

100 Insulation Selection—Hot Systems

Abstract

This section covers the selection of insulating materials for hot lines, tanks, and major equipment. It discusses the properties and uses of different types of insulation. Flexible removable covers are described, and the Company's specifications and standard drawings for insulating hot systems are listed.

Section 300 gives calculation methods and insulation selection charts, which will help you choose the most economical thickness for a given insulation system. Ceramic fiber insulating refractory is covered in Part 2 of this manual.

Refer to the *Pipeline Manual* for information on insulated pipelines.

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110 Introduction

This section covers the selection of suitable insulating materials for hot lines and major equipment. It outlines the operating conditions where insulation is required and types of insulation material commonly used.

111 Reasons for Insulating

Depending on the service and type of equipment, we insulate to minimize heat loss, to protect people from getting burned, to maintain operating stability, and to give freeze protection and fire protection.

Piping and Equipment

Economics – to minimize heat loss. Hot lines and equipment are insulated to save fuel costs. The insulation thickness charts in Section 300 are based on fuel savings.

Personnel Protection. Metal surfaces with temperatures over 140°F which may be inadvertently contacted by personnel should be insulated. The insulation should extend 7 feet above grade or operating or maintenance platforms and 15 inches horizontally beyond areas accessible to personnel during operations.

Judgment is required in applying this principle. For example, piping adjacent to a narrow passageway should be insulated. However, a steam turbine or the overhead condenser for a distillation column need not be insulated. Because they are large, they are unlikely to be touched accidentally. In summary, exposed piping is insulated for personnel protection; large pieces of equipment generally are not. If operation requirements preclude insulation or if corrosion under insulation is a concern, expanded metal guards should be considered for protection in lieu of insulation. Also, warning signs may be used for odd-shaped equipment that cannot be insulated.

Refer to the *Safety in Designs (SID) Manual* by the Corporate HE & LP group for guidance on application of guarding devices.

Operating Stability. A hot line into a water- or air-cooled condenser or cooler where heat loss is desirable would normally be left bare. Column overhead lines are typical. However, if the line is long enough so that its surface area is an appreciable percentage of the tube area in the condenser, a rain or snow storm could cause a sudden increase in heat loss which might affect stable operation of the column. In such cases, it may be necessary to insulate all or part of the line. Such cases should be discussed with operating and process representatives.

Hot lines handling heavy black oil are generally insulated to maintain sufficient temperature to keep the stocks pumpable. The justification is operating necessity more than economics.

Freeze Protection. Piping and equipment subject to freezing or solidification should be adequately protected by heat tracing and/or insulation.

Tanks

Tank insulation is usually a matter of economics. We insulate to:

- Maintain crude oil or product in a viscous state above its pour point to maintain its flowability.
- Reduce or eliminate the need for tank heaters, cooling coils, etc., to reduce operating costs.
- Stabilize operations, e.g., maintain a more constant temperature in a fluid being fed to a process.
- Reduce evaporation losses.
- Reduce fire hazard where justified by minimizing heat absorption from possible adjoining fires.

112 What To Insulate

The following criteria should be used in determining what surfaces to insulate:

Surfaces of piping and equipment normally operating at temperatures above 100°F where heat conservation is desirable should be insulated for economic reasons.

Piping and equipment should be insulated as required for process control.

Traced lines are insulated with oversized insulation. Tracer shields are used to secure the tracing to the pipe and prevent the tracer from expanding into the insulation. Insulation for traced lines must be capable of withstanding stock and tracer temperatures.

Valves, piping and vessel flanges, and manway covers in most services with operating temperatures above 100°F should be insulated for heat conservation. For the same reason, most large normally operating hot pumps and turbines should also be insulated. Refer to Section 150 for more detailed information on the design and insulation of hot flanges.

Preinsulated tubing (Dekeron from Eaton Control Systems) is preferred for steam tracer supply and steam trap condensate return lines. Preinsulated tubing is more cost-effective when compared to field insulated small diameter tubing.

Piping operating at temperatures over 140°F and easily accessible to personnel must be insulated or otherwise guarded for personnel protection.

Equipment may require insulation for fire protection regardless of its normal operating temperature.

Hot Equipment We Normally Don't Insulate

The following surfaces should not be insulated for heat conservation:

- Equipment and piping where heat loss to the atmosphere is a design requirement.

