plant preference. Used in horizontal seams to prevent the aluminum from working down.

4.7 STAPLES

4.7.1 Description

Standard staples are used.

4.7.2 Service

Fiberglass is light enough to be held by staples, and it has enough dimensional stability to retain staples. Stapling can be faster and more economical than wire ties.

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1. SCOPE

A statement to explain the content and logic of this section.

2. ITEMS INSULATED

These drawings are the record of items requiring insulation.

3. PURPOSE

3.1 HOT SERVICE

3.1.1 General

States the purposes for insulating hot service piping and equipment and defines the insulation design temperature.

3.1.2 Heat Conservation

Factors involved in the economic calculation of insulation thickness include costs of insulation, steam generation equipment, heat energy, money, depreciation, thermal conductivity, temperature differential, pipe size, hours of operation and maintenance costs.

3.1.3 Temperature Control

To prevent polymerization, maintain reaction temperature, etc.

3.1.4 Personnel Protection

Surface temperature of the insulation should be limited to 150°F to prevent burns to personnel. Insulation specified for heat conservation will normally have a lower surface temperature.

3.2 COLD SERVICE

States the purpose and extent of cold service insulation.

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4. GENERAL

4.1 SURFACES NOT INSULATED

Specificed surfaces not to be insulated for either (1) proper fulfillment of function (nameplates, steam traps, etc.) or (2) because effort required for irregular shapes and high maintenance items is not justified.

4.2 SURFACE PREPARATION

To prevent corrosion on carbon steel surfaces resulting from moisture trapped under the insulation, and to provide adhesion for spray urethane.

4.3 INSULATION SUPPORT

Supports will prevent compaction or crushing of the insulation due to its own weight.

4.4 PIPING SUPPORTS

Allows sufficient space for insulation below pipe (hot) and allows proper sealing of pipe to prevent condensation (cold).

4.5 TRACED LINES

Using insulation one pipe size larger is an industry recognized method. An alternate method would be to dado a groove for the tracer in the line size insulation.

4.6 ALUMINUM WEATHER-BARRIER

Table intended to simplify purchasing of material.

4.7 MASTIC WEATHER-BARRIER

The variety of irregular shapes will require individual calculation of quantities required.

5. DATA FORMS

To aid the engineer in the area of selection, specification, and procurement of insulation materials with a minimum of time. The two forms are designed to collect all the information required pertinent to that particular classification of insulation system.

5.1 HEAT INSULATION DATA FORM

This form covers all the materials for insulating items operating at temperatures above 70°F.

5.1.1 INSULATION MATERIAL

The insulation materials are not limited to those specifically listed in this section. If other materials are used this paragraph lists the items to be considered in making this selection. See "INSUL-1" Section, paragraphs 2.1.1, 2.3.1, 2.4.1, 2.5.1, 2.7.1, 2.8.1, and 2.9.1.

5.1.1.1 Piping and 36" Diameter and Smaller Equipment

Lists the materials and service limits normally used. See "INSUL-1" Section, paragraphs 2.1.2, 2.2.2, 2.3.2, 2.4.2, 2.7.2, and 2.9.2.

5.1.1.2 Equipment Greater than 36" Diameter

Lists the materials and service limits normally used. See "INSUL-1" Section, paragraphs 2.3.2, 2.4.2, and 2.9.2.

5.1.1.3 Bent Pipe and Tubing

Lists the materials and service limits normally used. See "INSUL-1" Section, paragraphs 2.7.2 and 2.8.2.

5.1.1.4 Irregular Surfaces

Gives the material and service limits normally used. See "INSUL-1" Section, paragraph 2.5.2.

5.1.2 WEATHER-BARRIER MATERIALS

Weather-barrier materials are not limited to those specifically listed. This paragraph lists the factors to be considered when selecting a weather-barrier system. See "INSUL-1" Section, paragraphs 3.1.1, 3.2.1, 3.3.1 and 3.4.

5.1.2.1 Straight Run Piping and 36" Diameter and Smaller Equipment

Lists the materials used and the factors to be considered when selecting the material to use. See "INSUL-1" Section, paragraphs 3.1.2, 3.3.2, and 3.4.

5.1.2.2 Elbows

Labor costs for application of mastic weather-barrier to elbows may offset the additional material cost for aluminum or PVC covers. See "INSUL-1" Section, paragraphs 3.1.2, 3.2.2 and 3.3.2.

5.1.2.3 Vessel and Exchanger Shells

Lists the materials normally used. See "INSUL-1" Section, paragraphs 3.1.2, 3.2.2, 3.3.2, and 3.4

5.1.2.4 Irregular Surfaces and Equipment Heads

Gives the material normally used. See "INSUL-1" Section, paragraph 3.2.2.

5.1.3 INSULATION SECUREMENT

Lists the materials normally used. See "INSUL-1" Section, paragraphs 4.4.1, 4.5.1, and 4.7.1.

5.1.3.1 Piping Through 16" Diameter

Lists the materials normally used. See "INSUL-1" Section, paragraphs 4.5.2 and 4.7.2.

5.1.3.2 Piping Greater than 16" Diameter and Equipment 24" Diameter and Less

Gives the material normally used. See "INSUL-1" Section, paragraph 4.4.2.2.

5. DATA FORMS (Continued)

5.1 HEAT INSULATION DATA FORM (Continued)

5.1.3 INSULATION SECUREMENT (Continued)

5.1.3.3 Equipment Greater than 24" Diameter

Gives the material normally used. See "INSUL-1" Section, paragraph 4.4.2.3.

5.1.4 ALUMINUM JACKET SECUREMENT

Lists the materials normally used. Aluminum screws resist atmospheric corrosion in coastal locations. Hex head screws are used if a socket type screwdriver is used. See "INSUL-1" Section, paragraphs 4.4.1 and 4.6.1.

5.1.4.1 Piping and 24" Diameter and Smaller Equipment

Lists the materials normally used. See "INSUL-1" Section, paragraphs 4.4.2.1 and 4.6.2.

5.1.4.2 Equipment Greater than 24" Diameter

Lists the materials normally used. See "INSUL-1" Section, paragraphs 4.4.2.1 and 4.6.2.

5.1.5 REINFORCEMENT

Lists the materials used and places where reinforcement is required. See "INSUL-1" Section, paragraphs 4.2.1 and 4.3.1.

5.1.5.1 Glass Cloth

Lists the materials normally used. See "INSUL-1" Section, paragraph 4.2.2.

5.1.5.2 Wire Netting

Gives the materials normally used. See "INSUL-1" Section, paragraph 4.3.2.

5.1.6 SPECIALTIES

For the engineers' use to specify any additional information desired.

5. DATA FORMS (Continued)

5.2 COLD INSULATION DATA FORM

This form covers all the materials for insulation items operating at temperatures of 70°F and below.

5.2.1 INSULATION MATERIALS

The insulation materials are not limited to those listed in this section. If other materials are used; however, this paragraph lists the items to be considered in making this selection. See "INSUL-1" Section, paragraphs 2.3.1, 2.8.1, and 2.9.1.

5.2.1.1 Piping

Gives the materials normally used. See "INSUL-1" Section, paragraphs 2.3.2 and 2.9.2.

5.2.1.2 Equipment

Gives the materials normally used. See "INSUL-1" Section, paragraphs 2.3.2 and 2.9.2.

5.2.1.3 Bent Pipe and Tubing

Gives the material normally used. See "INSUL-1" Section, paragraph 2.8.2.

5.2.1.4 Irregular surfaces

Gives the material normally used. See "INUL-1" Section, paragraph 2.3.2.

5.2.2 WEATHER-BARRIER MATERIALS

Weather-barrier materials are not limited to those specifically listed. This paragraph lists the factors to be considered when selecting a weather-barrier system. See "INSUL-1" Section, paragraphs 3.1.1, 3.2.1 and 3.3.1.

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INSULATION - APPLICATION
LOGIC LOG

INDEX
INSULATION - APPLICATION
LOGIC LOG

1. SCOPE

A statement to explain the contents and logic of this section.

2. GENERAL

2.1 TIMING

To enable detection of leaks during testing.

2.2 SURFACE PREPARATION

To prevent corrosion and to provide adhesion for urethane spray.

2.3 DRY INUSLATION

To prevent the insulation from deteriorating or retaining moisture which would cause corrosion to the insulated surface and degradation of urethane.

2.4 PIPING SUPPORTS

2.4.1 HOT SERVICE

To prevent damage to insulation due to weight of line and expansion movement.

2.4.2 COLD SERVICE

To prevent condensation, freezing, and the entry of moisture where support penetrates the weather-barrier.

3. APPLICATION PROCEDURE

3.1 STRAIGHT PIPE

3.1.1 INSULATION

3.1.1.1 Placement

To prevent heat loss at joints.

3. APPLICATION PROCEDURE (Continued)

3.1 STRAIGHT PIPE (Continued)

3.1.1 INSULATION (Continued)

3.1.1.2 Joint Sealer

To prevent vapor entry.

3.1.1.3 Exposed Ends

To shed water and prevent moisture from reaching the insulation.

3.1.1.4 Securement

To hold the insulation in place until the weather-barrier is installes. See "INSUL-4" Section, paragraphs 4.4.2.2, 4.5.2, and 4.7.2.

3.1.2 EXPANSION-CONTRACTION JOINTS

3.1.2.1 Location

To maintain the required vapor seal in cold service insulation and to prevent rupture of rigid insulation in hot service.

3.1.2.2 Design

An industry proven design.

3.1.3 ALUMINUM WEATHER-BARRIER

3.1.3.1 Application

To prevent water from reaching the insulation.

3.1.3.2 Securement

Plant preference.

3.1.4 MASTIC WEATHER-BARRIER

An industry wide application procedure which has proven acceptable to Celanese.

3.1.5 PVC WEATHER-BARRIER

Application methods are unique to each manufacturer.

3. APPLICATION PROCEDURE (Continued)

3.2 ELBOWS

3.2.1 INSULATION

Performed elbows are used if economical.

3.2.2 INSULATING CEMENT

To prevent heat loss and provide a uniform smooth surface.

3.2.3 WEATHER-BARRIER

Type of barrier depends on economics and plant preference. See "INSUL-3" Section, paragraphs 3.1.3, 3.1.4, and 3.1.5.

3.3 FLANGES, FLANGED FITTINGS AND VALVES

3.3.1 INSULATION

To prevent vapor entry and provide for expansion-contraction. Removable flange covers are used for high maintenance services.

3.3.2 Same logic as paragraphs 3.1.3 and 3.1.4 above.

3.4 EQUIPMENT

3.4.1 SHELL INSULATION

3.4.1.1 Placement

Pipe insulation is more economical to apply. To prevent heat loss the joints are staggered. Urethane spray will normally be applied by and insulation contractor. Because of vapor and fire hazards with urethane spray, Celanese engineer and Safety Department must approve all materials, warehousing of materials, and application.

3.4.1.2 Joint Sealer

To prevent the entry of moisture, see paragraph 3.1.1.2 above.

3.4 EQUIPMENT (Continued)

3.4.1 SHELL INSULATION (Continued)

3.4.1.3 Securement

To hold the insulation in place.

3.4.1.4 Cork-Filled Mastic

Each manufacturer has their own specifications which depend on product, purpose, and service conditions

3.4.2 SUPPORT INSULATION

3.4.2.1 General

To minimize heat gain, condensation, and to give an acceptable thermal gradient.

3.4.2.2 Metal Cradles

Common industry practice which has proven acceptable.

3.4.2.3 Structural Steel

Common industry practice which has proven acceptable.

3.4.2.4 Legs

Common industry practice which has proven acceptable.

3.4.2.5 Skirts

Common industry practice which has proven acceptable.

3.4.3 EXPANSION-CONTRACTION JOINTS

To allow for movement while maintaining a vapor seal.

3.4.4 WEATHER-BARRIER

See paragraphs 3.1.3, 3.1.4, and 3.1.5 above.

3. APPLICATION PROCEDURE (Continued)

3.4 EQUIPMENT (Continued)

3.4.2 SUPPORT INSULATION

3.4.2.1 General

To minimize heat gain, condensation, and to give an acceptable thermal gradient.

3.4.2.2 Metal Cradles

Common industry practice which has proven acceptable.

3.4.2.3 Structural Steel

Common industry practice has proven acceptable.

3.4.2.4 Legs

Common industry practice which has proven acceptable.

3.4.2.5 Skirts

Common industry practice which has proven acceptable.

3.4.3 EXPANSION-CONTRACTION JOINTS

To allow for movement while maintaining a vapor seal.

3.4.4 WEATHER-BARRIER

See paragraphs 3.1.3, 3.1.4, and 3.1.5 above.

3.5 IRREGULAR SURFACES

3.5.1 INSULATION

Common industry procedure which has proven acceptable.

3.5.2 See paragraph 3.1.4 above.

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MATERIAL REQUIREMENTS

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MATERIAL REQUIREMENTS
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INDEX
MATERIAL REQUIREMENTS
(Continued)

1. SCOPE

This section describes the minimum requirements for the purchase of exterior thermal insulation materials for pipe, instruments and equipment.

2. INSULATING MATERIALS

2.1 CALCIUM SILICATE

2.1.1 Description

Insulation shall be a rigid hydrous calcium silicate pipe covering of sectional or segmental form, block, scored block, or beveled lag. The insulation shall contain an inhibitor to reduce the possibility of stress corrosion cracking of stainless stell. CAUTION -- If asbestos containing materials are used, then precautions as per OSHA will need to be considered.

2.1.2 Service

2.1.2.1 Temperature Range

Calcium silicate is normally used for components operating in the temperature range of 451°F to 1200°F. For special applications, this material may be used for temperatures up to 1800°F.

2.1.2.2 Components Insulated

Calcium silicate is used for the insulation of the following components operating within the above temperature range:

a. Carbon steel piping, instruments, and cylindrical carbon steel equipment.

b. Stainless and alloy piping, instruments, and cylindrical equipment with a diameter of 24" or less in low humidity locations.

2.1.3 Thickness

Thickness should be specified as described in INSUL-5 Section 3.1.2. Above 600°F, two layers with staggered joints should be used to minimize heat loss at joints.

2. INSULATING MATERIALS (Continued)

2.2 MINERAL WOOL

2.2.1 Description

Insulation shall be a segmental, mat faced, felted refractory fiber pipe covering such as MF pipe insulation, block, or blanket.

2.2.2 Service

2.2.2.1 Temperature Range

MF pipe insulation is normally used for components operating in the temperature range of 451°F to 1200°F.

2.2.2.2 Components Insulated

MF pipe insulation may be used on any equipment 36" stainless steel items. Flexible mineral wool is used in including contraction joints. Compression strength must be considered where the insulated surface will be walked on or where banding might compress the insulation too tightly.

2.2.3 Thickness

Thickness should be specified as described in INSUL-5, Section 3.1.2. Above 600°F, two layers with staggered joints should be used to minimize heat loss at joints.

2.3 CELLULAR GLASS

2.3.1 Description

Insulation shall be a rigid cellular glass material in flat block, beveled lags, or pipe covering of sectional or segmental form.

2.3.2 Service

2.3.2.1 Temperature Range

Cellular glass is used for components operating in the range from -450°F to 800°F.

2. INSULATING MATERIALS (Continued)

2.3 CELLULAR GLASS (Continued)

2.3.2 Service (Continued)

2.3.2.2 Components Insulated

Cellular glass shall be used for the insulation of any equipment including stainless stell and alloys.

2.3.3 Thickness

Thickness should be specified as described in INSUL-5 Section 3.1.2 for hot service or 3.2 for cold service.

2.4 FIBERGLASS

2.4.1 Description

The insulation shall be sectional pipe covering, board, or blanket.

2.4.2 Service

2.4.2.1 Temperature Range

Fiberglass is used for components operating in the temperature range of -60°F to 450°F, with one type (Certainteed 850) usable up to 850°F. In cold service, a positive vapor barrier is needed to prevent water logging of the fiberglass.

2.4.2.2 Components Insulated

Fiberglass is used for all piping, instruments, and equipment. Flexible fiberglass is used in contraction joints. Compressive strength must be considered where insulated surface will be walked on or where banding might compress the insulation too tightly.

2.4.3 Thickness

Thickness should be specified as described in INSUL-5 Section 3.1.2 for hot service and 3.2 for cold service.

2.5 INSULATING CEMENT

2.5.1 Description

Insulation shall be a high temperature mineral wool type insulating cement such as Eagle-Picher Super 66 or equal.

2.5.2 Service

2.5.2.1 Temperature Range

Insulating cement is used for components operating at temperature of 71°F and above with upper limits depending upon the material used.

2.5.2.2 Components Insulated

Insulating cement is used for the insulating or irregular surfaces such as pumps and turbines. Insulating cement is also used to fill voids and smooth the surface of fabricated elbow covering.

2.5.3 Thickness

Thickness should be specified the same as fiberglass or mineral wool as described in INSUL-5, Section 3.1.2.

2.6 CORK-FILLED MASTIC

2.6.1 Description

Insulation shall be an asphalt base mastic containing a high content of ground cork. Cork-filled mastic shall be Lion Oil Nokorode "K Kote" or approval equal.

2.6.2 Service

2.6.2.1 Temperature Range

Cork-filled mastic is normally used for components operating in the temperature range of 30°F to 140°F.

2. INSULATING MATERIALS (Continued)

2.6 CORK-FILLED MASTIC (Continued)

2.6.2 Service (Continued)

2.6.2.2 Components Insulated

Cork-filled mastic is used for the insulating of pipe and equipment to control condensation of low temperature surfaces. Cork-filled mastic is also used on piping and equipment requiring insulation for process control if the reduction in heat loss need only be 50 to 70 percent. Protective coating must be applied on carbon steel surfaces for corrosion protection.

2.6.3 Thickness

Cork-filled mastic is normally applied to produce a 1/4" thickness; however, cured thickness up to 3/8" may be used, if required.

2.7 ASBESTOS TAPE

2.7.1 Description

Insulation shall be a woven asbestos cloth tape 1" wide x 1/8" thick.

2.7.2 Service

2.7.2.1 Temperature Range

Asbestos tape is used for components operating at temperatures of 180^{O}F and above.

2.7.2.2 Components Insulated

Asbestos tape is used on irregular surfaces such a bent pipe and tubing where the use of rigid insulation is considered impractical.

2.7.3 Thickness

Thickness should be specified the same as cellular glass as described in INSUL-5, Section 3.1.2.

2. INSULATING MATERIALS (Continued)

2.8 FOAMED PLASTIC

2.8.1 Description

Insulation shall be flexible foamed plastic tubular pipe insulation.

2.8.1 Service

2.8.2.1 Temperature Range

Foamed plastic insulation is used for components operating at temperatures of 180^{o}F and below.

2.8.2.2 Components Insulated

Foamed plastic is used on bent pipe or tubing where the used of rigid insulation is considered impractical.

2.8.3 Thickness

Thickness should be specified as described in INSUL-5, Section 3.2.

2.9 Urethane

2.9.1 Description

The insulation shall be sectional or segmental pipe covering, boards, beveled bags, shaped head segments, or foam spray.

2.9.2 Service

2.9.2.1 Temperature Range

Rigid urethane is used for services from -450 to +225^{o}F.

2.9.2.2 Chemical Resistance

Urethane should not be used where it will be exposed to acetone, methyl ethyl ketone, tetrahydrofuron, chloroform, ethylene dichloride, chlorine, hydrogen peroxide, or high concentration acids.

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MATERIAL REQUIREMENTS
(Continued)

2. INSULATING MATERIALS (Continued)

2.9 URETHANE (Continued)

2.9.2 Service (Continued)

2.9.2.3 Other Limitations

Urethane must be protected from sunlight and moisture, it cannot be exposed to flame, it should not be used in confined spaces with poor ventilation, and it must have a continuous vapor barried (integral vapor barried bonded to metal jacketing is not adequate for a vapor barrier).

2.9.2.4 Components Insulated

Urethane can be used on all pipes, instruments, and equipment except in high maintenance services where the vapor barrier is likely to be punctured. Spray foam can be economically used on large surface area tanks and towers.

2.9.3 Thickness

Thickness should be specified as described in INSUL-5, Section 3.1.2 for hot service or 3.2 for cold service. Maximum thickness for spray urethane is 3".

3. WEATHER-BARRIER MATERIALS

3.1 ALUMINUM

3.1.1 Description

Aluminum jacketing material shall be 5005 or 3003 alloy with H-14 temper. Sheets or rolls shall be 0.016" thick with 3/16" corrugations or 0.020" thick smooth. Jacketing both with and without attached moisture barrier are used. Aluminum elbow covers shall be 0.020" thick. Pipe sections with self-sealing lips may be economical to use on long piping runs.

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MATERIAL REQUIREMENTS
(Continued)

3. WEATHER-BARRIER MATERIALS (Continued)

3.3 POLYVINYL CHLORIDE (PVC)

3.3.1 Description

PVC pipe and fitting jacketing shall be preformed sections with a minimum thickness of 0.020". It shall be UV stabilized and rated 94 V-O (self-extinguishing) at the thickness used by ASTM Methods D 568, D 635, or D 1433, or rated on Oxygen Index valve greater than 25% by ASTM Method D 2863. Sheet stock for vessels shall meet the same specifications as pipe jacketing.

3.3.2 Service

3.3.2.1 Temperature Range

Used where surface temperature of insulation will be less than 150°F and where PVC will not be exposed to other sources of heat exceeding 150°F. If bonded to insulation such as urethane or fiberglass, service shall meet the temperature range of the insulation material.

3.3.2.2 Chemical Restrictions

Do not use where PVC will be exposed to ketones, esters, or aromatic hydrocarbons.

3.3.2.3 Components Jacketed

Used on straight pipe, elbows, ties, and valves indoors or outdoors. Sheet used on tanks and smooth wall equipment.

3.4 OTHER MATERIALS

Other weather-barrier materials such as stainless steel may be used where service conditions will not permit usage of aluminum, mastic, or PVC.

4. ACCESSORIES

4.1 JOINT SEALER

4.1.1 Description

Joint sealer shall be an aluminum gray vapor barrier sealer such as Benjamin Foster's No. 30 - 45 or an asphalt base sealer such as Lion Oil Nokorode "Low Temp". For PVC jacketing, use joint sealer specified by jacket manufacturer.

4.1.2 Service

Joint sealer shall be used on all butt edges of single layer insulation or outer layer of multi-layer applications.

4.2 GLASS CLOTH

4.2.1 Description

Glass cloth shall be 10 x 10 thread count such as Benjamin Foster's open weave #10, or 20 x 20 thread count asphalt impregnated glass cloth.