- Equipment and piping that are refractory lined. Use metal cages for personnel protection.
- Cooling water lines.
- Water side of coolers and condensers.
- Steam traps.
- Bellows expansion joints.
- Nameplates, code data plates, etc.
- Bearing housings of pumps.
- Seals pots, vent chambers, and drip pots should be insulated only if steam traced.

A word of caution about heat conservation and operating stability: regardless of the amount of insulation installed on low pressure vapor or gas lines, the heat loss may still be excessive due to heat loss through pipe support steel. In such cases, consider using insulated pipe hangers or low conductivity material between the line and the supports.

113 Problems with Insulation

Corrosion Under Insulation

Corrosion under insulation can be a problem, especially for equipment operating at less than 200°F. Where equipment must be insulated under these conditions, use coating system 12.1 or 12.2 of the *Coatings Manual Quick Reference Guide*, the coating system will depend on the operating temperature. For equipment that cannot be abrasive blasted, an alternative second choice is an epoxy mastic (system 1.8 of the *Coatings Manual Quick Reference Guide*).

Hot lines, vessels, and tanks are generally not primed or coated to prevent corrosion because the metal surface temperature is high enough to prevent condensation. If a primer is to be used on metal surfaces over 300°F or equipment operated intermittently, use the appropriate system 12.3 or 12.7 of the *Coatings Manual Quick Reference Guide*. For a discussion on corrosion under insulation, refer to the *Corrosion Prevention and Metallurgy Manual*, Section 600.

Corrosion is a particularly severe problem offshore. Therefore, insulation should only be used where process conditions require. Piping and equipment under decks and other hard-to-reach areas should not be insulated and weatherjacketed. Piping design (thoughtful location of lines) and use of protective cages, not insulation, should be used to protect personnel.

High-temperature, Waxy Services

Reportedly, wax can build up in insulation materials (such as mineral wool) and become flammable. Consider a low-permeable insulation for high-temperature, waxy services.

114 How to Choose the Proper Insulation Material

The process of selecting an appropriate insulation system involves three steps. These steps are:

1. Select candidate materials based on the requirements of the equipment to be insulated. These requirements basically include temperature limits and physical strength. See Section 120 for more information on materials properties and applications of different types of insulation and weatherjacketing.
2. Calculate the most economical thickness for each candidate material using the methods given in Section 300.
3. Go for bids on those candidate materials at thicknesses calculated in Step 2. A more expensive material may be less costly to install, making it overall the least expensive candidate.

120 Insulation for Vessels, Lines, and Equipment

This section discusses insulation for hot systems. For details of tank insulation, see Section 130. For details of cold system insulation, see Section 200.

121 Materials

Figure 100-1 gives the important properties for the most frequently used insulating materials. These materials are briefly described next.

Calcium Silicate. For plant applications, physical strength and durability in addition to thermal conductivity are important factors in selecting insulation. For this reason, calcium silicate rigid, pre-formed block insulation is preferred for lines and major equipment up to 1200°F in refinery service, particularly in areas subject to mechanical damage and for vessels insulated for fire protection.

Perlite. Goodtemp (manufactured by Howred Corporation) is made of expanded perlite and sodium silicate reinforced with fibers. This product has properties and appears similar to calcium silicate. Perlite can be used for insulating piping, vessels, etc., up to 1200°F and is an acceptable alternative to calcium silicate.

Mineral Wool. Mineral wool insulation is also used up to 1200°F. Mineral wool has lower heat conductivity than calcium silicate for temperatures below 600°F. However, even with metal weatherjacketing, mineral wool is subject to mechanical damage due to its low compressive strength and lack of resiliency, which can lead to increased heat loss and/or increased maintenance. For example, mineral wool should not be used to insulate piping such as pipe racks — even above ground — that workers are likely to walk on.

The Pascagoula Residuum Conversion Project used mineral wool insulation for most vessels 8 feet in diameter and larger except for top and bottom heads on vertical vessels and certain areas where fire or mechanical strength dictated the use of calcium silicate. Smaller horizontal vessels had calcium silicate insulation.