4.2.2 Service

Glass cloth is used to reinforce mastic weather barriers. The 10 x 10 thread count cloth is used to reinforce polyvinyl acetate coatings and the 20 x 20 thread count cloth is used with solvent cutback mastics.

4.3 WIRE NETTING

4.3.1 Description

Wire netting shall be 1" HEX pattern, 20 gauge Monel, 316 stainless steel, or galvanized poultry netting, depending upon environmental conditions.

4.3.2 Service

Wire netting is used to reinforce insulating cement when thickness of 1 - 1/2" or greater is required.

4. ACCESSORIES (Continued)

4.4 BANDS

4.4.1 Description

Bands shall be 3/8", 1/2", or 3/4" wide x .020" thick stainless steel with matching double prong seals.

4.4.2 Service

4.4.2.1 Aluminum Jacketing

At high humidity locations 3/8" wide bands on 9" centers are used to secure all aluminum jacketing. Self-sealing pipe jacketing is banded only on the ends of the jacket sections.

4.4.2.2 Pipe Insulation

Bands 1/2" wide are used on 9" centers to secure insulation on pipe greater than 16" in diameter and equipment with a diameter of 24" or less.

4.4.2.3 Vessel Insulation

Bands 3/4" wide are used on 12" centers to secure insulation on equipment with a diameter greater than 24".

4.5 WIRE

4.5.1 Description

Wire shall be 16 gauge stainless stell or galvanized.

4.5.2 Service

Wire is used on 9" centers to secure pipe insulation on lines through 16" diameter. Stainless steel wire is used at high humidity locations and galvanized wire is used at low humidity locations.

4. ACCESSORIES (Continued)

4.6 SCREWS

4.6.1 Description

Screws shall be No. 8 x 1/2" long cadmium plated or aluminum slotted HEX head or pan head sheet metal screws.

4.6.2 Service

Sheet metal screws shall be used on 6" centers to secure aluminum pipe or equipment jacketing at low humidity locations. On vertical equipment surfaces at all locations, screws are used at the horizontal laps. Screws are not used to fasten jacketing over urethane insulation.

4.7 STAPLES

4.7.1 Description

Staples shall be stainless steel suitable for application with a staple gun.

4.7.2 Service

Staples shall be used to fasten longitudinal seam of rigid fiberglass pipe insulation, and to reinforce the lap fastening on fiberglass with self-sealing jacket lap.

INSUL - 5

Chemical Engineering

How To Select Insulation Thickness For Hot Pipes

Rising fuel costs have made traditional insulation-thickness-selection criteria obsolete. Here is a group of nomographs that can be used to choose insulation for hot pipes that will be economic under present-day and future conditions.

JULES L. ABRAMOVITZ and RENE CORDERO,

Allied Chemical Corp.

Energy shortages and higher fuel costs have made insulation more important. Engineers must reevaluate the insulation thickness that provides optimum insulation at the most reasonable cost.

A new set of standards is desirable, because the older standards have been strained beyond reasonable extrapolation. The new standards should be simplified—by moderate sacrifices of mathematical accuracy, if necessary—and tailored to typical plant applications. Also, the standards should provide modifying factors to adjust for most conceivable variations in design conditions.

The procedures outlined in this article meet these conditions. Although these procedures have not yet been applied to an actual design, test calculations have been made for numerous applications, with results that show very favorable recovery periods for the added investment.

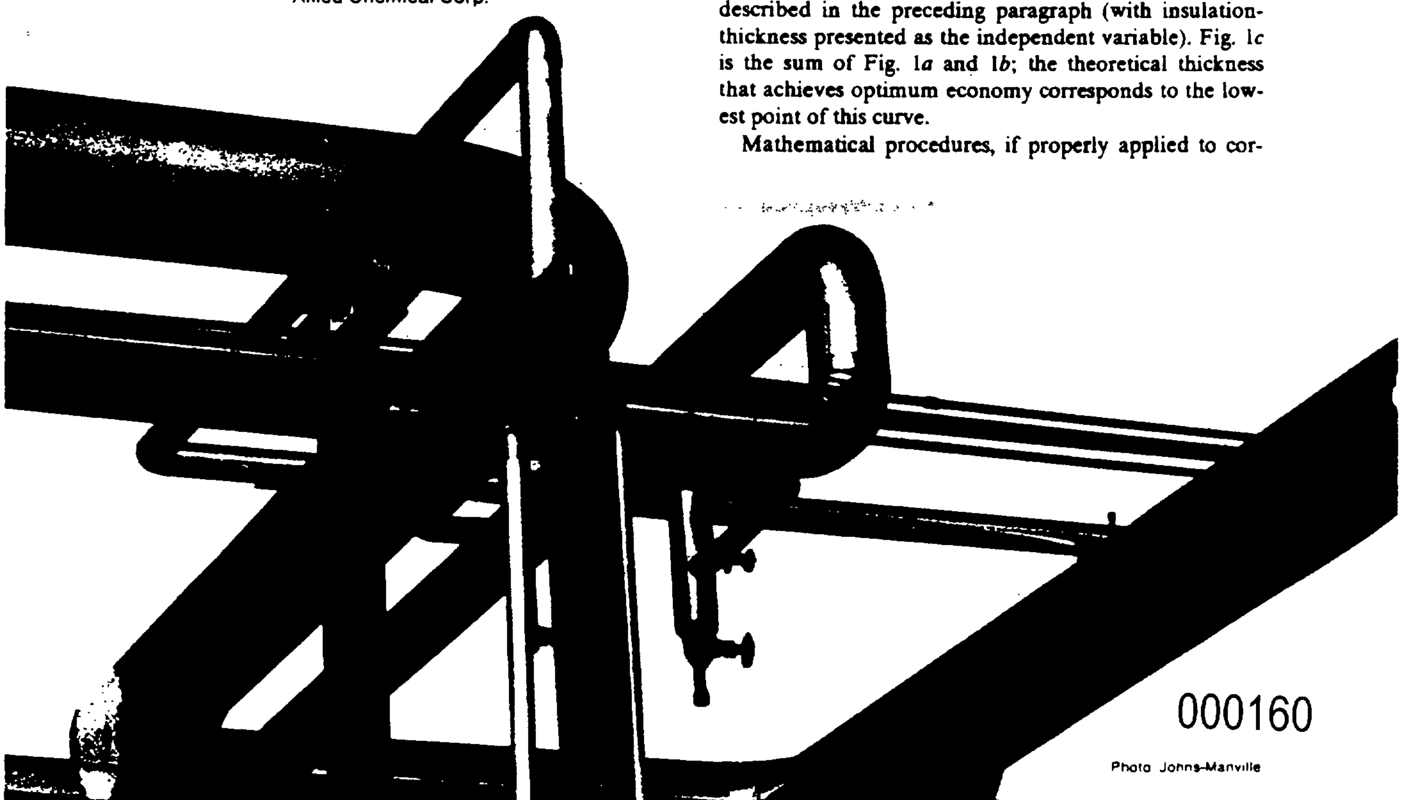
Only hot systems are covered in this article. (We are preparing another article on cold systems that we expect will appear in a future issue. In that situation, the new economic criteria indicate that the thicknesses needed for economic purposes are close to those needed for functional antisweat needs.)

Evaluating the Basic Economic Forces

Two major costs enter into the economics of insulation—that of the installation itself (materials and labor), and the operating expense caused by heat loss through the insulation. A direct comparison of heat-loss costs with initial costs is possible when the initial cost is expressed as an equivalent annual cost. Optimum economy is achieved when the annual cost of the capital investment plus the annual cost of the heat loss is at a minimum.

Fig. 1*a* through 1*c* picture the economic phenomena described in the preceding paragraph (with insulation-thickness presented as the independent variable). Fig. 1*c* is the sum of Fig. 1*a* and 1*b*; the theoretical thickness that achieves optimum economy corresponds to the lowest point of this curve.

Mathematical procedures, if properly applied to cor-



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■ Reducing raw material costs . . . increasing processing profits. Your objectives for mixer investments.

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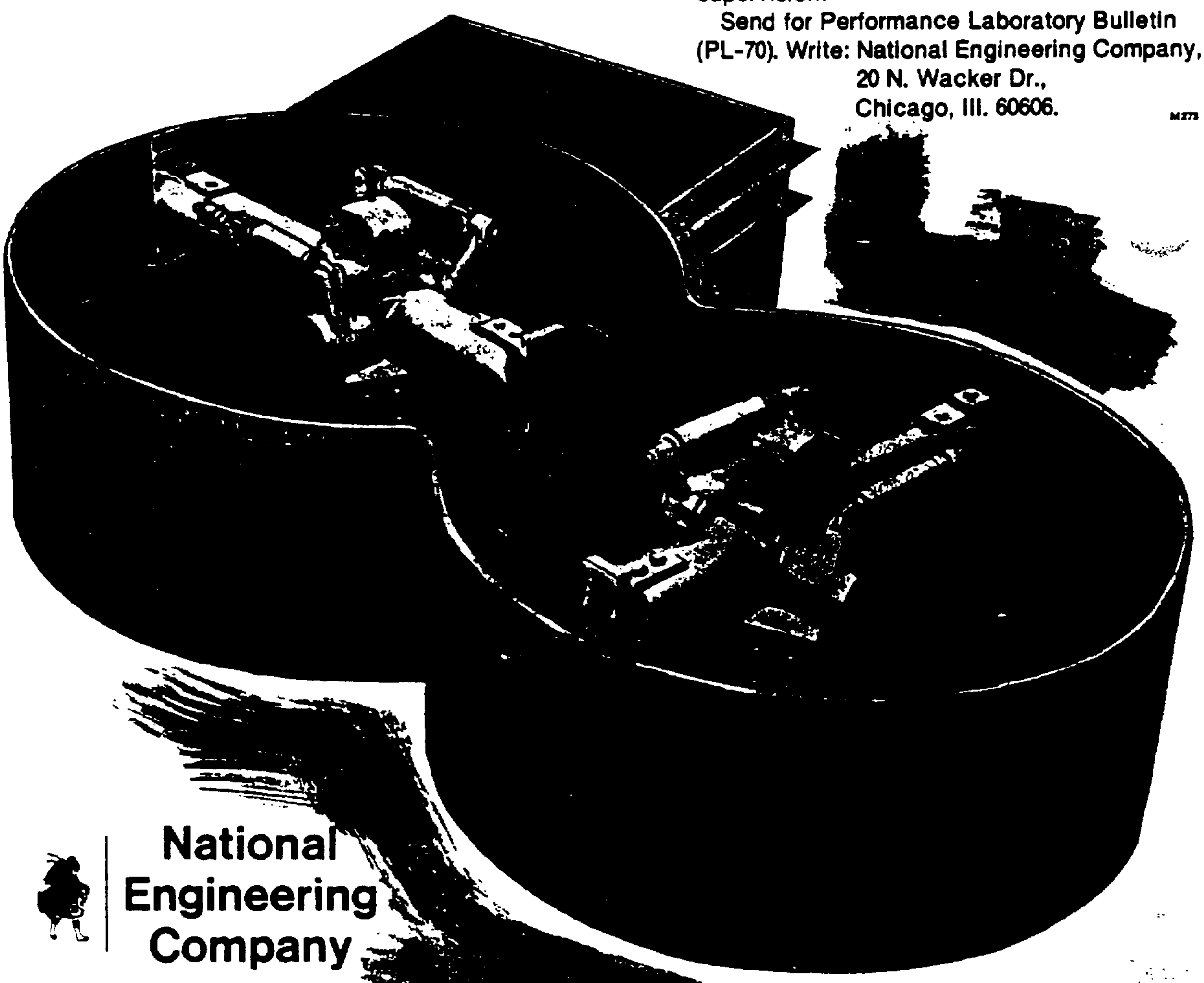

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rect basic data, will indicate one specific value for this optimum. However, owing to the wide U-shape of the curve (Fig. 1c), commercially available thicknesses that are slightly greater or less than the theoretical one will yield a system whose life-economy differs only slightly from the theoretical minimum. Hence, even though the "optimum thickness" may be impractical, the overall economy is essentially the same with the next higher, or lower, commercial thickness.

Engineering Impact of New Economic Criteria

The economic thicknesses indicated by the new procedure are, in most cases, nearly double those calculated by older standards. It is apparent that the new standard cannot be applied (practically) to the repair or replacement of damaged insulation in existing installations. In most cases, existing spacing and available pipe-rack space would prohibit the change.

To test the value of the new criteria, a recent installation that was designed under the old standard was re-evaluated in light of the new criteria. The initial cost of applying the thicker insulation (at the time of construction) was estimated as $75,600. With current fuel prices, the incremental fuel saving would have been about $25,000/yr. Unfortunately, as in most cases, hindsight could not be usefully employed.

Using the Insulation Nomographs

The assumptions that have been built into the following nomographs for hot insulation are listed below:

Assumptions affecting the value of heat losses:

- Overall conversion efficiency, fuel to useful heat—72%.
- Annual hours of operation of insulated system—8,760.
- Average annual ambient temperature—45 to 75°F.
- Capital cost of heat-generating equipment, realized over a 15-yr life span—negligible.
- Effect of wind on heat loss of well-insulated outdoor pipe and equipment—negligible.

Assumptions affecting equivalent annual cost of capital investment in insulation:

- Anticipated service life—15 yr.
- Annual cost of money—10%.
- Annual cost of maintenance of insulation—negligible.

The overalll conversion efficiency (the first item noted) incorporates an 80% efficiency (based on higher heating value) of heat-generation equipment, which is typical of modern oil-burning boilers in the medium-size range, and the use of 10% of the steam produced (or the equivalent value in electrical energy) to drive auxiliaries and otherwise serve the boilers.

The annual cost of money is obviously subject to change in today's fluctuating money markets. (We will explain later how to adjust for such changes.)

User Inputs

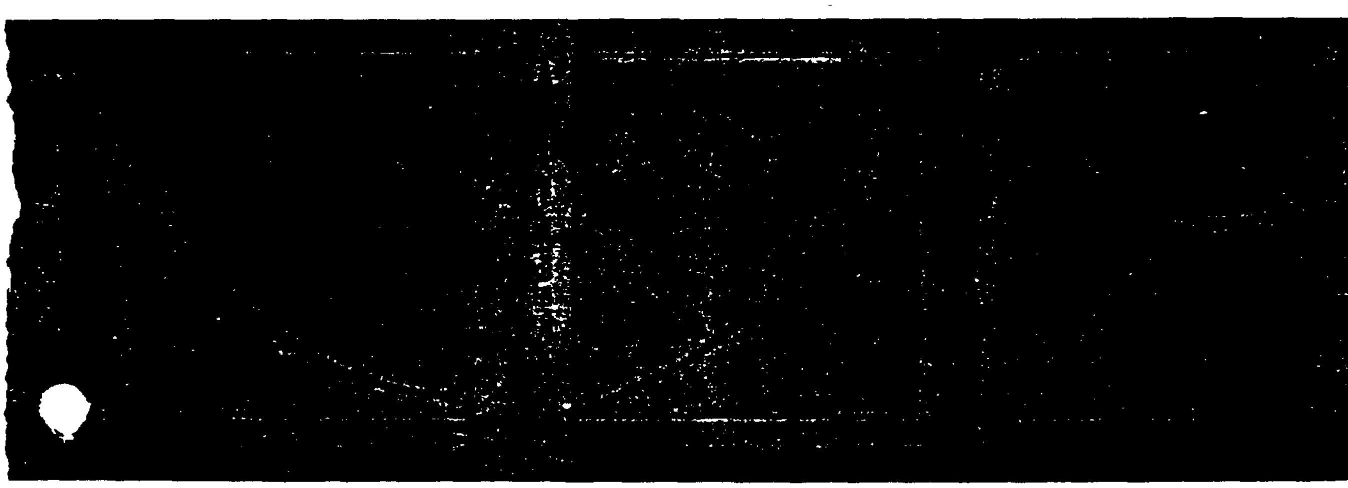
There are five user-selected variables:

- Pipe size.
- Operating fluid temperature.
- Raw fuel cost—projected at plant's mid-life.
- Insulation material.
- Installed cost of insulation.

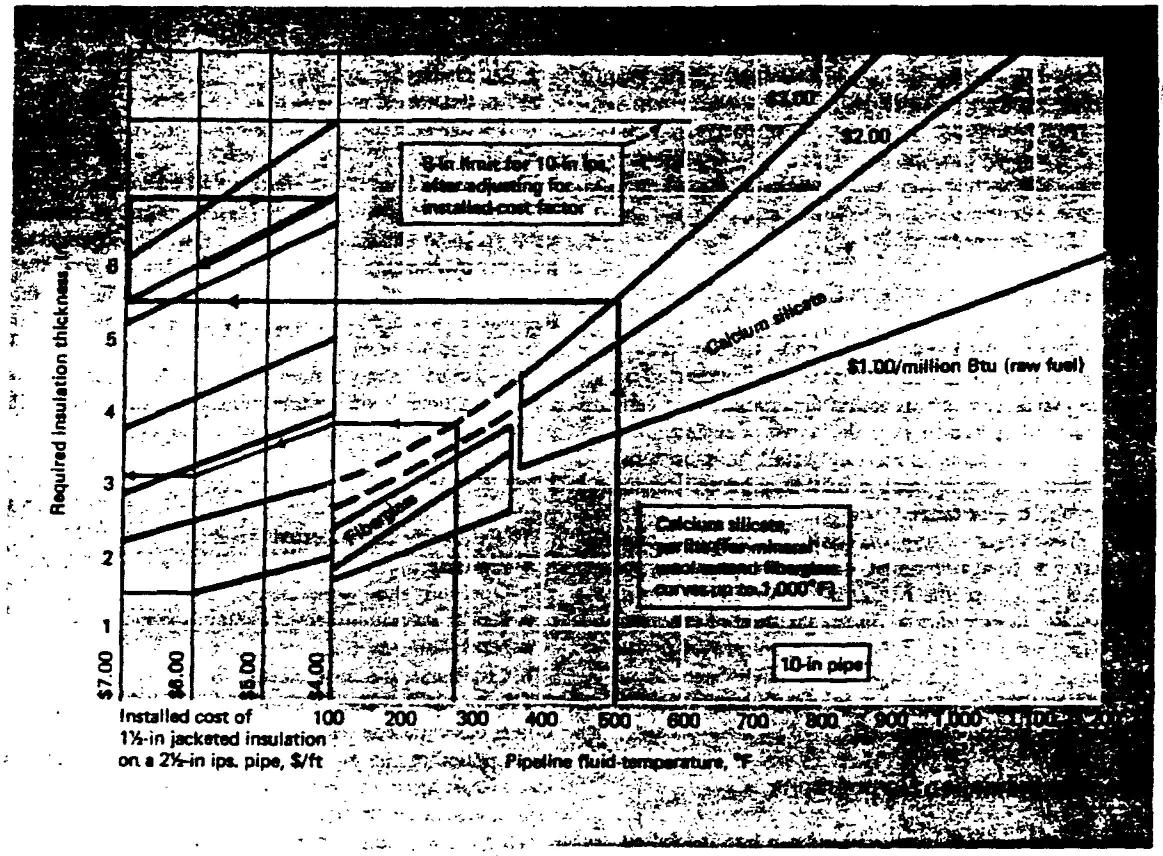
For the sake of simplicity, the installed cost of insulation is based on one thickness (1½ in) of jacketed insulation applied to one pipe size (2½ in). This is the only installed-cost figure needed, no matter what the actual pipe size or insulation thickness.

There is a separate nomograph of each pipe size or limited group of pipe sizes. On each, an array of curves (for various fuel costs) has been drawn for calcium silicate, and another array for fiber glass, each within the temperature range of its normal application. Where there is a preference for such application, the calcium silicate lines may be projected to temperatures below 350°F.

For mineral wool, use the fiber-glass lines. For this application they can be projected (as straight lines) to temperatures as high as 1,000°F. The projected curves can also be used with fiber-glass having higher temperature limits. *(Continued on p. 96)*



COST of insulation. *a*: Cost of thermal losses. *b*: Cost of investment. *c*: Total yearly cost—Fig. 1



EXAMPLE for use of subsequent nomographs for determining optimum thickness of insulation—Fig. 2

Example of Selection of Insulation Thickness

For an application where calcium silicate insulation is preferred. See Fig. 2.

Given:	Solution:
a. Pipe size—10-in	a. Use 10-in pipe curves
b. Fluid temperature—275°F	b. Project CaSi curves to lower temperature region
c. Material—CaSi	c. Enter at 275°F and proceed vertically to CaSi curves
d. Raw-fuel cost-$2.85/10⁶	d. Intersect $2.85 curve (by interpolation)
e. Local installed cost—$6/ft (for 1½-in on 2½-in pipe)	e. Proceed horizontally to $4 cost line and follow sloping lines to $6 cost line
f. Find economic insulation	f. Proceed horizontally and read 3.1-in

Answer: Use 3-in insulation as closely approximating the optimum.