Fig. 100-1 Typical Material Properties for Frequently Used Insulation Materials (1 of 2)

Piping Insulation					
Material					
Generic Type	Commercial Brands	K Factor (Btu-in/ hr-ft²-°F)	Compressive Strength (psi)	Density (lb/ft³)	Maximum Usage Temp. (°F)
Calcium Silicate ⁽¹⁾	Calsilite (preferred) ⁽²⁾ Johns Manville	ASTM C335 0.47 at 400°F 0.50 at 600°F 0.54 at 800°F ASTM C177 0.45 at 400°F ⁽³⁾	100	10-13	1200
Mineral Wool ⁽⁴⁾	Partek - Paroc 1200	0.30 at 200°F 0.35 at 300°F 0.40 at 400°F 0.46 at 500°F 0.53 at 600°F 0.60 at 700°F	1.3 @ 10% deformation	10-12	1200
Perlite ⁽⁵⁾	Calsilite/Sproul Corp Sproul WR1200	0.50 at 300°F 0.60 at 500°F 0.71 at 700°F	80 at 5% deformation	12-14	1200
Cellular Glass ⁽⁶⁾	Pittsburgh Corning - Foamglas (-290°F to 250°F)	0.42 at 200°F 0.49 at 300°F 0.59 at 400°F 0.70 at 500°F 0.85 at 600°F 1.03 at 700°F	100	8.5	800
Fiberglass	Owens/Corning - ASJ-SSL-11 Fiberglass Certainteed - ASJ-APT-Snap on ⁽⁷⁾ Schuller - APT-APJ-Micro Loc Knauf - ASJ-SSL-Knauf Pipe Insulation	0.27 at 200°F 0.35 at 300°F 0.45 at 400°F 0.55 at 500°F	No effective compressive strength	5-6	450
Ceramic Fiber ^{(7),(8)}	A.P. Green - Inswool HP Carborundum - Fiberfrax Thermal Ceramics - Kaowool Thermal Ceramics - Cerablanket	0.90 at 1000°F 1.70 at 1500°F 2.30 at 1800°F	No effective compressive strength	4-8	2300
Soluble Amorphous Wool	Carborundum - Insulfrax 1800 (preferred) Thermal Ceramics - SF607	0.85 at 1000°F 1.35 at 1500°F 1.70 at 1800°F	No effective compressive strength	8 6	1800
Calcium Carbonate ⁽⁹⁾	American Thermal Products - Gilsulate 500	0.60 at 175°F 0.65 at 300°F	83 min	40-42	800

Fig. 100-1 Typical Material Properties for Frequently Used Insulation Materials (2 of 2)

Tank Insulation					
Material					
Generic Type	Commercial Brands	K Factor (Btu-In/hr-ft ² -°F)	Compressive Strength (psi)	Density (lb/ft ³)	Maximum Usage Temp. (°F)
Fiberglass ⁽¹⁰⁾ (Block)	Owens/Corning - Insul-Quick Schuller - Precipitator Spin Glass Certaineed - 850 Board	0.25 at 100°F 0.30 at 200°F 0.35 at 300°F 0.48 at 400°F	0.5 @ 10% deformation	3	450
Mineral ⁽¹⁰⁾ Wool (Block)	Partek - Industrial Board 1240	0.30 at 200°F 0.36 at 300°F 0.45 at 400°F 0.50 at 500°F 0.59 at 600°F 0.68 at 700°F	1.3 @ 10% deformation	8	1200
Polyurethane ⁽¹¹⁾ (FoamBoard) or Modified Polyurethane	Celotex - Thermax Polymer Building Systems - PBS/800 RMAX-TSX 2000 Dow-Trymer	0.15 at 75°F	25	2	300 (Isocyanu- rate cured)
Cellular Glass	Pittsburgh Corning - Foamglas		Properties are the same as shown for piping insulation		

- (1) High compressive strength—good for resistance to physical abuse. Does not burn. Absorbs moisture, which can raise the K factor.
- (2) Manufactured at the Brunswick, GA plant only.
- (3) Independent laboratory testing results from State of California Department of Consumer Affairs, Bureau of Home Furnishings and Thermal Insulation.
- (4) Not strong—not good for physical abuse. Uses a binder which burns out, making it more friable. Better K factor than calcium silicate.
- (5) Use this material for insulating stainless steel.
- (6) Will crack near 500°F due to differences in thermal expansion between ID and OD if installed in a single layer. A system is available for use to 900°F (Pittsburgh-Corning Stratafab).
- (7) 6 lb/ft³ density
- (8) Very high temperature usage. Often used as refractory material.
- (9) Not to be confused with Gilsonite, which is no longer available.
- (10) Other densities available. K factor and compressive strength varies with density. Consult manufacturer for more information.
- (11) Should be double-laminated with aluminum foil.