Adjusting for Higher Fuel Costs

For fuel costs above $\$3/10^6$ Btu, proceed as follows:

Given:	Solution:
a. Pipe size—10-in	a. Use 10-in pipe curves
b. Fluid temperature—500°F	b. Enter Fig. 2 at 500°F
c. Material—CaSi	c. Proceed vertically to CaSi curves
d. Raw-fuel cost—$\$4/10^6$ Btu	d. Intersect $3 curve and proceed horizontally [illegible] the way to "insulation thickness" ordinate (5½-in). Enter Table [illegible] and read out correction factor of 1.27. Multiply insulation thickness [illegible] 1.27 and plot on [illegible] nomograph (7-in). Project horizontally [illegible] to $4 "Installed cost" line
e. Local installed cost—$6/ft (for 1½-in insulation on 2½-in pipe).	e. Follow sloping lines to [illegible] line
f. Find economic insulation	f. Proceed horizontally [illegible] and read 6-in, which [illegible] an available thickness

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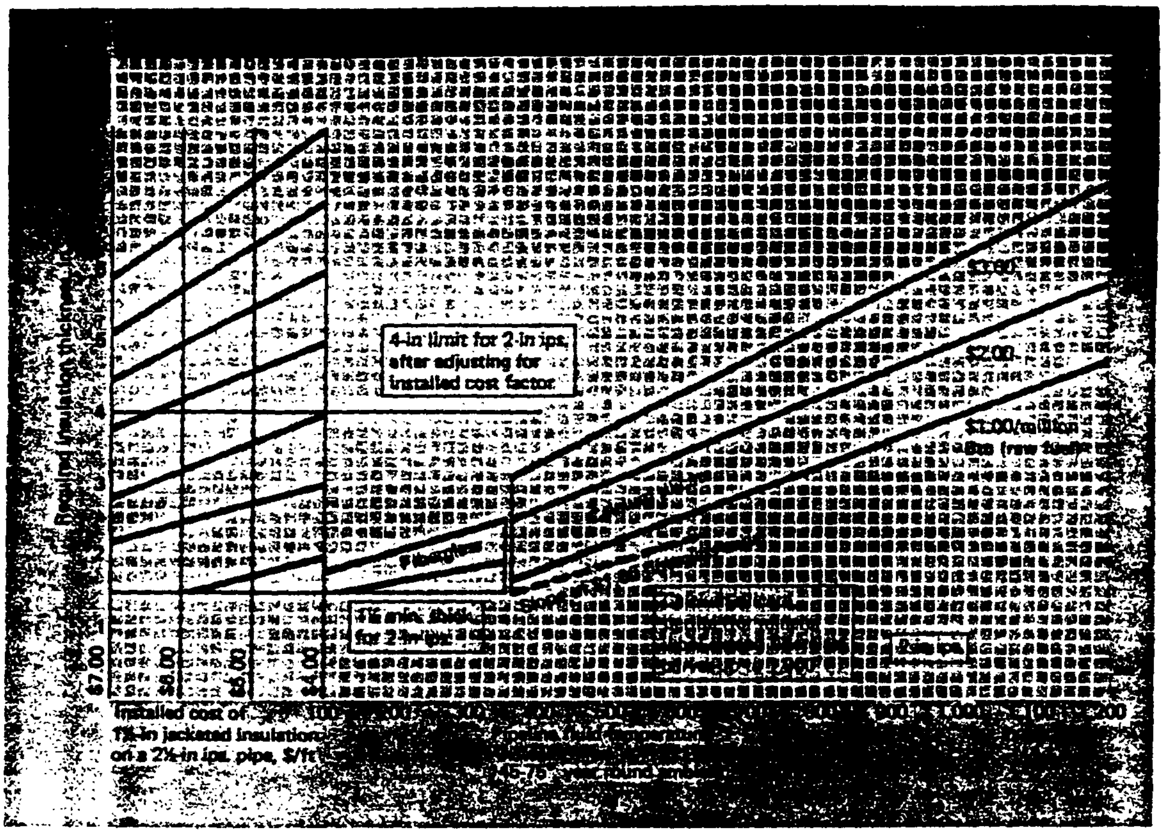
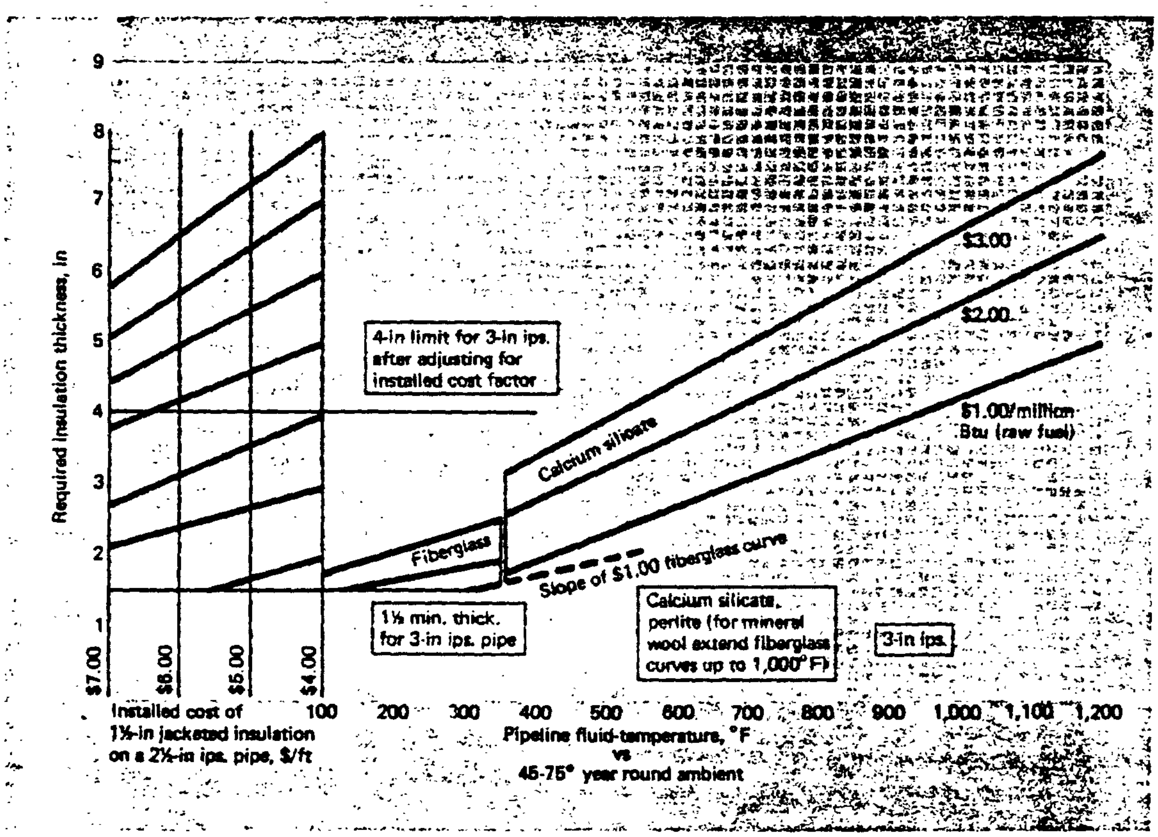
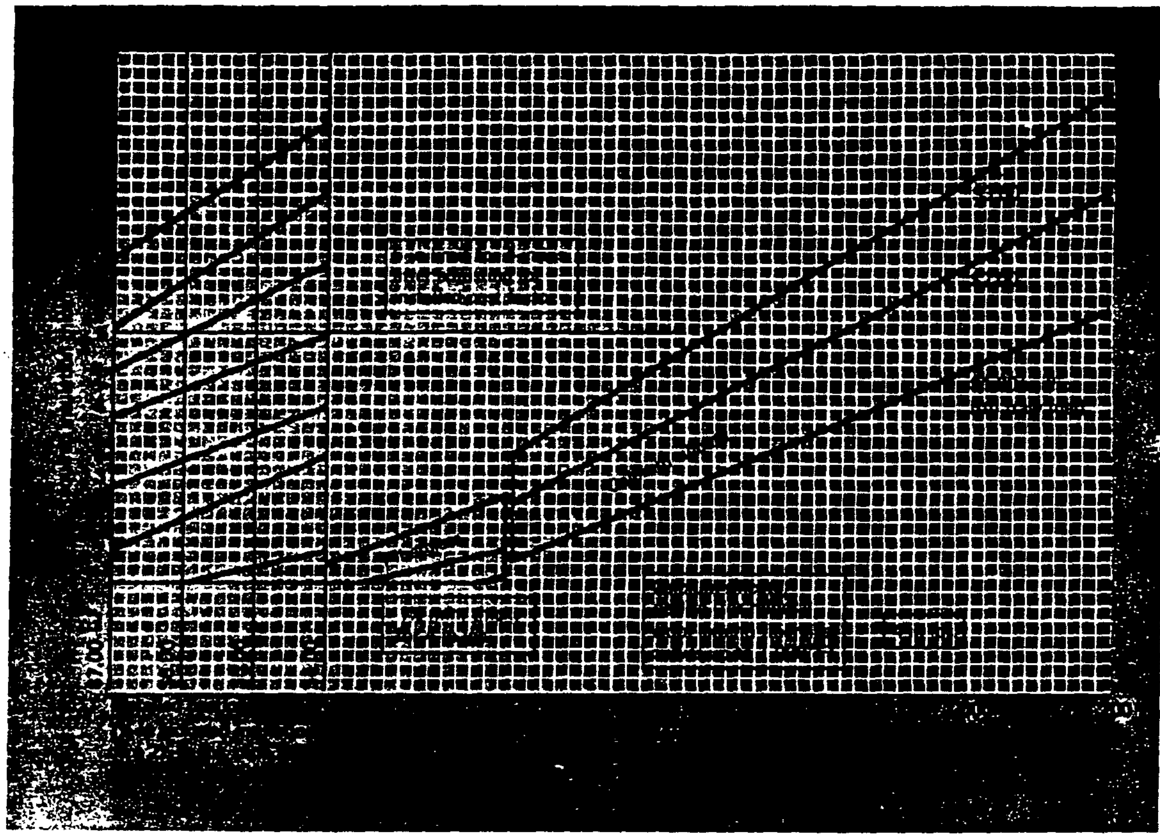


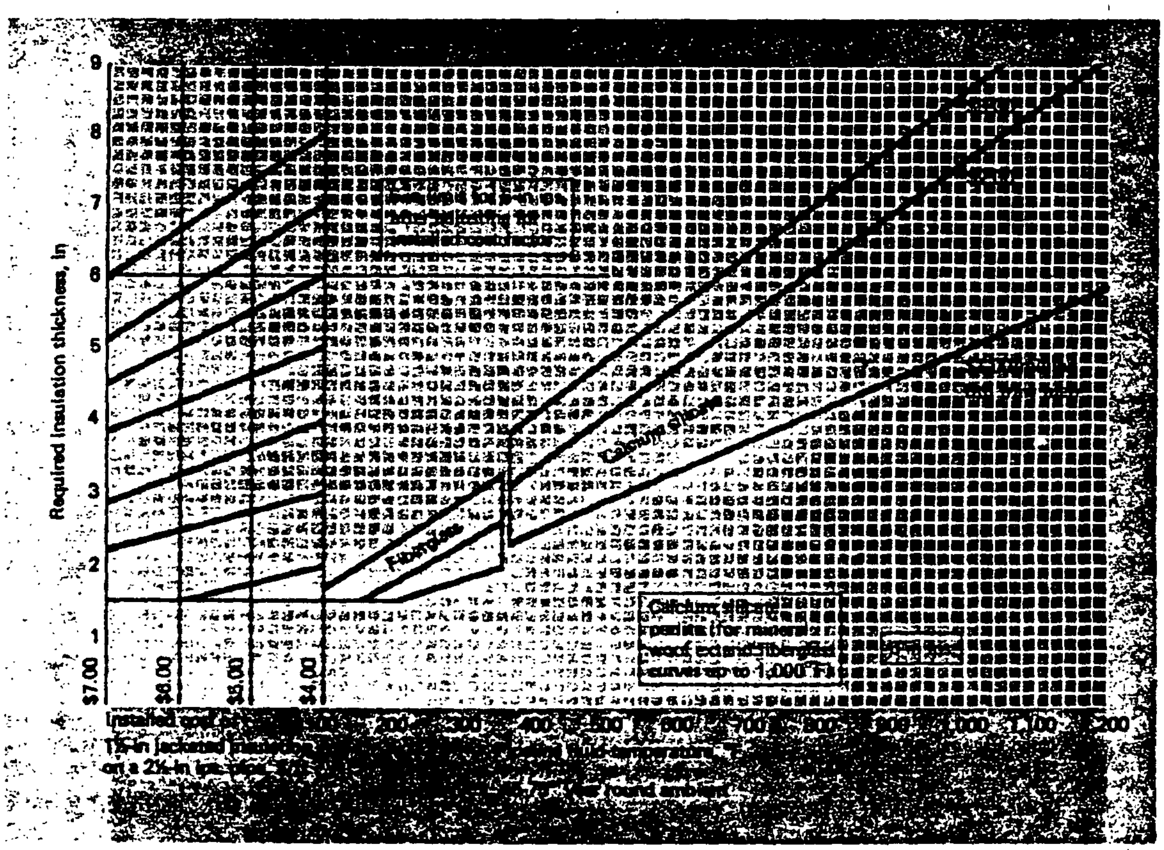
4-in limit for 2-in ips.
after adjusting for
installed cost factor
$3.00
$2.00
$1.00/million
Btu (raw fuel)
Fiberglass
1½ min. thick.
for 2-in ips.
$7.00
$6.00
$5.00
$4.00
Installed cost of
1½-in jacketed insulation
on a 2½-in ips. pipe, $/ft
100



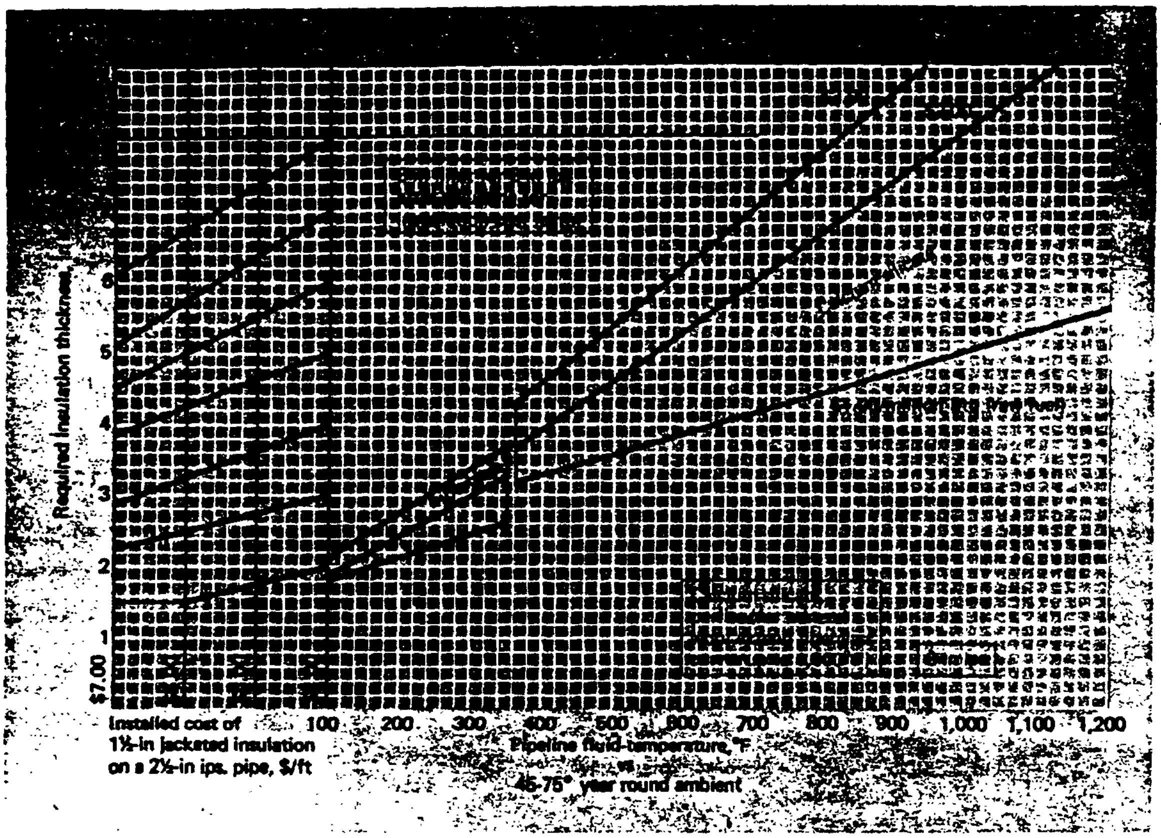
Required insulation thickness, in
9
8
7
6
5
4
3
2
1
$7.00
$6.00
$5.00
$4.00
4-in limit for 3-in ips.
after adjusting for
installed cost factor
$3.00
$2.00
$1.00/million
Btu (raw fuel)
Calcium silicate
Fiberglass
Slope of $1.00 fiberglass curve
1½ min. thick.
for 3-in ips. pipe
Calcium silicate,
perlite (for mineral
wool extend fiberglass
curves up to 1,000°F)
3-in ips.
Installed cost of
1½-in jacketed insulation
on a 2½-in ips. pipe, $/ft
100 200 300 400 500 600 700 800 900 1,000 1,100 1,200
Pipeline fluid-temperature, °F
vs
45-75° year round ambient

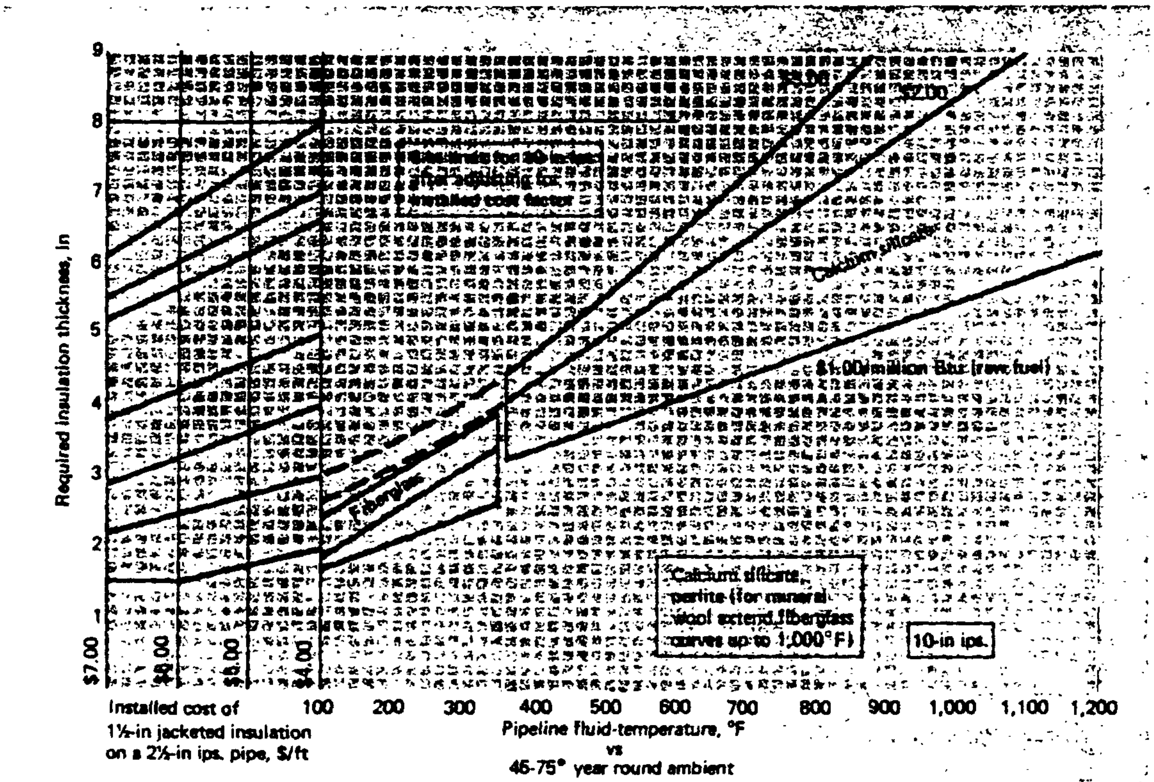
000164



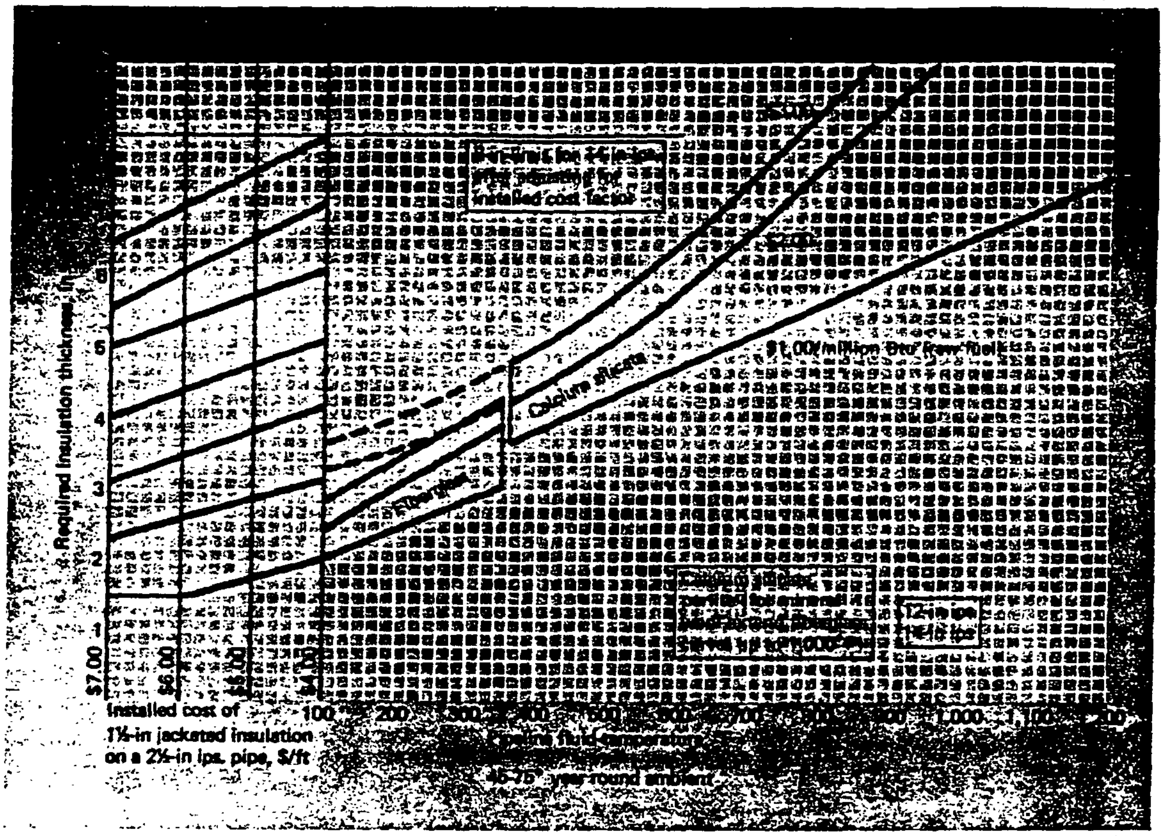

Required insulation thickness, in
9
8
7
6
5
4
3
2
1
$7.00
$6.00
$5.00
$4.00
Fiberglas
Calcium Silicate
200
300
400
500
600
700
800
900
1,000
1,100
1,200

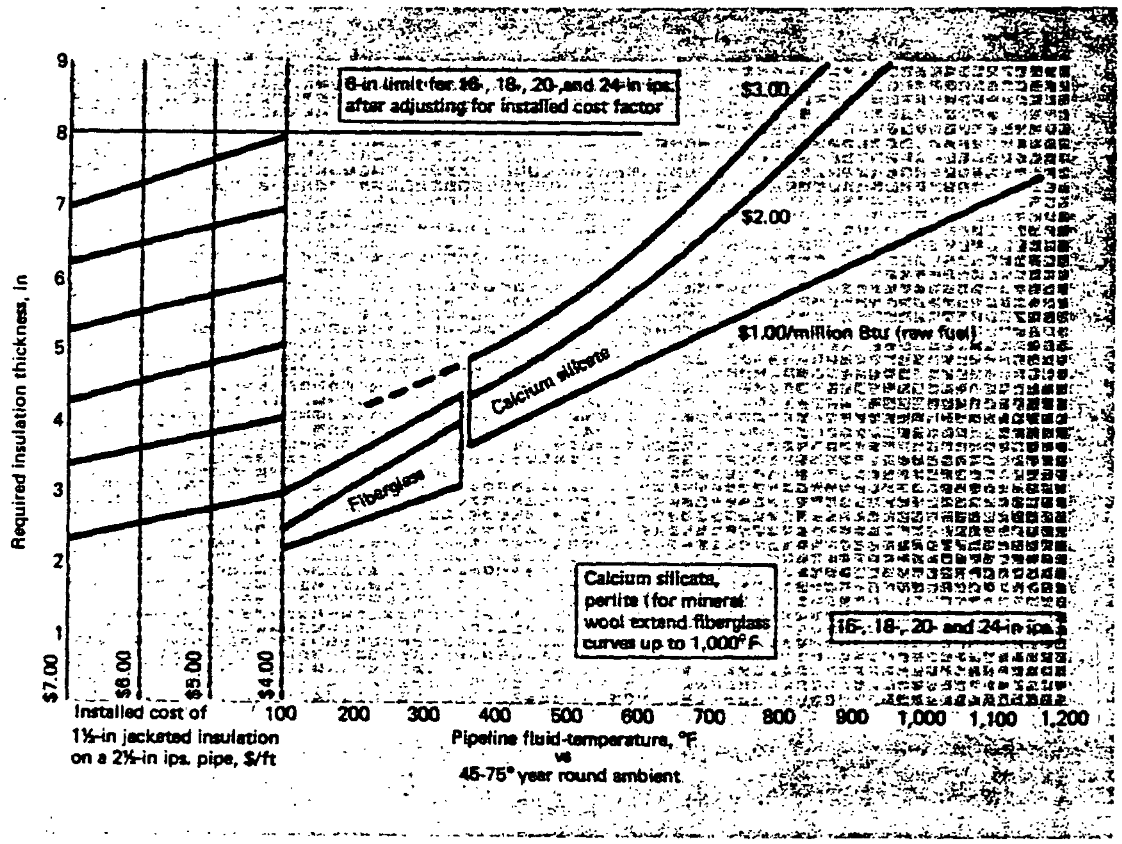
000165


Required insulation thickness, in
$7.00
Installed cost of
1½-in jacketed insulation
on a 2½-in ips. pipe, $/ft
100 200 300 400 500 600 700 800 900 1,000 1,100 1,200
Pipeline fluid-temperature, °F
45-75° year round ambient


9
8
7
6
5
4
3
2
1
Required insulation thickness, in
$7.00
$6.00
$5.00
$4.00
$2.00
Calcium silicate
$1.00/million Btu (raw fuel)
Fiberglass
Calcium silicate,
perlite (for mineral
wool extend fiberglass
curves up to 1,000°F)
10-in ips.
Installed cost of
1½-in jacketed insulation
on a 2½-in ips. pipe, $/ft
100 200 300 400 500 600 700 800 900 1,000 1,100 1,200
Pipeline fluid-temperature, °F
vs
45-75° year round ambient

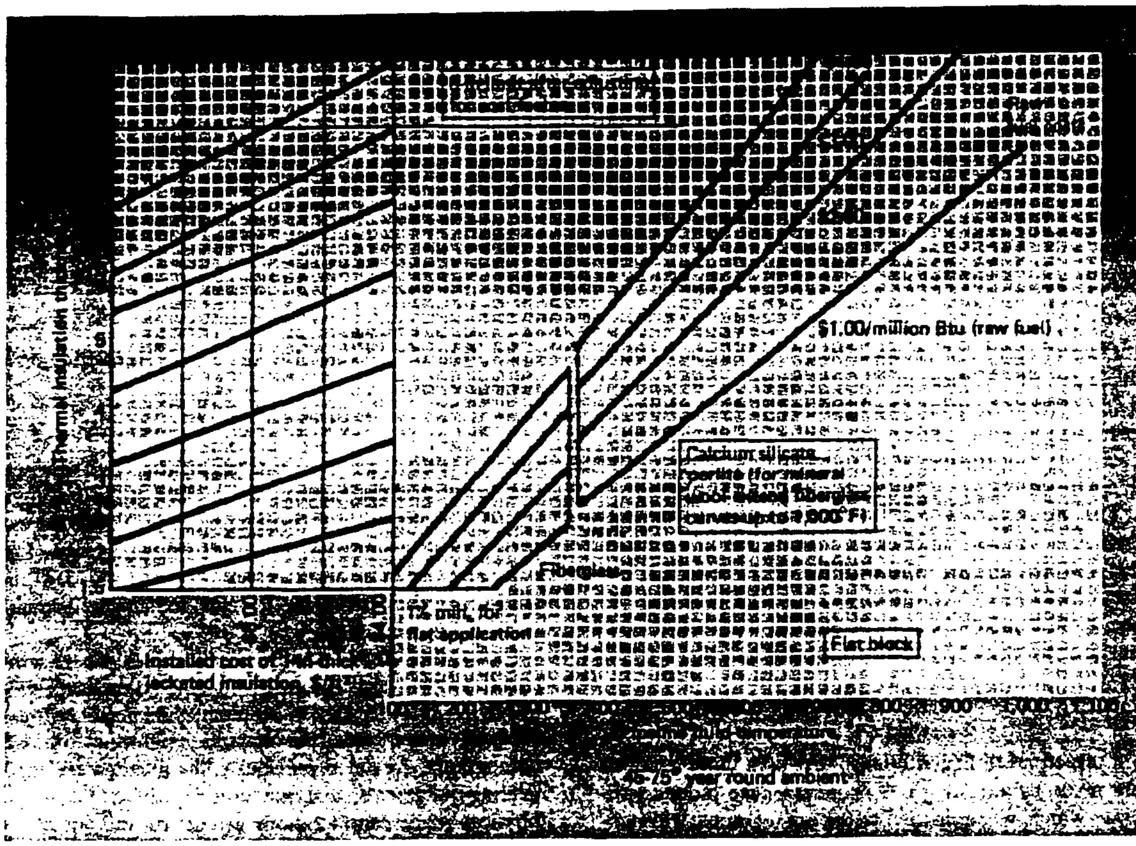
000166





8-in limit for 16-, 18-, 20-, and 24-in ips. after adjusting for installed cost factor
$3.00
$2.00
$1.00/million Btu (raw fuel)
Calcium silicate
Fiberglass
Calcium silicate, perlite (for mineral wool extend fiberglass curves up to 1,000°F.
16-, 18-, 20- and 24-in ips.
Required insulation thickness, in
$7.00
$6.00
$5.00
$4.00
Installed cost of 1½-in jacketed insulation on a 2½-in ips. pipe, $/ft
100
200
300
400
500
600
700
800
900
1,000
1,100
1,200
Pipeline fluid-temperature, °F vs 45-75° year round ambient

000167



Specified Annual Interest (Factor A)—Table I

Amortization Period, Yr	Value of A for Various Interest Rate, Annual, 6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10.0	10.5	11.0	11.5	12.0
1	1.060	1.065	1.070	1.075	1.080	1.085	1.090	1.095	1.100	1.106	1.110	1.115	1.120
2	0.5454	0.5493	0.5531	0.5569	0.5608	0.5646	0.5685	0.5723	0.5762	0.5801	0.5839	0.5878	0.5917
3	0.3741	0.3776	0.3811	0.3845	0.3880	0.3915	0.3961	0.3986	0.4021	0.4057	0.4092	0.4128	0.4163
4	0.2886	0.2919	0.2952	0.2986	0.3019	0.3053	0.3087	0.3121	0.3155	0.3189	0.3223	0.3258	0.3292
5	0.2374	0.2406	0.2439	0.2472	0.2505	0.2538	0.2571	0.2604	0.2638	0.2672	0.2706	0.2740	0.2774
6	0.2034	0.2066	0.2088	0.2130	0.2163	0.2263	0.2229	0.2263	0.2296	0.2330	0.2364	0.2398	0.2432
7	0.1791	0.1823	0.1856	0.1888	0.1921	0.1954	0.1987	0.2020	0.2054	0.2088	0.2122	0.2157	0.2191
8	0.1610	0.1642	0.1675	0.1707	0.1740	0.1773	0.1807	0.1840	0.1874	0.1909	0.1943	0.1978	0.2013
9	0.1470	0.1502	0.1535	0.1568	0.1601	0.1634	0.1668	0.1702	0.1736	0.1771	0.1806	0.1841	0.1877
10	0.1359	0.1391	0.1424	0.1457	0.1490	0.1524	0.1558	0.1593	0.1627	0.1663	0.1698	0.1733	0.1770
11	0.1268	0.1301	0.1334	0.1367	0.1401	0.1435	0.1469	0.1504	0.1540	0.1575	0.1611	0.1648	0.1684
12	0.1193	0.1226	0.1259	0.1293	0.1327	0.1362	0.1397	0.1432	0.1468	0.1504	0.1540	0.1577	0.1614
13	0.1130	0.1163	0.1197	0.1231	0.1265	0.1300	0.1336	0.1372	0.1407	0.1444	0.1482	0.1519	0.1557
14	0.1076	0.1109	0.1143	0.1178	0.1213	0.1248	0.1284	0.1321	0.1357	0.1395	0.1432	0.1470	0.1509
15	0.1030	0.1064	0.1098	0.1133	0.1169	0.1204	0.1241	0.1277	[illegible]	0.1352	0.1391	0.1429	0.1468
16	0.0990	0.1024	0.1059	0.1094	0.1130	0.1166	0.1203	0.1240	0.1278	0.1316	0.1355	0.1394	0.1434
17	0.0954	0.0989	0.1024	0.1060	0.1096	0.1133	0.1170	0.1208	0.1247	0.1285	0.1325	0.1364	0.1405
18	0.0924	0.0959	0.0994	0.1030	0.1067	0.1104	0.1142	0.1180	0.1219	0.1259	0.1298	0.1339	0.1379
19	0.0896	0.0932	0.0968	0.1004	0.1041	0.1079	0.1117	0.1156	0.1195	0.1235	0.1276	0.1316	0.1358
20	0.0872	0.0908	0.0944	0.0981	0.1019	0.1057	0.1095	0.1135	0.1175	0.1215	0.1256	0.1297	0.1339
21	0.0850	0.0886	0.0923	0.0960	0.0998	0.1037	0.1076	0.1116	0.1156	0.1197	0.1238	0.1280	0.1322
22	0.0830	0.0867	0.0904	0.0942	0.0980	0.1019	0.1059	0.1099	0.1140	0.1181	0.1223	0.1265	0.1308
23	0.0813	0.0850	0.0887	0.0925	0.0964	0.1004	0.1044	0.1084	0.1126	0.1167	0.1210	0.1252	0.1285
24	0.0797	0.0834	0.0872	0.0910	0.0950	0.0990	0.1030	0.1071	0.1113	0.1155	0.1198	0.1241	0.1285
25	0.0782	0.0820	0.0858	0.0887	0.0937	0.0977	0.1018	0.1060	0.1102	0.1144	0.1187	0.1231	0.1275

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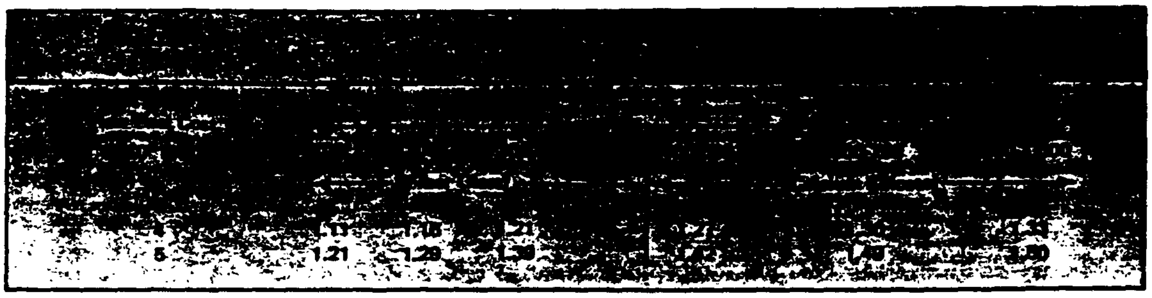

Observe that Fig. 2 shows a 1½-in minimum insulation thickness—this is common to all the nomographs. Several manufacturers have indicated that they are discontinuing insulation material thinner than 1½ in. in recognition of dwindling user interest. It is probable that 1½-in insulation will soon be the thinnest competitively available.

The nomographs also indicate maximum recommended insulation thicknesses. These maxima vary with the pipe size, and are in recognition of the economic impact of excessive thickness in such areas as pipe-rack capacity, pipe support problems, and the like. These maxima are based solely on our engineering judgments.

Adjusting for Variations in Assumptions

Corrections to fit conditions other than those assumed are made by adjusting one or more of the plotted variables which, when applied to the nomographs, will indicate the optimum insulation thickness.

Hours of Operation and Efficiency—To adjust for fewer than 8,760 hr/yr operation, or for overall efficiency other than 72%, multiply "Raw fuel cost per million Btu" by:

$$(\text{hours of operation}/8{,}760)\ (72\%/\%\ \text{efficiency})$$

Ambient Temperature Other Than 45-75°F—For *higher* ambients, *subtract* from "Pipeline-fluid temperature" the quantity:

$$\text{Ambient} - 60$$

For *lower* ambients, *add* to "Pipeline-fluid temperature" the quantity:

$$60 - \text{Ambient}$$

Service Life, Maintenance, Cost of Money—To adjust for a service life of other than 15 yr, a cost of money other than 10%, or appreciable insulation maintenance, multiply "Installed cost of 1½-in jacketed insulation on a 2½-in pipe" by:

$$(A + M)/0.1315$$

where A is the uniform annual payment needed to reach unit value over the expected service life, while paying a specified annual interest (read from Table I). M is the expected average annual maintenance charge, expressed as a decimal part of the installed cost. (0.1315 is the uniform annual payment at 10% for 15 years, the assumed conditions for the nomograph.)

Fuel Costs Above \$3—For applications where projected raw-fuel costs exceed $\$3/10^6$ Btu, adjust curve values by using Table II. The resultant thicknesses will exceed, in many cases, the maxima established on the nomographs. As stated previously, the maxima are engineering judgments, and the user is advised to weigh physical space considerations against overall operating economy.

Differing Energy-Cost Levels—Applications will arise where a portion of the plant's piping owes its temperature level to conventional combustion of fossil fuels, while other streams are heated by significantly differing energy sources such as low-pressure waste steam, exhaust gases and direct-fired calciners. The user is encouraged to apply appropriate raw-fuel costs and efficiency adjustments for each distinct system to derive maximum benefit from this article.

Cylindrical Equipment—Cylindrical equipment of less than 30-in. O.D. may be treated as pipe of approximately the same O.D. #

References

1. "Econ-I—How to Determine Economic Thickness of Thermal Insulation," Thermal Insulation Manufacturers Assn., 7 Kirby Plaza, Mt. Kisko, NY 10549, 1973.
2. King, Reno C., Crocker, Sabin, eds., "Piping Handbook," 5th ed., McGraw-Hill, New York, 1967.

Meet the Authors

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Guidelines for Heat-Loss Calculations From Storage Tanks—Table

Condition	Neglect	Graphical Solution—Use	Algebraic Solution—Calculate
Vessel is uninsulated. Contained liquid is agitated.	Film resistance of contained liquid.	Fig. 1. Correct for wind velocity or outside surface emissivity, if required.	Heat loss through outside air film only, by using Eq. (7b) and (4b).
Vessel is uninsulated. Contained vapor condenses appreciably at wall temperature.	Film resistance of contained vapor.	Fig. 1. Correct for wind velocity or outside surface emissivity, if required. Temperature correction factor, W = 1.0	Heat loss through outside air film only, by using Eq. (7b) and (4b).
Vessel is unisulated. Contained liquid fouls or solidifies at wall temperature.	Film resistance of both contained liquid and vapor adjacent to fouled surface.	Fig. 1 with temperature correction factor W = 0.4; and wind velocity or emissivity correction as required.	Heat loss through fouling layer and adjacent air film by using Eq. (4a) or (8).
Vessel is uninsulated, and contains stagnant liquid or dry vapor.		Fig. 1 with temperature correction factor, W, obtained from table for type of contained material; and wind velocity or emissivity correction as required.	Heat loss through inside-fluid film and adjacent air film by using Eq. (6) or (6a), (7) and (4).
Vessel is insulated with calcium silicate or similar material.	Film resistance of both contained liquid and vapor adjacent to insulated surface.	Fig. 2 with wind-velocity correction factor obtained from table. Insulation thickness may be obtained from Fig. 2.	Heat loss through insulation and adjacent air film by using Eq. (7a) and (3).

Insulation Saves Energy

Shortcut graphical methods allow rapid evaluation of heat losses from uninsulated and insulated vessels. Depending on the temperature difference between vessel and ambient air, the method also sets the required thickness of outside insulation.

RICHARD HUGHES and VICTOR DEUMAGA, The Badger Co.

Accurate calculations for determining the heat flow between the contents of a vessel and its surroundings are often complex. Multiple resistances in series are usually present in the heat-flow path. In addition, conduction, convection and radiation flows may be simultaneously involved. And there may be heat flow by evaporation and condensation within the confines of the vessel.

Therefore, the particular assumptions and simplifications involved in the method used to calculate heat losses must be understood, and the accuracy of the method must be consistent with a particular requirement.

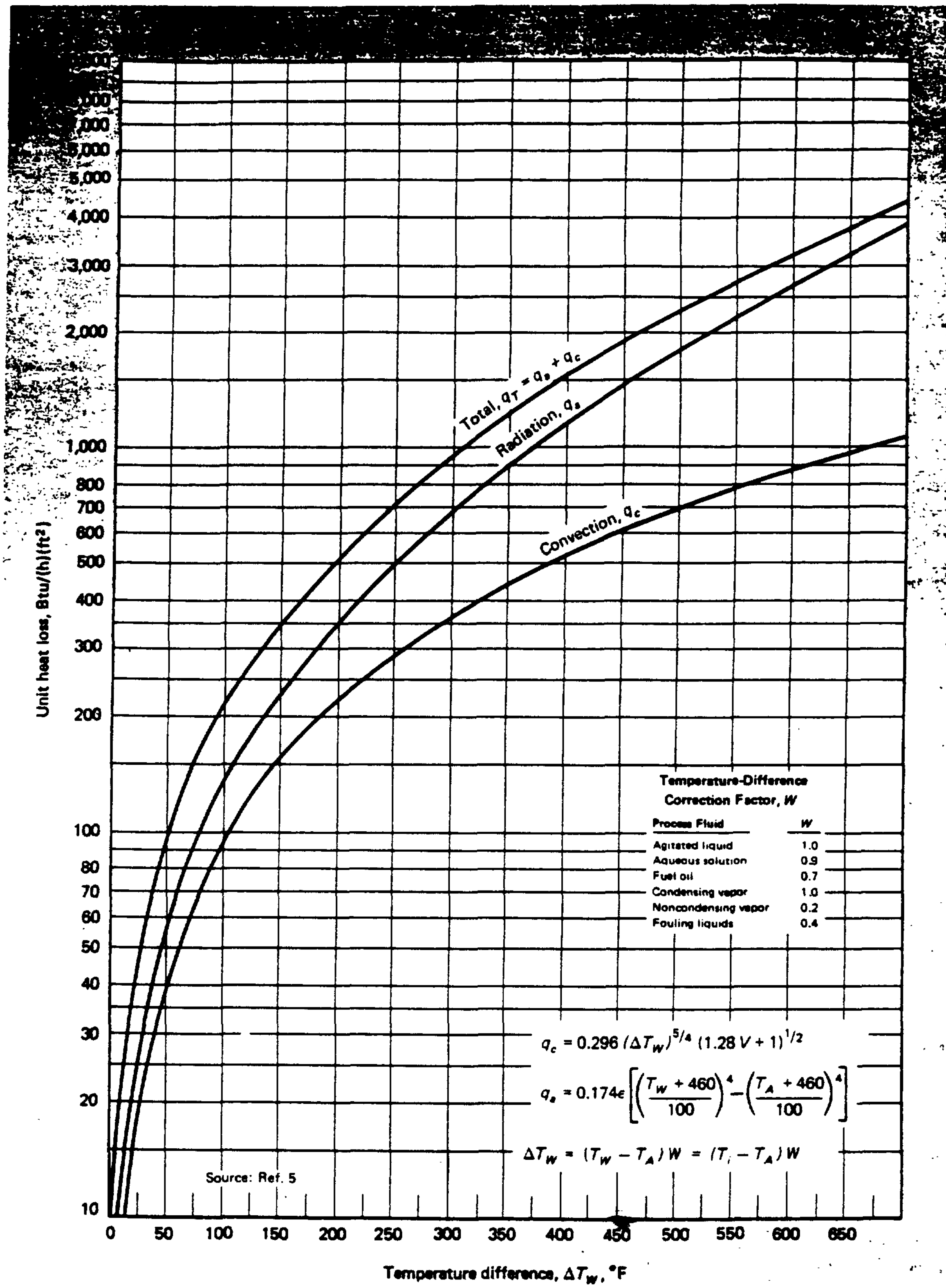
For example, a simple shortcut approximation will usually indicate whether outside insulation of a given thickness is required. On the other hand, it is often desirable to accurately check a final design (sometimes at varying ambient or internal tank conditions) to determine the average annual heat losses.

Accordingly, we will present two methods of heat-loss calculation:

1. A rapid graphical method that can be used for exploratory evaluation of heat losses.
2. A more accurate algebraic method that is suitable for a computerized solution if multiple calculations are required.

Graphical Method Is Rapid

We can obtain an approximate value for the unit heat loss from Fig. 1 or 2. The unit heat loss when multiplied by the surface area under review yields the overall hourly



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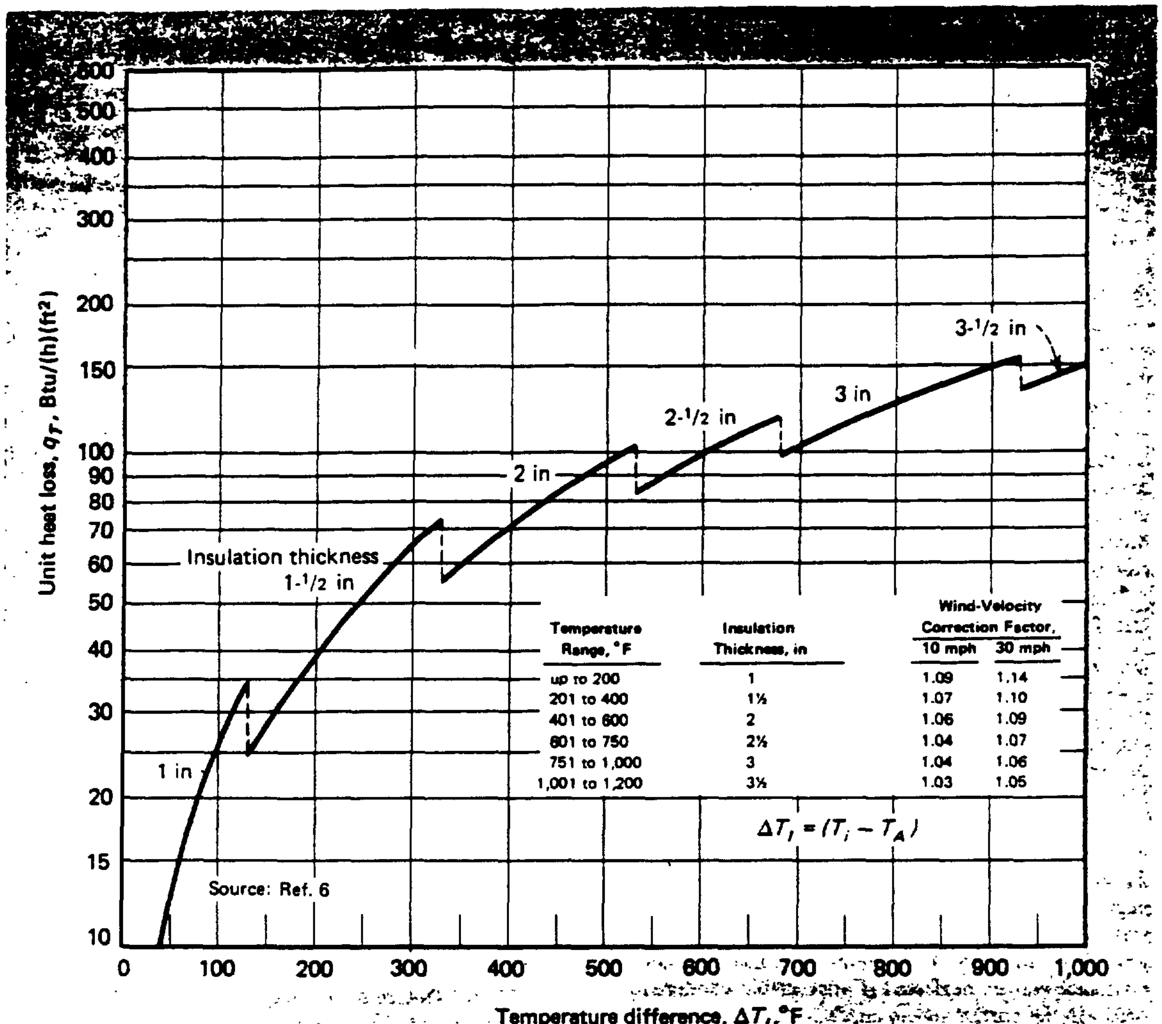
UNINSULATED tanks have heat losses that depend on nature of tank contents. Values in chart are for wind velocity of zero, surface emiss-ivity of 0.9, and ambient air temperature of 70°F—F.. I



Temperature Range, °F	Insulation Thickness, in	Wind-Velocity Correction Factor, 10 mph	30 mph
up to 200	1	1.09	1.14
201 to 400	1½	1.07	1.10
401 to 600	2	1.06	1.09
601 to 750	2½	1.04	1.07
751 to 1,000	3	1.04	1.06
1,001 to 1,200	3½	1.03	1.05

INSULATED tanks, covered with calcium silicate, have heat losses based on negligible resistance to heat flow on process side. Values in chart are for wind velocity of zero, emissivity of 0.8, ambient air temperature of 70°F—Fig. 2

heat loss. A summation of the discrete losses through the tank roof and tank side, exposed to both liquid and vapor, gives the total hourly heat loss to the atmosphere. In addition, heat loss from the bottom of the tank to the ground is easily calculated from Eq. (5) to complete the heat-loss approximation. Table I summarizes conditions for which Fig. 1 and 2 are recommended.

Fig. 1 is used to approximate heat losses from uninsulated tanks. A table of correction factors for temperature difference is included to compensate for common internal resistances to heat flow. In addition, the unit heat loss is divided into a convection and a radiation component. This allows rapid, independent correction for wind velocity and surface emissivity, if required. Fig. 1 also contains a total unit-heat-loss curve at zero wind velocity and 0.9 radiation emissivity.

Fig. 2 is used to approximate heat losses from insulated tanks. A table of recommended insulation thickness for various temperature ranges is included, and wind-loss correction factors at the recommended insulation thickness are given.

Analysis of Algebraic Method

Heat losses from tanks are calculated by using the natural-convection heat-transfer relations for the sides and roof of the tank, and the conduction heat-transfer relation for the bottom where the tanks rest on the ground.

The total heat loss, Q_T, is divided into four components:

$$Q_T = Q_L + Q_V + Q_R + Q_G \tag{1}$$

where Q_L is heat loss from liquid in tank to atmosphere through sidewall; Q_V is heat loss from vapor in tank to atmosphere through sidewall; Q_R is heat loss from vapor

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in tank to atmosphere through roof; and Q_G is heat loss from liquid in tank to ground through the bottom of the tank.

Table I summarizes conditions for which specific equations are recommended to calculate the component heat losses.

Heat Losses: Sidewall and Top

The method for calculating side and top heat losses, Q_L, Q_V and Q_R, is essentially the same. In all cases, heat loss is calculated through two series resistances to heat transfer. These resistances are: (1) the tank inside-film or the tank insulation, and (2) the air film (when insulation is used, the inside-film resistance is neglected). Note that in all cases the tank wall itself is neglected as a separate resistance. If the tank is fabricated of heat-transfer-resistant material, then the wall itself can be treated as an insulation layer. Similarly, if appreciable fouling or solidification occurs within the tank, the fouling layer becomes equivalent to an insulation layer.

The usual individual and overall relationships for heat transfer are given by:

$$Q/A = q_a + q_c = q = U(T_i - T_A) = h_i(T_i - T_W) = (k_I/X_I)(T_W - T_I) = h_A(T_I - T_A) \quad (2)$$

When the tank surface under consideration is insulated, the unit heat loss, q, is given by:

$$q = (k_I/X_I)(T_i - T_I) = h_A(T_I - T_A) \quad (3)$$

Note that the inside-film resistance is neglected, and $T_W = T_i$. The inside liquid-film resistance can also be neglected, even in the absence of insulation, if the liquid contents are agitated. In this case, a direct resolution is possible by using Eq. (4b). Similarly, the inside vapor-film resistance can be neglected if appreciable condensation occurs in the portion of the tank's surface that is exposed to vapors.

When the tank surface under consideration is not insulated, the unit heat loss, q, is given by:

$$q = h_i(T_i - T_W) = h_A(T_W - T_A) \quad (4)$$

For either insulated or uninsulated tanks, the method of computation is the same. The air temperature, T_A, and the tank-contents temperature, T_i, are known. Individual film heat-transfer coefficients [as defined by Eq. (6) and (7)] are used, together with insulation resistance, where applicable, to calculate the remaining unknown intermediate temperature, T_I, in Eq. (3), or T_W in Eq. (4), and hence to calculate the unit heat loss. The total heat loss is then calculated as the product of the unit heat loss and tank surface area under consideration.

When the tank surface is coated internally with a fouling or solidified layer, the unit heat loss is found from a modification of Eq. (4), which is:

$$q = (1/R_i)(T_i - T_W) = h_A(T_W - T_A) \quad (4a)$$

When the inside-film resistance is small and the tank surface is insulated, the unit heat loss becomes a particular case of Eq. (4), which is:

$$q = h_A(T_i - T_A) \quad (4b)$$

Nomenclature

- A Area of heat transfer, ft²
- C Specific heat, Btu/(lb)(°F)
- D Diameter of tank, ft
- g Gravity acceleration, 4.17 × 10⁸ ft/h²
- H Tank height, ft ← h = Film heat transfer coefficient, Btu/hr-ft²
- k Thermal conductivity, Btu/(h)(ft²)(°F/ft)
- P Pressure, psia
- Q Heat transferred, Btu/h
- q Unit heat transferred, Btu/(h)(ft²)
- R Fouling factor, (hr)(ft²)(°F)/Btu
- T Temperature, °F
- U Overall heat-transfer coefficient, Btu/(h)(ft²)(°F)
- V Wind velocity, mph
- W Temperature-difference correction factor
- X Thickness, ft
- β Coefficient of volumetric expansion, 1/°F
- ϵ Emissivity
- μ Viscosity, lb/(h)(ft)
- ρ Density, lb/ft³

Subscripts

- A Environment
- a Radiation
- c Convection
- F Fluid film
- G Ground
- i Tank content
- I Insulation
- L Liquid
- M Insulation mean
- R Roof
- r Fouling layer
- T Total
- V Vapor
- W Tank wall

Heat Losses: From Bottom of Tank

When a tank rests on the ground, the heat loss through the bottom, Q_G, is given by:

$$Q_G = 2Dk_G(T_L - T_G) \quad (5)$$

Eq. (5) was derived [1] from an equation given by McAdams [3]. The inside-film resistance to heat transfer is neglected.

If the tank is mounted aboveground, the bottom tank surface, A_G, is then added to the side-surface, A_L, when calculating Q_L by Eq. (3) or (4).

Finally, Q_T is found as the sum of the component heat losses from Eq. (1).

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Film Coefficients and Fouling

Inside liquid-film coefficient for a liquid in contact with the tank surface ($h_i = h_L$) is given by:

$$h_L = 0.45k_F\left[\frac{\rho_F^2 g\beta_F C_F(T_i - T_W)}{\mu_F k_F}\right]^{0.25} \quad (6)$$

Eq. (6) was derived [2] from an equation given by McAdams [4].

Inside vapor-film coefficient for a vapor in contact with the tank surface ($h_i = h_V$) is given by:

$$h_V = 9.686 \times 10^{-2} P^{0.5}(T_F)^{-0.1}(T_V - T_W)^{0.25} \quad (6a)$$

Eq. (6a) is a particular case of Eq. (6), and can be used for both nitrogen and air at moderate temperatures (50 to 400°F) and pressures (0 to 500 psig). When the vapor present is appreciably different from air, the vapor-film coefficient is calculated from Eq. (6) by using vapor-film physical properties. For a condensing vapor, the vapor-film resistance is neglected, and hence the coefficient is not calculated.

The outside air-film coefficient is calculated from one of the following equations.

When the tank surface is uninsulated, Eq. (7) is recommended for substitution into Eq. (4):

$$h_A = 0.296(T_W - T_A)^{1/4}(1.28V + 1)^{1/2} + 0.174\epsilon\left[\frac{\left(\frac{T_W + 460}{100}\right)^4 - \left(\frac{T_A + 460}{100}\right)^4}{T_W - T_A}\right] \quad (7)$$

Eq. (7) includes a wind-velocity correction factor and a radiation loss factor [5].

When the tank surface is insulated, Eq. (7a) is recommended for substitution into Eq. (3):

$$h_A = 0.296(T_I - T_A)^{1/4}(1.28V + 1)^{1/2} + 0.174\epsilon\left[\frac{\left(\frac{T_I + 460}{100}\right)^4 - \left(\frac{T_A + 460}{100}\right)^4}{T_I - T_A}\right] \quad (7a)$$

Eq. (7a) differs only from Eq. (7) in that the surface temperature of the insulation, T_I, is used instead of the tank-wall temperature, T_W.

In either case, Eq. (3) or (4) is then solved by trial and error for the intermediate temperature, T_I or T_W, which is then used to calculate the unit heat loss, q.

When the tank surface is uninsulated and the liquid-film or vapor-film resistance for the material contained in the tank is small, Eq. (7b) is recommended for substitution into Eq. (4b):

$$h_A = 0.296(T_i - T_A)^{1/4}(1.28V + 1)^{1/2} + 0.174\epsilon\left[\frac{\left(\frac{T_i + 460}{100}\right)^4 - \left(\frac{T_A + 460}{100}\right)^4}{T_i - T_A}\right] \quad (7b)$$

For these conditions, Eq. (4b) can be used directly to calculate the unit heat loss, q.

If the thickness of the fouling layer can be estimated, the inside fouling factor used in Eq. (4a) can be calculated from:

$$R_i = X_r/k_r \quad (8)$$

The thermal conductivity, k_r, is usually taken as the fluid thermal conductivity at the mean temperature across the fouling layer.

Temperatures and Physical Properties

Initially, we can assume that the intermediate temperature, T_W or T_I, is midway between T_i and T_A. The inside fluid properties are used at the average inside-film temperature of $(T_i + T_W)/2$. Similarly, outside properties at the average outside-film temperature of $(T_W + T_A)/2$ are used to evaluate physical properties for the film coefficients in Eq. (4).

When the tank is insulated, the average insulation temperature, T_M, becomes $(T_i + T_I)/2$. Similarly, the average outside-film temperature becomes: $(T_I + T_A)/2$. These average temperatures are used to evaluate physical properties for the film coefficients in Eq. (3).

For greater accuracy, the average film temperatures can be recalculated by using T_I or T_W, as found from Eq. (3) and (4). Hence, a new heat loss can be obtained by using physical property data at the new average film temperature.

Emissivity of Surfaces—Table II

Surface	[illegible] of Black-Body [illegible] at 50°-100°F	at 1,000°F
Black nonmetallic surfaces such as asphalt, carbon, slate, paint, paper	0.90-0.98	0.90-0.98
Red brick and tile, concrete and stone, rusty steel and iron, dark paints (red, brown, green)	0.85-0.95	0.75-0.90
White or light-cream brick, tile, paint or paper, plaster, whitewash	0.85-0.95	0.60-0.75
Bright aluminum paint, gilt or bronze paint	0.40-0.60	
Dull brass, copper, or aluminum; galvanized steel; polished iron	0.20-0.30	0.30-0.50
Polished brass, copper, Monel metal	0.02-0.05	0.05-0.15
Highly polished aluminum, tin plate, nickel, chromium	0.02-0.04	0.05-0.10

Source: "ASHRAE Guide (Heating, Ventilating, Air-Conditioning Guide)," Chap. 5, p. 82, American Soc. of Heating, Refrigerating and Air-Conditioning Engineers, New York, 1959.

Problem Illustrates Procedures

A fuel oil at 12° API at 60°F with a viscosity of 50 SSF (Saybolt seconds furol) at 122°F is stored at 300°F in a 20-ft-dia. by 30-ft-high carbon-steel tank at atmospheric pressure. The oil level in the tank is 18 ft. Air temperature is 70°F. Let us calculate heat losses to the environment for the following two cases:

Case 1—Total surface of the tank is uninsulated and black. Wind velocity is 0 mph. Surface emissivity of tank is 0.9. Thermal conductivity of ground is 0.8 Btu/(h)(ft²)(°F/ft).

We will begin the computations by finding the heat loss from the wetted inside surface of the tank. The wetted area is:

$$A_L = \pi D H_L = \pi(20)(18) = 1{,}130\ \text{ft}^2$$

$$\Delta(T_i - T_A) = (300 - 70) = 230°\text{F}$$

From Fig. 1, we find the unit heat loss to be 664 Btu/(h)(ft²) for this temperature difference. Therefore:

$$Q_L = A_L q_L = 1{,}130(664) = 750{,}320\ \text{Btu/h}$$

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Next, we calculate the heat loss from the dry inside surface and roof surface of the tank:

$$A_V = \pi D H_V + \pi D^2/4$$
$$A_V = \pi(20)(30 - 18) + \pi(20)^2/4$$
$$A_V = 754 + 314 = 1{,}068 \text{ ft}^2$$
$$\Delta T_W = (T_i - T_A)W = 230(0.20) = 46°\text{F}.$$

Note that W is the temperature-difference correction factor for a noncondensing vapor (Fig. 1).

For this temperature difference, we find the unit heat loss from Fig. 1 to be: 84.3 Btu/(h)(ft²). Hence:

$$Q_V = A_V q_V = 1{,}068(84.3) = 90{,}030 \text{ Btu/h}$$

Assuming that $T_G = T_A$, we substitute the appropriate quantities into Eq. (5) to find Q_G as:

$$Q_G = 2(20)(0.8)(300 - 70) = 7{,}360 \text{ Btu/h}$$

Therefore, the total heat loss is:

$$Q_T = Q_L + Q_V + Q_G$$
$$Q_T = 750{,}320 + 90{,}030 + 7{,}360 = 847{,}710 \text{ Btu/h}$$

Alternatively, we can find the exact solution by using the algebraic equations. After making the necessary calculations, we find that:

$$Q_T = Q_L + Q_V + Q_G$$
$$Q_T = 750{,}980 + 135{,}782 + 7{,}360 = 894{,}122 \text{ Btu/h}$$

Case 2—Roof of tank is uninsulated and is coated with aluminum paint. Side-wall is insulated with calcium silicate, or equivalent, and has a surface emissivity of 0.8. Wind velocity is 30 mph. Tank contents are not agitated. Thermal conductivity of ground is 0.8 Btu/(h)(ft²)(°F/ft).

As in Case 1, the wetted surface of the tank, A_L, is 1,130 ft.² This represents the interior circumferential area of the tank wetted by the fuel oil to a height of 18 ft.

Heat loss from the vessel wall to ambient air is a function of:

$$\Delta T_I = (T_W - T_A) = (300 - 70) = 230°\text{F}$$

From Fig. 2, we find the recommended insulation thickness to be 1½ in, and the wind-velocity correction factor to be 1.10. Also, from Fig. 2, we find that the unit heat loss, corrected for wind velocity, becomes:

$$q_L = 46(1.10) = 50.6 \text{ Btu/(h)(ft}^2)$$

Hence: $Q_L = A_L q_L = 1{,}130(50.6) = 57{,}178$ Btu/h

Now, we calculate the heat loss from the insulated dry-side surface:

$$A_V = \pi(20)(30 - 18) = 754 \text{ ft}^2$$
$$\Delta(T_W - T_A) = 230°\text{F}$$
$$q_V = 46(1.10) = 50.6 \text{ Btu/(h)(ft}^2)$$
$$Q_V = A_V q_V = 754(50.6) = 38{,}152 \text{ Btu/h}$$

In order to calculate the heat loss from the uninsulated roof, we must use Fig. 1. We find that $A_R = \pi(20)^2/4 = 314$ ft,² and that surface emissivity = 0.4 from Table II.

$$\Delta T_W = (T_i - T_A)W = 230(0.20) = 46°\text{F}$$

Using this corrected temperature difference and Fig. 1, we find that the unit heat loss for radiation and convection (correcting the radiation loss for an emissivity of 0.4 and the convection loss for the wind velocity) is:

$$q_a = 54.2(0.4) = 21.7 \text{ Btu/(h)(ft}^2)$$
$$q_c = 35.5[(1.28)(30) + 1]^{1/2} = 222.8 \text{ Btu/(h)(ft}^2)$$
$$q_R = q_a + q_c = 21.7 + 222.8 = 244.5 \text{ Btu/(h)(ft}^2)$$

Hence: $Q_R = A_R q_R = 314(244.5) = 76{,}773$ Btu/h

Heat loss to the ground is the same as Case 1, i.e. $Q_G = 7{,}360$ Btu/h.

Therefore, the total heat loss is the sum of the component parts, or:

$$Q_T = 57{,}743 + 38{,}529 + 76{,}773 + 7{,}360$$
$$Q_T = 180{,}405 \text{ Btu/h}$$

Again, we can calculate a more-exact answer by using the algebraic equations. For this case:

$$Q_T = 54{,}419 + 36{,}279 + 49{,}887 + 7{,}360$$
$$Q_T = 147{,}945 \text{ Btu/h}$$

This problem illustrates the ease with which rapid approximations to heat loss can be made. #

References

1. Stuhlburg, D., How to Design Tank Heating Coils, *Petrol. Refiner*, Apr. 1959, p. 143.
2. Ibid, p. 146.
3. McAdams, W. H., "Heat Transmission," 3rd ed., p. 54, McGraw-Hill, New York, 1954.
4. Ibid, p. 172.
5. Malloy, J., "Thermal Insulation," p. 35, Van Nostrand Reinhold, New York, 1969.
6. "Heat Insulation Manual," pp. 72–79, Pabco Div., Fibreboard Corp., Emeryville, Calif.

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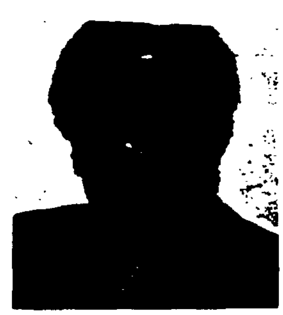

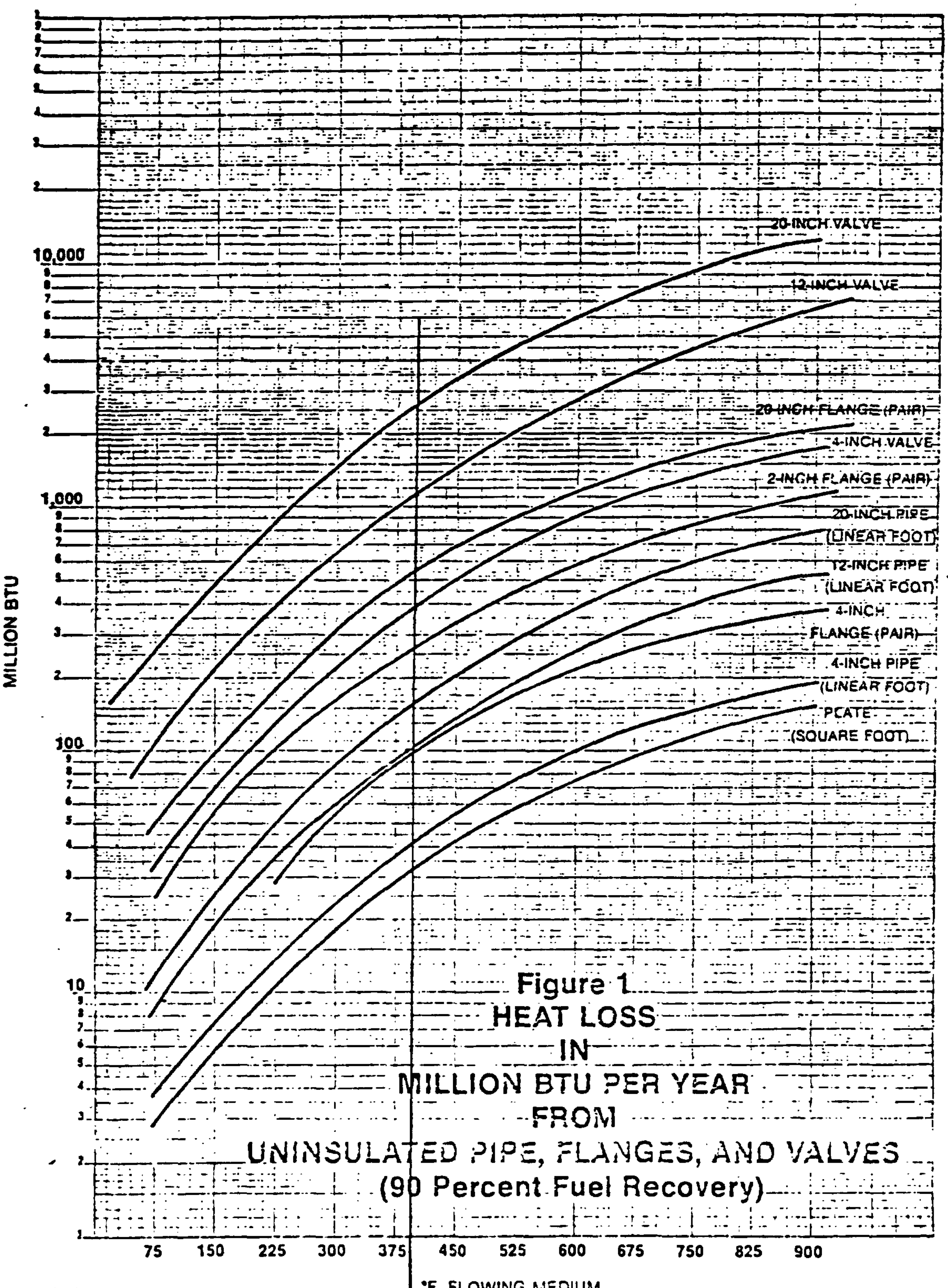

Figure 1
HEAT LOSS
IN
MILLION BTU PER YEAR
FROM
UNINSULATED PIPE, FLANGES, AND VALVES
(90 Percent Fuel Recovery)

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1. SCOPE

This section describes the guidelines to be considered by the engineer in designing and selecting insulation.

2. ITEMS INSULATED

Pipelines, valves, instruments and equipment to be insulated are defined on the mechanical flowsheets and/or piping drawings.

3. PURPOSE

3.1 HOT SERVICE

3.1.1 General

Hot service insulation serves four purposes: heat conservation, temperature control, personnel protection, and condensation prevention. The temperature used to determine the need for insulation or insulation thickness is the normal operating fluid temperature. One exception to this is when piping or equipment has internal insulation or refractory lining, the temperature that determines insulation thickness is the metal temperature. Composite insulation (one layer of one type of insulation and one layer of a second type) can be used where economical.

3.1.2 Heat Conservation

Operating temperatures of 100^{o}F or greater justify insulation for heat conservation. Since energy costs, money costs, and installed insulation costs can vary widely, no single table for economic insulation thickness can be constructed. For pipe, economic thickness can be determined by using the graphs in the article "How to Select Insulation Thickness for Hot Pipes", Chemcial Engineering, July 21, 1975. J. L. Abramovitz and R. Cordero, or by using the computer program T 2013 developed by CCTC. For tanks, heat loss can be estimated from Figure I of the article "Insulation Saves Energy", Chemical Engineering, May 27, 1974, R. Hughes and V. Deumagh or calculated using the equations in the same article. Economic thickness can be calculated using net present value. Program T 2013 can also be used to determine heat loss and economic thickness. For flanges and values, heat loss can be estimated from Figure I, "Heat Loss in Million BTU per Year from Uninsulated Pipe, Flanges and Values". Insulation thickness will normally be the same as used on associated piping.

3. PURPOSE (Continued)

3.1 HOT SERVICE (Continued)

3.1.2 Heat Conversation (Continued)

More extensive help in specifying economic thickness can be found in ECON-1, the Economic Thickness Manual supplied by Thermal Insulation Manufacturers Association.

3.1.3 Temperature Control

In some cases piping or equipment which would not be insulated for heat conservation will require insulation for close process temperature control.

3.1.4 Personnel Protection

Operating temperatures above 150^{o}F justify protective insulation. Insulate piping or equipment to a height of 7 ft. above the operating level, or wherever there exists the probability of human contact.

3.2 COLD SERVICE

Cold service insulation serves two main purposes; to minimize heat gain, and to prevent condensation on the cold surface. All components in cold service insulation systems shall be insulated. Insulation manufacturers publish tables showing required thickness to prevent condensation under various temperature and humidity conditions. Composite insulation is commonly used in cold services.

4. GENERAL

4.1 SURFACES NOT INSULATED

Unless specifically called for on the mechanical flowsheets or piping drawings, the following hot surfaces do not require insulation.

Apparatus Nozzles (unless piping into nozzle is Insulated)
Nameplates
Steam Traps
Expansion Joints
Glass Surface on Sight Glasses

4. GENERAL

4.2 SURFACE PREPARATION

Refer to "INSUL-6" Section, paragraph 2.2.

4.3 INSULATION SUPPORT

Insulation on vertical pipe shall be supported near the bottom of the run, if required. Additional supports will be used at intervals dependent upon the insulation materials being used.

Insulation on vertical vessels shall have insulation supports or the stiffening rings may be used to provide the supports.

4.4 PIPING SUPPORTS

Refer to "INSUL-6" Section, paragraph 2.4.

4.5 TRACED LINES

Pipe requiring steam or water tracing should be insulated. Provisions shall be made to allow room for teh tracer tubing, such as using insulation one pipe size larger than line size. Insulation must be able to withstand operating temperature of the fluid in the tracing.

4.6 ALUMINUM WEATHER-BARRIER

See Table I for coverage.

4.7 MASTIC WEATHER-BARRIER

Individual requirements should be calculated.

5. DATA FORMS

Data forms for the specification of specific materials to be used for the design, purchase and application of an insulation system are as follows:

Form DF-1	Heat Insulation Data Form
Form DF-2	Cold Insulation Data Form

To expedite filling out the data forms, numbers appear on the forms that correspond to the following paragraphs.

5. DATA FORMS (Continued)

5.1 HEAT INSULATION DATA FORM

5.1.1 INSULATION MATERIAL

The selection of an insulation material for a particular application must take into consideration such factors as operating temperature, temperature limits of the materials, availability of material, cost, required thickness, and maximum allowable surface temperature and heat loss. The materials listed below for a given service are those normally used by the Plastics Company. See "INSUL-4" Section, paragraphs 2.1.1, 2.2.1, 2.3.1, 2.4.1, 2.5.1, 2.6.1, 2.7.1, 2.8.1, and 2.9.1 for description, service, and thickness for these materials.

5.1.1.1 Piping and 24" Diameter and Smaller Equipment

Carbon steel piping and small diameter equipment is insulated with urethane material, see INSUL-4, Section 2.9.2, for operating temperatures up to 225°F, or with fiberglass material, see "INSUL-4", Section 2.4.2, for operating temperatures up to 450°F. Above 450°F either calcium silicate, see "INSUL-4" Section 2.1.2, mineral wool insulation, see "INSUL-4" Section 2.2.2. Certainteed 850 fiberglass, see "INSUL-4" Section 2.4.2, or cellular glass, see "INSUL-4" Section 2.3.2 is used. The upper temperature limit varies with the different materials, and for operating temperatures above this limit special high temperature materials may be required.

Alloy piping and small diameter equipment is also insulated with urethane material see "INSUL-4" Section 2.9.2, for operating temperatures up to 225°F, or with fiberglass material, see "INSUL-4" Section 2.4.2, for operating temperature up to 450°F. Between 450°F and 800°F cellular glass, calcium silicate, mineral wool, or certainteed 850 fiber-glass is used, see "INSUL-4" Sections 2.3.2, 2.1.2, 2.2.2, and 2.4.2. Above

5. DATA FORMS (Continued)

5.1 HEAT INSULATION DATA FORM (Continued)

5.1.1 INSULATION MATERIAL (Continued)

5.1.1.1 Piping and 24" Diameter and Smaller Equipment

800°F, material must be specified to meet the requirements of temperature and yet not contribute to the initiation of stress corrosion cracking.

Long straight piping runs can economically use insulation factory bonded to aluminum or PVC jacketing.

Valves, flanges, and ells are insulated with fabricated sections of the same material used on associated piping, or with flexible fiberglass or mineral wool or with asbestos tape, see "INSUL-4" Sections 2.4.2, 2.2.2, and 2.7.2.

5.1.1.2 Equipment Greater than 24" Diameter

Large diameter equipment is insulated with urethane, see "INSUL-4, Section 2.9.2, for operating temperatures up to 225°F (large storage tanks or towers may justify spray-on urethane), with fiberglass board, see "INSUL-4" Section 2.4.2, up to 450°F, with certainteed 850 fiberglass board, see "INSUL-4" Section 2.4.2, up to 850°F, or with cellular glass, see "INSUL-4" Section 2.3.2, for operating temperatures up to 800°F. Above 850°F material must be specified to meet the requirements of the application, see Section 5.1.1.

5.1.1.3 Bent Pipe and Tubing

Bent pipe and tubing is insulated with foamed plastic insulation, see "INSUL-4" Section 2.8.2, for operating temperatures up to 180°F. Above 180°F, use asbestos tape, see "INSUL-4" Section, 2.7.2. (Preinsulated tubing can be purchased on reels like electrical cable).

5. DATA FORMS (Continued)

5.1 HEAT INSULATION DATA FORM (Continued)

5.1.1 INSULATION MATERIAL (Continued)

5.1.1.4 Irregular Surfaces

Irregular surfaces are insulated with insulating cement, see "INSUL-4" Section 2.5.2. Insulated boxes are used around installations such as control valves, pump headers, instruments, etc., where operability, inspection, or maintenance would be hampered by individual insulation of all components, and around equipment like banks of double pipe heat exchangers where the insulated box is more economical.

5.1.2 WEATHER-BARRIER MATERIALS

Weather-barriers used are aluminum, see "INSUL-4" Section 3.1.1, mastic, Section 3.2.1, PVC, Section 3.3.1, and special types, Section 3.4. The material used varies with the component insulated, environment, type of insulation, labor and material costs, and plant preference. For type "E" specify the brand or type of mastic. Type "F" is used for specials such as plastic, stainless, etc.

5.1.2.1 Straight Run Piping and 36" Diameter and Smaller Equipment

All locations use aluminum jacketing, see "INSUL-4" Section, 3.1.2. Material cost and plant preference dictates the choice of smooth or corrugated type. Coastal locations use jackets with moisture-barrier over calcium silicate insulation. PVC pipe jacketing, see "INSUL-4" Section 3.3.2, can be used below 150^{o}F, and snap fit molded jackets are available for valves, tees, and elbows. For indoor use where pipe will not be exposed to water or foot traffic, insulation with a factory applied all service jacket is satisfactory. Jacket temperature must be maintained between -10 and +150^{o}F for bonding to remain effective.

5. DATA FORMS (Continued)

5.1 HEAT INSULATION DATA FORM (Continued)

5.1.2 WEATHER-BARRIER MATERIALS (Continued)

5.1.2.2 Elbows

Material and labor cost and plant preference will dictate the choice of mastic, see "INSUL-4" Section 3.2.2, aluminum, see "INSUL-4" Section 3.1.2, or PVC, see "INSUL-4" Section 3.3.2, weather-barrier for elbows.

5.1.2.3 Vessel and Exchanger Shells

The weather-barrier used on vessel and exchanger shells is mastic, see "INSUL-4" Section 3.2.2, or aluminum, see "INSUL-4" Section, 3.1.2, or PVC, see "INSUL-4" Section 3.3.2. If aluminum is used on horizontal shells it should be smooth type.

5.1.2.4 Irregular Surfaces and Equipment Heads

Mastic is used on irregular surfaces where aluminum jacketing is impractical, see "INSUL-4" Section 3.2.2.

5.1.3 INSULATION SECUREMENT

The insulation is secured by using staples, see "INSUL-4" Section 4.7.1, galvanized or stainless steel tie wire, see "INSUL-4" Section, 4.5.1, or stainless steel bands, see "INSUL-4" Section, 4.4.1.

5.1.3.1 Piping Through 16" Diameter

Coastal locations use stainless steel wire and non-coastal locations use galvanized wire, see "INSUL-4" Section, 4.5.2. Staples, see "INSUL-4" Section, 4.7.1, can be used to secure fiberglass insulation if the insulation will be covered with a jacket which is banded. All service jackets with self-sealing laps are reinforced with staples.

5. DATA FORMS (Continued)

5.1 HEAT INSULATION DATA FORM (Continued)

5.1.3 INSULATION SECUREMENT (Continued)

5.1.3.2 Piping Greater than 16" Diameter and Equipment 24" Diameter and Less

For large diameter pipe and small diameter equipment use 1/2" wide bands, see "INSUL-4" Section, 4.4.2.2.

5.1.3.3 Equipment Greater than 24" Diameter

For large diameter equipment use 3/4" wide bands, see "INSUL-4" Section, 4.4.2.3.

5.1.4 ALUMINUM JACKET SECUREMENT

Aluminum jacket material is secured by the use of stainless steel bands, see "INSUL-4" Section, 4.4.1, or sheet metal screws, see "INSUL-4" Section 4.6.1. Aluminum screws may be preferred at coastal locations. Choice of Hex head or Pan head depends on tool used by insulators.

5.1.4.1 Piping and 24" Diameter and Smaller Equipment

For securing jacket material on piping and small diameter equipment 3/8" wide bands, see "INSUL-4" Section 4.4.2.1, or sheet metal screws, see "INSUL-4" Section 4.6.2, are used depending on material and labor costs, and plant preference at a particular location. For long piping runs, aluminum jacketing with self-locking features can be used to eliminate or reduce banding requirements.

5.1.4.2 Equipment Greater than 24" Diameter

For securing jacket material on large diameter equipment 3/8" wide bands, see "INSUL-4" Section 4.4.2.1, or sheet metal screws, see "INSUL-4" Section 4.6.2, are used depending on material and labor costs, and plant preference at a particular location. The horizontal laps on vertical equipment at all plants are secured with screws.

5. DATA FORMS (Continued)

5.1 HEAT INSULATION DATA FORM (Continued)

5.1.5 REINFORCEMENT

Glass cloth reinforcement, see "INSUL-4" Section, 4.2.1, is required for mastic weather barrier. Wire netting reinforcement, see "INSUL-4" Section 4.3.1, is required for thick applications of insulating cement.

5.1.5.1 Glass Cloth

Specify the type and weave of glass cloth to be used, see "INSUL-4" Section 4.2.2.

5.1.5.2 Wire Netting

Specify the material, see "INSUL-4" Section, 4.3.1, depending on avilability and cost.

5.1.6 SPECIALTIES

This space is used to specify special materials, items to be insulated, thickness tables or brand names desired to complete the Insulation Data Form.

5.2 COLD INSULATION DATA FORM

5.2.1 INSULATION MATERIAL

The selection of an insulation material for a particular application must take into consideration such factors as operating temperature, temperature limits of the materials, availability of materials, cost, required thickness, minimum allowable surface temperature, and maximum heat gain. The materials normally used by the Plastics Company are cellular glass, see "INSUL-4", 2.3.1, urethane, see "INSUL-4 Section 2.9.1, and foamed plastic, see "INSUL-4" Section 2.8.1. Foamed plastic is mainly used on bent pipe and tubing but may be used for any application where compressive strength is not required.

5.2.1.1 Piping

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Cellular glass, see "INSUL-4" Section 2.3.2, and urethane, 2.9.2 are used to insulate pipe and small diameter equipment, see "INSUL-4" Section 2.3.2.

5. <u>DATA FORMS</u> (Continued)

5.2 <u>COLD INSULATION DATA FORM</u> (Continued)

5.2.1 <u>INSULATION MATERIAL</u> (Continued)

5.2.1.2 <u>Equipment</u>

Cellular glass, see "INSUL-4" Section, 2.3.2, and urethane, 2.9.2, are used to insulate equipment.

5.2.1.3 <u>Bent Pipe and Tubing</u>

Foamed plastic is used to insulate bent pipe and tubing, see "INSUL-4" Section, 2.8.2.

5.2.1.4 <u>Irregular Surfaces</u>

Cellular glass, see "INSUL-4" Section 2.3.2, and urethane, 2.9.2, are used to box in and insulate irregular surfaces. Loose or flexible insulation materials are used to fill voids around flanges, manhole covers, valves, and enclosed equipment.

5.2.2 <u>WEATHER-BARRIER MATERIALS</u>

Weather-barriers used are aluminum, see "INSUL-4" Section 3.1.1, mastic, see "INSUL-4" Section 3.2.1, and PVC, see "INSUL-4" Section 3.3.1. The material used varies with the component insulated, environment, labor and material costs, and plant preference. For Type "E" specify the brand or type of mastic to be used. Type "F" is used for specials such as plastic, stainless, etc.

TABLE I

COVERAGE TABLE FOR
ALUMINUM JACKETING, BANDS, CLIPS, & SCREWS

I. NO. OF SQUARE FEET OF JACKETING* PER LINEAL FOOT OF INSULATED PIPE (COMPENSATING FOR 3" OVERLAP PER LIN. YD. & 3" LAP ON CIRCUMFERENCE

PIPE SIZE	1"	1 1/2"	2"	2 1/2"	3"	3 1/2"	4"	5"	6"
1/2"	1.08	1.37	1.65	1.94	2.22	2.51	2.80	3.37	3.94
3/4"	1.14	1.43	1.71	2.00	2.28	2.57	2.86	3.43	4.00
1"	1.22	1.50	1.79	2.08	2.36	2.65	2.93	3.50	4.07
1 1/4"	1.32	1.60	1.89	2.17	2.46	2.74	3.03	3.60	4.17
1 1/2"	1.39	1.67	1.96	2.24	2.53	2.81	3.10	3.67	4.24
2"	1.52	1.81	2.09	2.38	2.66	2.95	3.23	3.80	4.38
2 1/2"	1.66	1.95	2.23	2.52	2.81	3.09	3.38	3.95	4.52
3"	1.84	2.13	2.41	2.70	2.98	3.27	3.55	4.13	4.70
3 1/2"	1.99	2.27	2.56	2.84	3.13	3.41	3.70	4.27	4.84
4"	2.13	2.41	2.70	2.98	3.27	3.55	3.84	4.41	4.98
4 1/2"	2.27	2.56	2.84	3.13	3.41	3.70	3.98	4.55	5.12
5"	2.43	2.72	3.00	3.29	3.57	3.85	4.14	4.71	5.39
6"	2.73	3.02	3.30	3.59	3.88	4.16	4.45	5.02	5.59
7"	3.02	3.30	3.59	3.88	4.16	4.45	4.73	5.30	5.87
8"	3.30	3.59	3.88	4.16	4.45	4.73	5.02	5.59	6.16
	3.59	3.88	4.16	4.45	4.73	5.02	5.30	5.87	6.44
10"	3.91	4.20	4.48	4.77	5.05	5.34	5.62	6.19	6.87
12"	4.48	4.77	5.05	5.34	5.62	5.91	6.19	6.76	7.34
14"	4.84	5.12	5.41	5.69	5.98	6.27	6.55	7.12	7.69
15"	5.12	5.41	5.69	5.98	6.27	6.55	6.84	7.41	7.98
16"	5.41	5.69	5.98	6.27	6.55	6.84	7.12	7.69	8.26
18"	5.98	6.27	6.55	6.84	7.12	7.41	7.69	8.26	8.83
20"	6.55	6.84	7.12	7.41	7.69	7.98	8.26	8.83	9.40
22"	7.12	7.41	7.69	7.98	8.26	8.55	8.83	9.40	9.98
24"	7.69	7.98	8.26	8.55	8.83	9.12	9.40	9.98	10.55
26"	8.26	8.55	8.83	9.12	9.40	9.69	9.98	10.55	11.12
28"	8.83	9.12	9.40	9.69	9.98	10.26	10.55	11.12	11.69
30"	9.40	9.69	9.98	10.26	10.55	10.83	11.12	11.69	12.26
32"	9.98	10.26	10.55	10.83	11.12	11.40	11.69	12.26	12.83
34"	10.55	10.83	11.12	11.40	11.69	11.97	12.26	12.83	13.40
36"	11.12	11.40	11.69	11.97	12.26	12.54	12.83	13.40	13.97

II. Banding - Number from above Table X 1.3 gives feet of banding per foot of insulated pipe.

III. Clips - (Feet of insulated pipe) X (1.3) = Clips required

IV. Screws - (Feet of insulated pipe) X (3) = Screws required

*Jacketing commonly available in rolls 36" x 100'. Also available 48" x 100'.

HEAT INSULATION DATA FORM NO. DF-1

5.1.1 Insulation Material

5.1.1.1 Piping and 36" Diameter and Smaller Equipment

Carbon Steel		Alloy	
to 450°F,	________	to 450°F,	________
451°F to ____°F,	________	451°F to ____°F,	________
___°F to ____°F,	________	___°F to ____°F,	________

5.1.1.2 Equipment Greater than 36" Diameter
To 800°F ________________ 801°F to ________°F, ____________

5.1.1.3 Bent Pipe and Tubing to 180°F ____________ above 180°F ________

5.1.1.4 Irregular Surfaces ____________________

5.1.2 Weather-Barrier Materials Used Shall be One of the Following Types:
Type A - .016" thick aluminum with 3/16" corrugations and without moisture barrier
Type B - .016" thick aluminum with 3/16" corrugations and with moisture barrier
Type C -.020" thick aluminum smooth without moisture barrier
Type D - .020" thick aluminum smooth with moisture barrier
Type E - ________________ mastic with glass cloth reinforcement
Type F - ____

5.1.2.1 Straight Run Piping and 36" Diameter and Smaller Equipment

C.S. to 450°F type____,451°F to____type____,____°F to____°F type____
Alloy to 450°F type____,451°F to____type____,____°F to____°F type____

5.1.2.2 Elbows

C.S. to 450°F type____,451°F to____type____,____°F to____°F type____
Alloy to 450°F type____,451°F to____type____,____°F to____°F type____

5.1.2.3 Vessel and Exchanger Shells
Horizontal Type ______________ Vertical Type ________________

5.1.2.4 Irregular Surfaces and Equipment Heads Type ________________

5.1.3 Insulation Securement

5.1.3.1 Piping Through 16" Diameter, ____________ Wire Ties or ____ Staple

5.1.3.2 Piping Greater Than 16" Diameter & Equipment 24" Diameter and Less, ½" Wide Bands

5.1.3.3 Equipment Greater Than 24" Diameter, 3/4" Wide Bands

5.1.4 Aluminum Jacket Securement

HEAT INSULATION DATA FORM NO. DF-1
(Continued)

5.1.4.1 Piping and 24" Diameter and Smaller Equipment________________

5.1.4.2 Equipment Greater Than 24" Diameter___________________________

5.1.5 Reinforcement

5.1.5.1 Glass Cloth_________________________

5.1.5.2 Wire Netting________________________

5.1.6 Specialties ____

COLD INSULATION DATA FORM NO. DF-2

5.2.1 Insulation Material

5.2.1.1 Piping, ________________________

5.2.1.2 Equipment,________________________

5.2.1.3 Bent Pipe and Tubing,______________________

5.2.1.4 Irregular Surfaces,________________________

5.2.2 Weather-Barrier Materials Used Shall be One of the Following Types:
Type A - .016" thick aluminum with 3/16" corrugations without moisture barrier
Type B - .020" thick aluminum smooth without moisture barrier
Type C - ___________________mastic with glass cloth reinforcement
Type D - ____

5.2.2.1 Straight Run Piping and 24" Smaller Equipment Type__________

5.2.2.2 Elbows Type________________

5.2.2.3 Vessel and Exchanger Shells
Horizontal Type________________Vertical Type______________

5.2.2.4 Irregular Surfaces and Equipment Heads Type_______________

5.1.3 Insulation Securement

5.1.3.1 Piping Through 16" Diameter_________Wire Ties or ____Staples

5.1.3.2 Piping Greater than 16" Diameter & Equipment 24" Diameter & Less, ½" Wide Bands

5.1.3.3 Equipment Greater than 24" Diameter, 3/4" Wide Bands

COLD INSULATION DATA FORM NO. DF-2
(Continued)

5.1.4 Aluminum Jacket Securement

5.1.4.1 Piping and 24" Diameter and Smaller Equipment ____________

5.1.4.2 Equipment Greater than 24" Diameter ____________

5.1.5 Glass Cloth Reinforcement ____________

5.1.6 Specialties ____________

INSUL - 6

INDEX
APPLICATION REQUIREMENTS

INDEX
APPLICATION REQUIREMENTS
(Continued)

1. SCOPE

This section describes the application of the thermal insulation described in the material requirements section.

2. GENERAL

2.1 TIMING

Insulation shall not be applied to any flanged, machined, or welded surfaces until they have passed all field tests, including hydrostatic, and have been released for insulation by the field engineer.

2.2 SURFACE PREPARATION

The pipe, instruments or equipment to be insulated shall be cleaned of all oil, water, and other foreign matter before insulation is installed. Insulated carbon steel surfaces operating under 140°F shall have a protective coating on the steel. All metal surfaces must be primed before application of urethane spray insulation.

2.3 DRY INSULATION

All insulation shall be protected from moisture before and during application. If applied insulation should get wet before it is jacketed, it shall be thoroughly dried by heating the line or by other means before it is sealed with weatherproofing.

2.4 PIPING SUPPORTS

2.4.1 HOT SERVICE

Insulated piping shall be supported on shoes 4" above the BOP of the uninsulated piping, unless specified higher when thicker insulation will be used.

2.4.2 COLD SERVICE

Low-temperature piping below 32°F shall be supported on outside of insulated surfaces if possible, with metal cradle to provide for adequate support and distribution of weight. Cradle shall be secured with at least two insulation bands looped about cradle and insulation. When pipe is suspended with hangers attached directly to the pipe, the hanger shall be insulated the same as the adjoining pipe. Insulation shall extend up the hanger for a distance of four times the specified thickness.

3. APPLICATION PROCEDURE

3.1 STRAIGHT PIPE

3.1.1 INSULATION

3.1.1.1 Placement

Pipe insulation shall be applied with tightly butted end joints in a staggered position. Additional layers, where specified, shall be applied in the same manner as the first layer, with side and end joints staggered over joints of preceding layer so that no two joints coincide, except where they cross at right angles.

3.1.1.2 Joint Sealer

All butt edges and ends of the outer layer of cold service insulation shall be buttered with joint sealer before application. The joints shall be drawn together when the insulation is applied so that only a very thin, vapor-tight coat separates the sections of insulatio

3.1.1.3 Exposed Ends

Exposed ends are to be beveled and covered with aluminum pipe bevels and flashed with high temperature sealer or they may be weatherproofed with fiberglass cloth and mastic.

3.1.1.4 Securement

Secure the insulation with tie wire or bands depending upon the pipe diameter. Fiberglass can be stapled instead of fastened with wire, and fiberglass with self-sealing jacket can be press sealed and the lap reinforced with staples.

3.1.2 EXPANSION-CONTRACTION JOINTS

3.1.2.1 Location

Expansion-contraction joints should be installed in cold service piping, and in hot service piping above 700°F, if specified, in both horizontal and vertic straight run piping for each 50 ft.

3. APPLICATION PROCEDURE (Continued)

3.1 STRAIGHT PIPE (Continued)

3.1.2 EXPANSION-CONTRACTION JOINTS (Continued)

3.1.2.1 Location (Continued)

When flanged fittings or valves occur within this limit, expansion-contraction joint shall be provided for in the flang cover only.

3.1.2.2 Design

Expansion-contraction joint shall be ½" space between adjoining pipe insulation sections. Appropriate compressible insulation, such as flexible fiberglass or thermal wool, shall be packed into the space. Insulation cover over the joint shall be the specified thickness on each side of the 1/2" space. To provide for slip joint construction, the joint cover and adjoining pipe insulation shall be coated with joint sealer prior to application.

3.1.3 ALUMINUM WEATHER-BARRIER

3.1.3.1 Application

Aluminum jacketing shall be applied with longitudinal and circumferential joints lapped 2" minimum. Joints shall be positioned to shed water and be away from prevailing wind.

3.1.3.2 Securement

Jacketing shall be secured with bands, see "INSUL-4" Section, 4.4.2, or screws, see 4.6.2.

3.1.4 MASTIC WEATHER-BARRIER

Outer surface of insulation shall receive an adhesive coat of mastic. While still tacky, reinforcing glass cloth shall be stretch taut and thoroughly embedded in the coating, care being exercised that the weave is not stretched and that the cloth is overlapping approximately 1 1/2". Before the surface becomes dry to touch, a second coating shall be applied and allowed to dry. Total

3. APPLICATION PROCEDURE (Continued)

3.1 STRAIGHT PIPE (Continued)

3.1.4 MASTIC WEATHER-BARRIER (Continued)

dry thickness of coating shall be a minimum of 1/8". Cloth shall not be visible on the finished surface.

3.1.5 PVC WEATHER-BARRIER

PVC weather barrier is usually supplied already bonded to straight pipe insulation sections. It is fastened by clamping self-sealing closure on the longitudinal seam and sealed with a solvent or glue. Butt end joints are covered with vinyl tape to form a vapor seal. It is also supplied in rolls bonded to insulation for equipment insulation. Sheets are fastened to equipment surface with mastic and welded pins. Joints are sealed with solvent or glue and taped with PVC tape. Jacket is banded with stainless bands.

3.2 ELBOWS

3.2.1 INSULATION

If preformed elbows are not used, fabricate elbow cover from mitered segments of pipe covering secured with wire ties, or wrap with flexible insulation secured with wire ties.

3.2.2 INSULATING CEMENT

When mastic weather-barrier is specified, insulating cement is used over fiberglass, calcium silicate, cellular glass, urethane, or mineral wool insulation to give the surface a smooth finish and to fill all cracks and voids.

3.2.3 WEATHER-BARRIER

Aluminum or mastic weather-barrier shall be applied in accordance with 3.1.3 and 3.1.4 above. PVC weather-barrier is usually snapped on with self-sealing closure or with metal snaps, with mastic used on the seam and vinyl tape or metal bands used to clamp it to adjoining pipe jacketing.

3. APPLICATION PROCEDURE (Continued)

3.3 FLANGES, FLANGED FITTINGS AND VALVES

3.3.1 INSULATION

Insulation shall be prefabricated and shall extend over adjacent pipe insulation so as to provide a slip joint at each end. All joints shall be sealed as per 3.1.1.2 above, and insulation is secured with wire or bands depending upon pipe diameter. Where specified, flange covers shall be removable.

3.3.2 WEATHER-BARRIER

Aluminum or mastic weather-barrier shall be applied in accordance with 3.1.3 and 3.1.4 above.

3.4 EQUIPMENT

3.4.1 SHELL AND HEAT INSULATION

3.4.1.1 Placement

Equipment shells shall be insulated with pipe insulation where diameter is small enough (generally 36"). Block or blanket insulation is used on large diameter shells and on heads. Block insulation shall be applied to shell using standard broken joing method, starting with alternate full and half length lags. Application of lags shall start at one end, proceeding circumferentially and then axially. Each lag shall be tightly butted against adjacent lags. Blanket insulation shall be draped around horizontal vessels. On vertical vessels, it can be applied in horizontal wraps or vertical strips. Where multi-layer pipe, block, or blanket application is required, all joints shall be staggered over joints of the preceding layer. Urethane spray is used on very large surface area tanks and towers. It is applied in a manner approved by the Celanese Project Engineer and Safety Department. Specific materials and storage of materials must also be approved.

3. APPLICATION PROCEDURE (Continued)

3.4 EQUIPMENT (Continued)

3.4.1 SHELL AND HEAT INSULATION (Continued)

3.4.1.2 Joint Sealer

Joint sealer shall be applied to cold service insulation in accordance with 3.1.1.2.

3.4.1.3 Securement

Secure pipe, block, and blanket insulation with bands. Blanket insulation on vertical surfaces is further secured by impaling on metal pins welded to the vessel shell. Pin spacing is as needed for the specific insulation, generally 16 to 24" centers.

3.4.1.4 Cork Filled Mastic

Spray apply to desired thickness in accordance with manufacturer's recommendations.

3.4.2 SUPPORT INSULATION

3.4.2.1 General

Supports of equipment in cold service require insulation to the extent shown below. Application is the same as for the shell of the equipment.

3.4.2.2 Metal Cradles

Where equipment is supported on metal cradles, insulation shall be carried down over cradles to concrete or to a distance four times the specified thickness from the junction of the vessel and the insulated cradle, whichever is less. The top of the concrete is to be coated with joint sealer before application of insulation.

3.4.2.3 Structural Steel

000202

When equipment is supported by structura steel beams, insulation shall be extended not less than four times the

3. APPLICATION PROCEDURE (Continued)

3.4 EQUIPMENT (Continued)

3.4.2 SUPPORT INSULATION (Continued)

3.4.2.3 Structural Steel (Continued)

specified thickness in each direction, measured from the junction of the equipment and the insulated support lug. Thickness of insulation over steel supports shall be one-half that specifie for the equipment. Thickness of insulation over support lugs to be the same as body insulation.

3.4.2.4 Legs

Where equipment is supported by legs, insulation shall extend over structural legs and the down legs a distance of four times insulation thickness, but not less sthan 12". Thickness shall be as specified for body of equipment. Body insulation shall be brought up to and butted firmly against tank leg flange. Space between flanges and webs of structural members shall be filled with block cemented in place with adhesive.

3.4.2.5 Skirts

Where equipment is supported by skirts, insulation shall be applied inside and outside as part of equipment area, insulation to extend downward from junction of inside of skirt with insulated bottom head a distance of not less than one foot. Thickness shall be as specified for body of equipment. Nuts shall be secured to the bottom head and the inside of the skirt to allow insulation attachement.

3.4.3 EXPANSION-CONTRACTION JOINTS

Longitudinal contraction of cold service vessels shall be provided for by installing expansion-contraction joints below insulation supports. Joint sealer shall be applied to surfaces of insulation to provide proper slip joint where movement is likely to occur.

3. APPLICATION PROCEDURE (Continued)

3.4 EQUIPMENT (Continued)

3.4.4 WEATHER-BARRIER

Aluminum, mastic, or PVC weather-barrier shall be applied in accordance with 3.1.3, 3.1.4 or 3.1.5 above.

3.5 IRREGULAR SURFACES

3.5.1 INSULATION

Irregular surfaces in hot service shall be insulated with insulating cement. Insulating cement shall be applied with a trowel on the surface to be insulated, filling all depressions for entire depth to eliminate voids of any nature. Care shall be exercised that the thickness of each application will be no greater than that which will set on vertical surfaces without excessive cracking upon drying. When sufficiently dry, additional applications may be made as required to build cement to full specified thickness. Where specified thickness of cement insulation exceeds 1 1/2", cement shall be reinforced with one layer of wire netting for each additional 1 1/2", or a part thereof, uniformly embedded midway between metal and finished surface. Irregular surfaces in cold service shall be insulated by boxing in with equipment insulation.

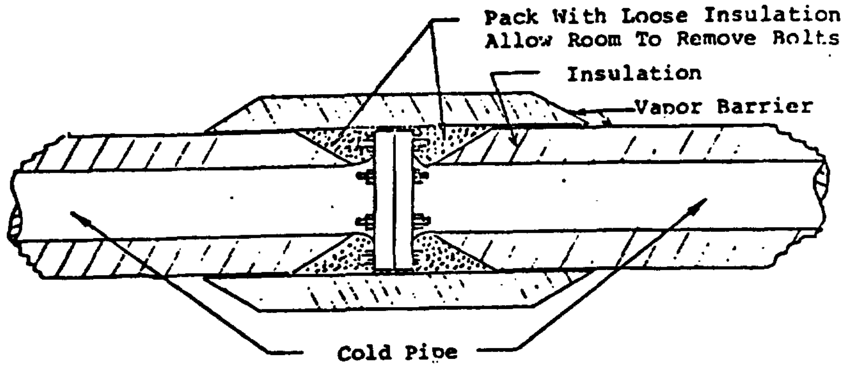
3.5.2 WEATHER-BARRIER

Mastic weather-barrier shall be applied in accordance with Section 3.1.4 above.

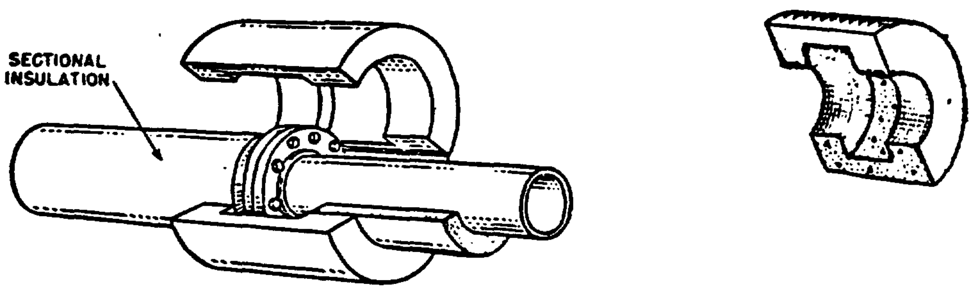
SUGGESTED APPLICATION DRAWINGS

AD-1

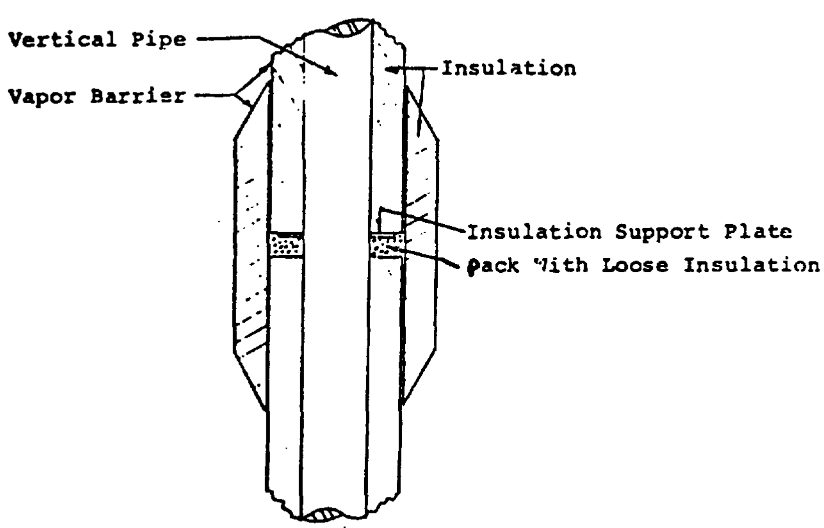
PIPING INSULATION SUPPORT AND FLANGE COVER



Flanged Joint

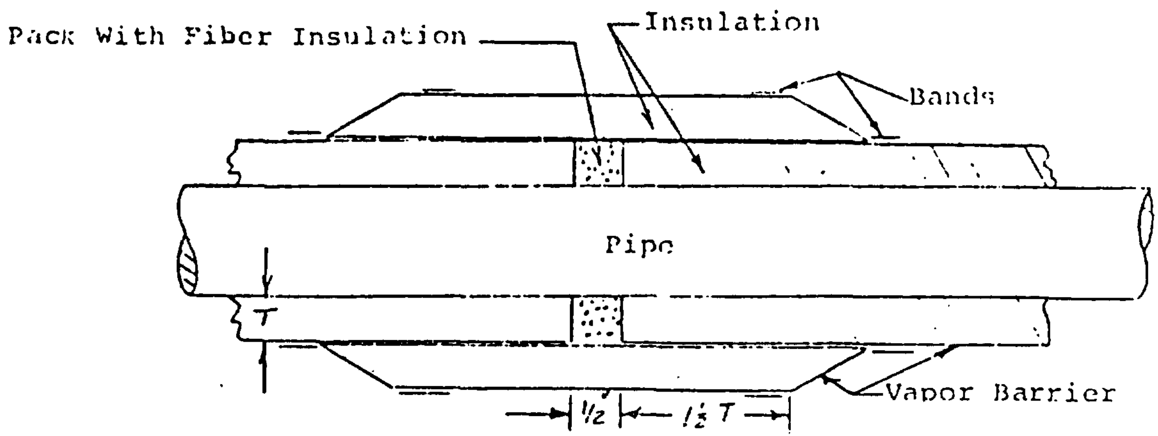


Removable type flange cover

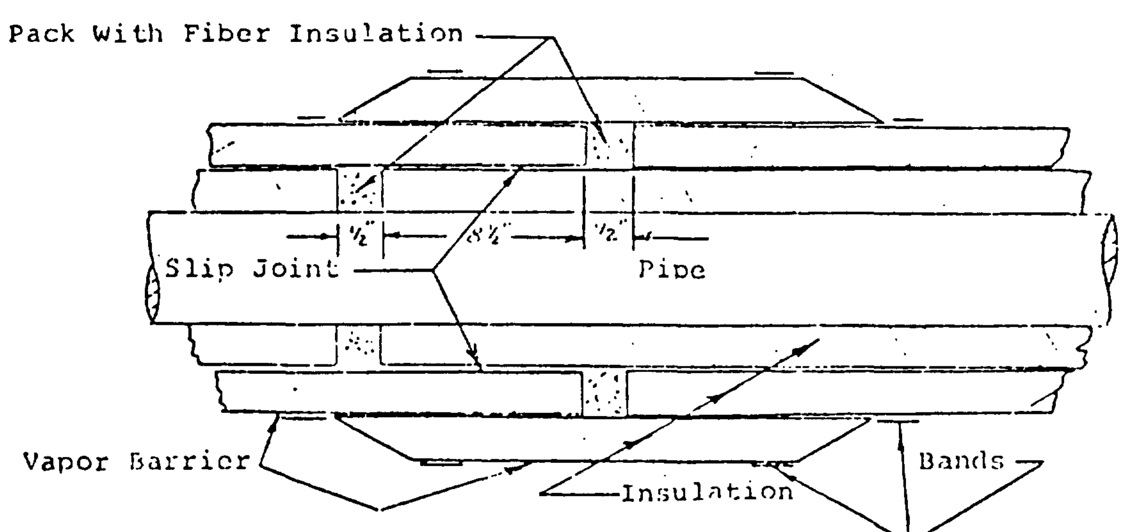


Vertical Piping

INSULATION HORIZONTAL CONTRACTION JOINTS



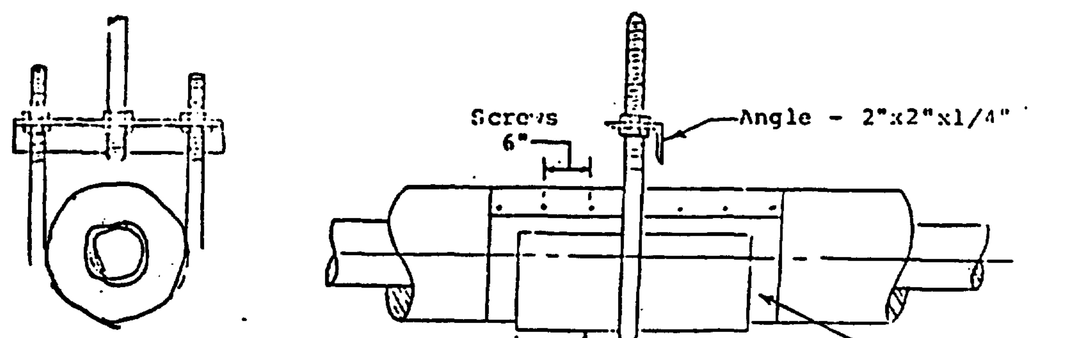
SINGLE LAYER INSULATION



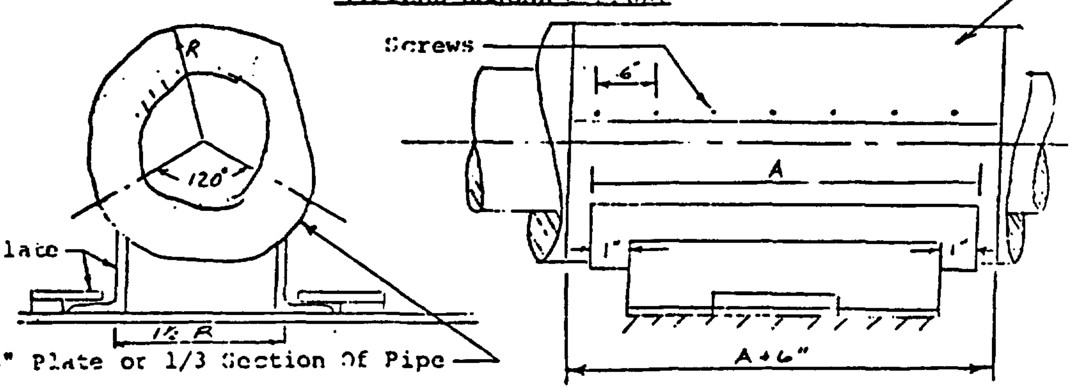
DOUBLE LAYER INSULATION

AD-3

COLD INSULATION - PIPE HANGERS AND SUPPORTS



TYPICAL HANGER SUPPORT

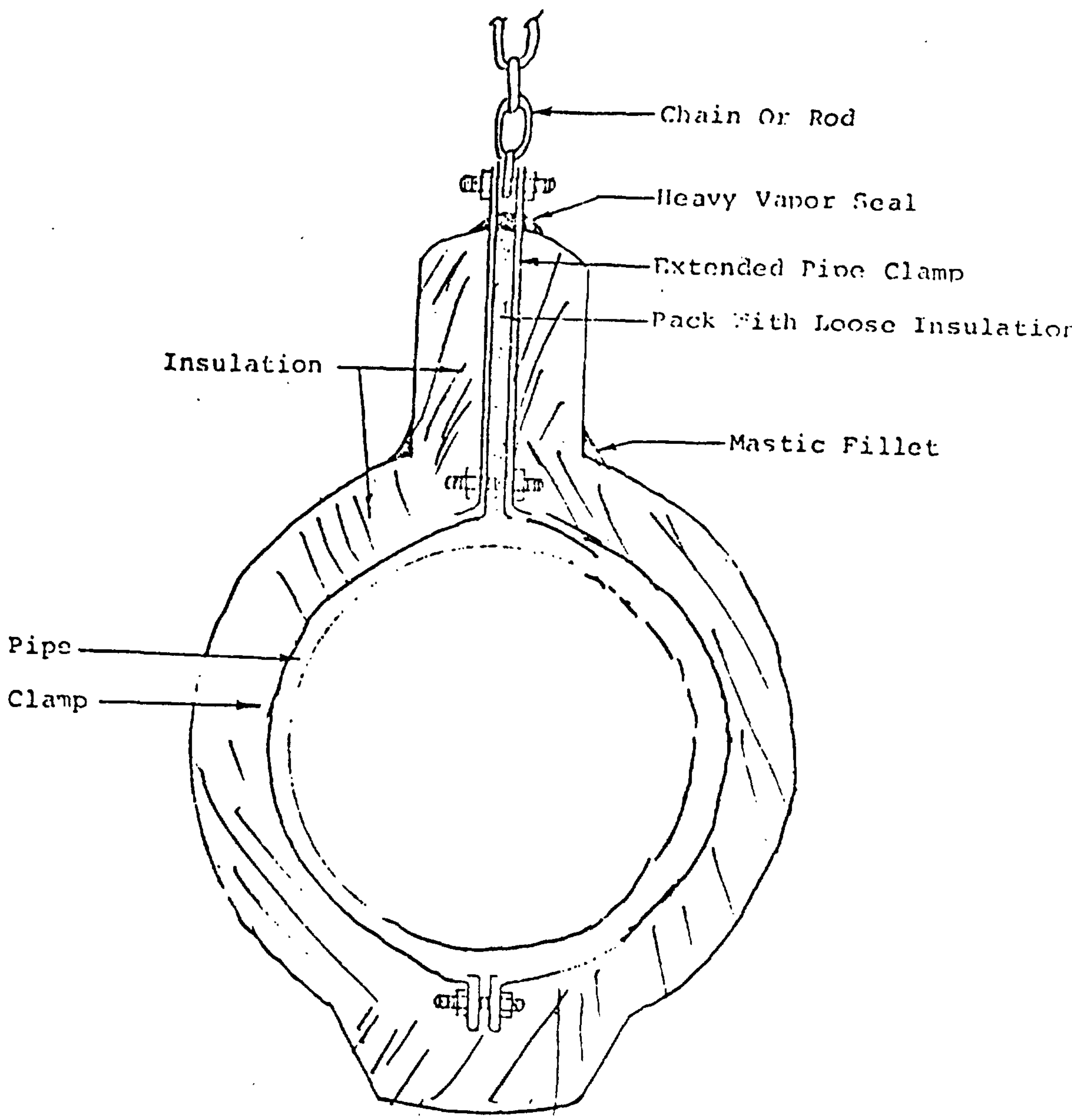


TYPICAL SADDLE SUPPORT

NOTE : A = 8" FOR PIPE SIZES TO 6"
A = 16" FOR PIPE SIZES TO 24"
A = 24" FOR PIPE SIZES TO 36"

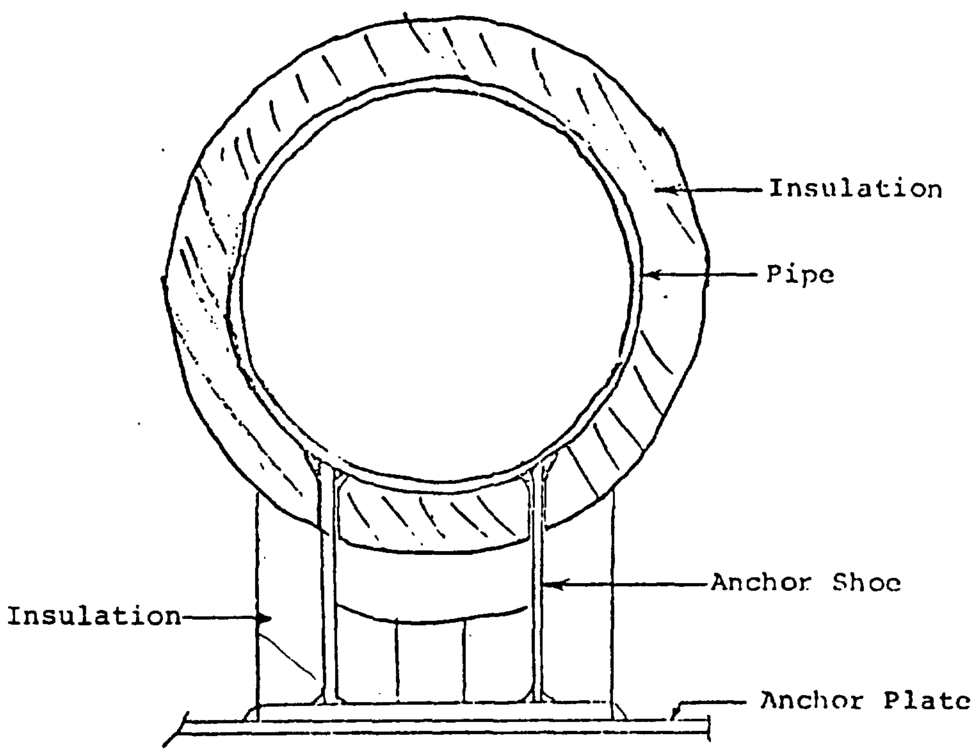
AD-4

COLD PIPING HANGAR AND HANGAR INSULATION



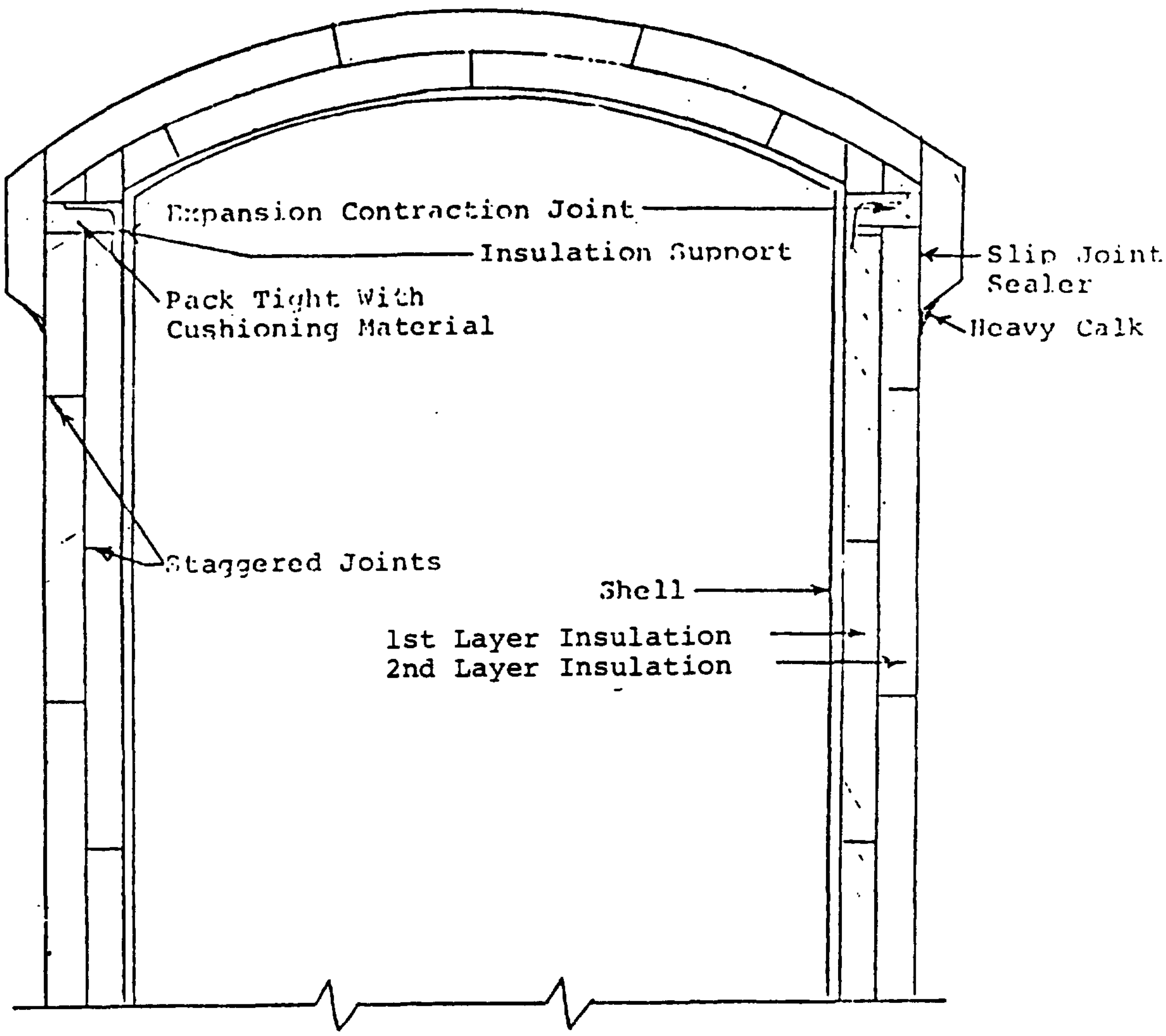
AD-5

COLD PIPE ANCHOR INSULATION



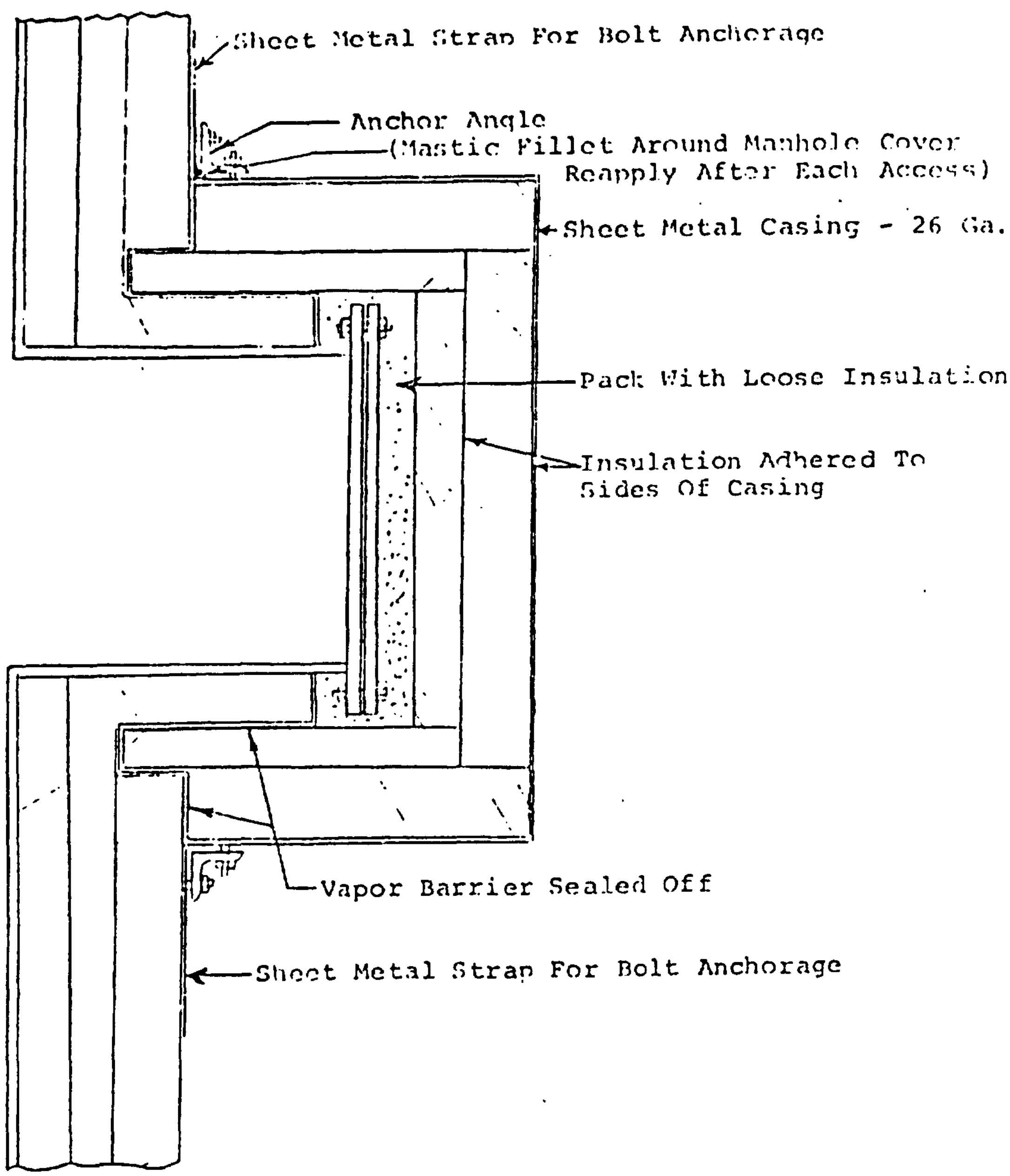
AD-6

VERTICAL EQUIPMENT INSULATION



AD-7

VESSEL INSULATION - REMOVABLE MANHOLE COVER



NOTES TO USERS

The Insulation Section consists of three basic information packages: requirements for vendors, guidelines for engineers, and requirements for application of the insulation.

A Logic Log is provided for each section to explain the reasoning for inclusion of each portion of the section. Any alterations of a section shall also include alteration of the Logic Log for that paragraph or section. These sections have been identified as "INSUL-1", "INSUL-2" and "INSUL-3".

The Material Requirements and Engineers' Guide sections, identified as "INSUL-4" and "INSUL-5", respectively, will be supplied to a potential vendor for his consideration and to aid in his supplying of materials and expertise for Plastics Company jobs.

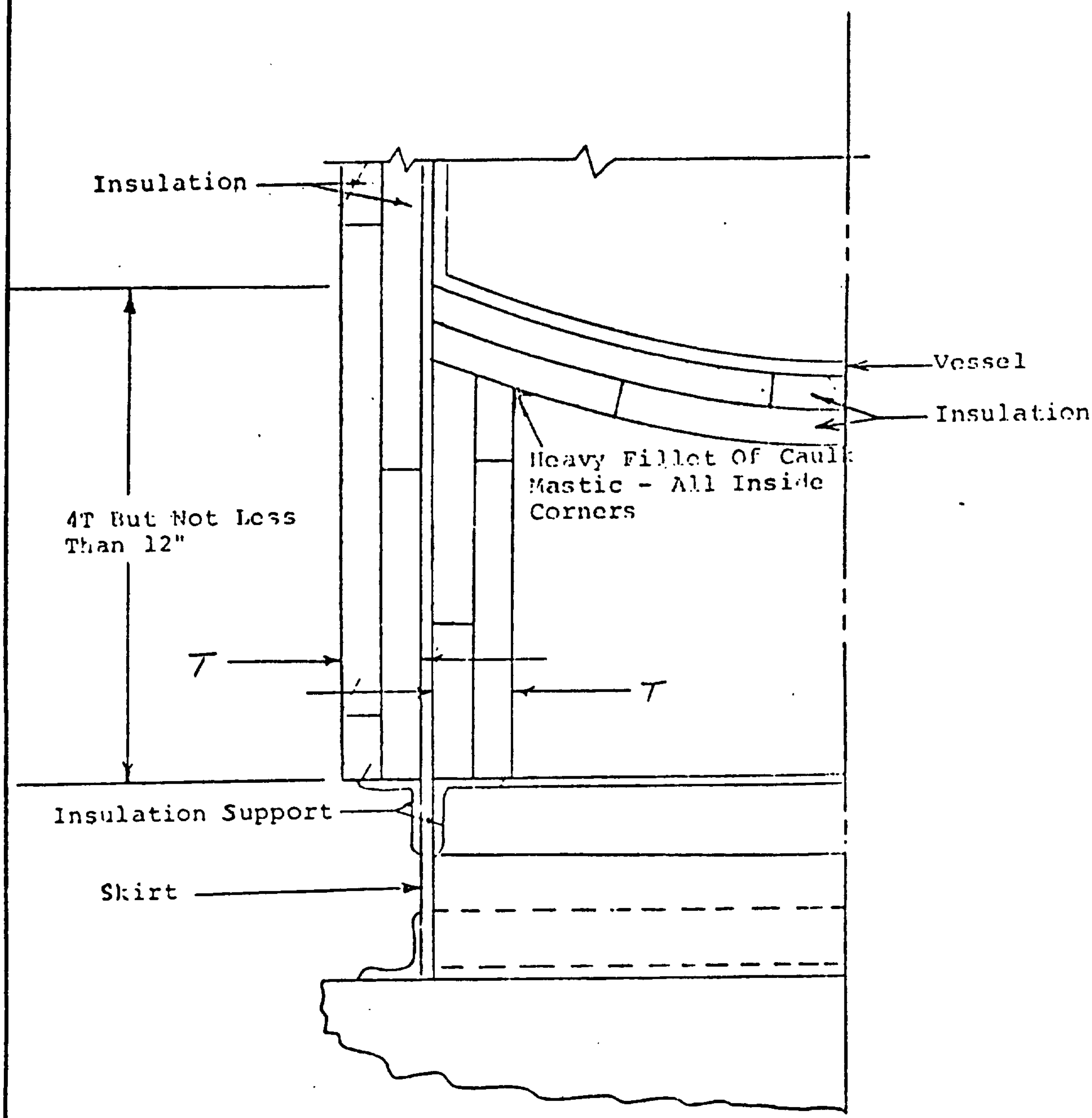
The Application Requirements section, identified as "INSUL-6", will be supplied to a contractor when bids are being obtained for jobsite maintenance or construction.

This section should be used strictly as a guideline and may be changed consistent with good engineering practices and the approval of the Project Engineer. This section should not be construed to prohibit continual testing and evaluation of any insulation material.

INDEX
INSULATION

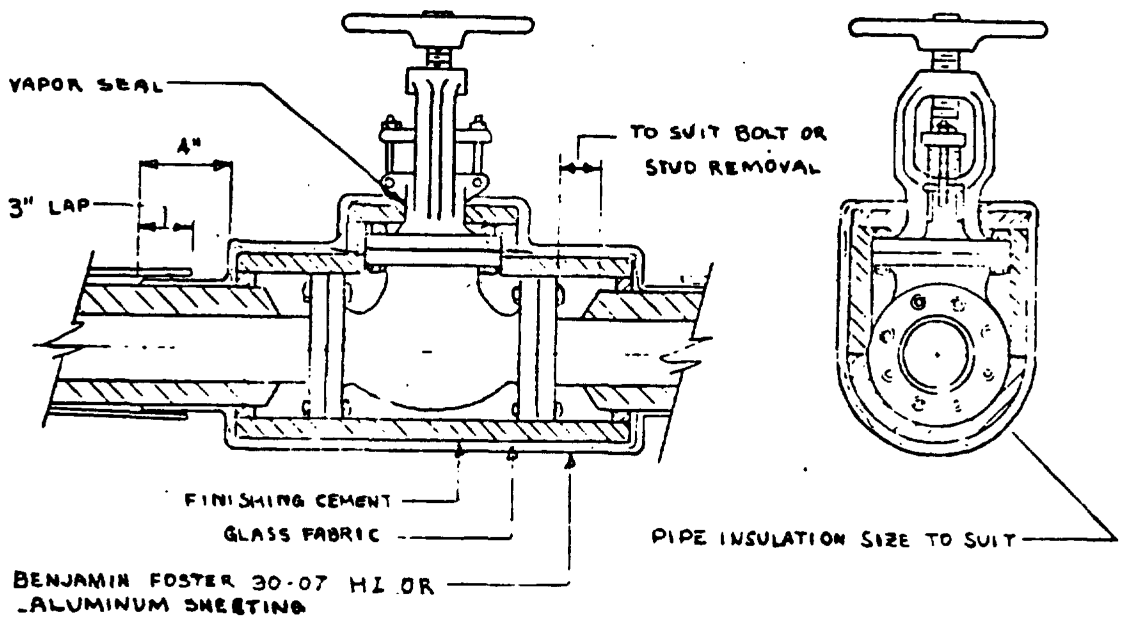
AD-10

COLD EQUIPMENT SKIRT AND BOTTOM INSULATION



AD-11

VALVE INSULATION



COLD EQUIPMENT STRUCTURAL STEEL SUPPORT