Bids for the Richmond Lube Oil Project indicated a considerable cost advantage for mineral wool compared to calcium silicate piping insulation. The mineral wool insulation system used in high traffic areas was high density 12-pound mineral wool with 0.020-inch or 0.024-inch weather jacket.

Fiberglass. Fiberglass is widely used as industrial insulation, particularly for buildings; however, it is easily damaged, for the same reasons as for mineral wool, and has a Chevron-imposed temperature limit of 450°F due to binder burnout.

Note that preinsulated copper tubing with fiberglass insulation and a PVC jacket has been used for steam tracing systems on several large projects recently with significant cost savings over conventional insulation. This product, called Dekeron from Eaton Control Systems, has a 400°F maximum temperature limit.

Refractory Ceramic Fiber (RCF). For very high temperature above 1100°F and up to 2300°F, RCF insulation is used. Very few refinery services except furnaces require insulation in this temperature range.

Polyurethane. We no longer recommend the use of spray or poured-in-place polyurethane foam insulation (PUF) for the reasons discussed in Section 130.

PUF has been used to insulate cross-country and submarine pipelines [6, 7]. Straight sections of pipe are shop-insulated by securing the pipe in a cylindrical mold and pouring in the PUF. Bends are hand-insulated with calcium silicate and hand-poured PUF. Drawbacks include difficult application and the tendency of the foam to creep at high temperatures and under the weight of the pipe.

Polyisocyanurate Rigid Foam. Dow manufactures a polyisocyanurate rigid foam (Trymer) which is not laminated and can be formed to fit pipes, tanks, etc. This polyisocyanurate is often used for cold insulation and can also be used up to 300°F (same as isocyanurate-cured urethanes). More information on this material is given in Section 131.

Cellular Glass Block (Foamglas). Foamglas is a silica-based, closed-cell glass manufactured by Pittsburgh Corning. Its use has been restricted primarily to cold insulation because of high cost. Foamglas has a thermal efficiency similar to calcium silicate and can be used to 350°F without concern for thermal cracks (Stratafab system). Pittsburgh Corning markets a special system for up to 900°F. However, we have no experience with it to date (1988).

The blocks are impermeable to moisture. However, moisture penetration at block edges and nozzles can occur. Because Foamglas is rigid and impermeable to water, care must be taken to keep water away from the hot metal surface. If the water vaporizes, the expanding steam can damage the insulation. The insulation system on a warm tank failed when water leaked in and was vaporized at the surface of the tank, resulting in disintegration of the brittle foamglas, destroying the insulation.

Foamglas has also been used for insulating buried lines because of its low K factor and high compressive strength. Again, moisture penetration at seams and joints is a concern in preventing corrosion.

Calcium Carbonate. Gilsulate 500 (American Thermal Products, Inc.) is used as insulation for underground pipes and tanks up to roughly 800°F. Gilsulate 500 is a granular blend of inert inorganic particles composed primarily of calcium carbonate. Gilsulate 500 is hydrophobic and has good load bearing capabilities. It competes with Foamglas for underground applications because it is easier and cheaper to install, less likely to allow water penetration, and eliminates several design problems associated with Foamglas such as thrust blocks and double layer joint overlap.

Insulating Cement. Small valves, turbines, pumps, and other equipment with complex shapes are normally insulated with thermal insulating cement sealed with a coating of mastic.

122 Weather Jackets

Weather jackets must be applied over insulation to prevent entry of water under normal operating conditions. Typical weatherjacketing is aluminum with a moisture barrier. Configuration of aluminum depends on the equipment: corrugated for vertical vessels, cross-crimped for horizontal vessels and piping, and flat weather jackets for vessel heads. For discussion of weather jackets for tanks, see Section 130. Recommendations for other applications are given below. Refer to Specification IRM-MS-1381 for more details on materials and installation requirements for weather jackets.

Specific Applications

Equipment Within 25 Feet of Furnaces and Reactor Structures. Use fire-resistant weather jackets of stainless steel, galvanized steel, or coated steel. In some cases, piping in these areas will also have steel weather jackets for fire resistance.

Equipment Insulated for Relief Load Reduction and Critical Vessels Such as Reactors, Other Expensive Vessels, or Vessels With Large Liquid Volumes. Use fire-resistant steel weather jacket.

Surfaces With Complex Shapes. These usually have a mastic weathercoat if a fire-resistant jacket is not required. Mastic weathercoat should only be applied over calcium silicate or perlite insulation, or over insulating cement.

High-maintenance Areas. Heavier gage weatherjacketing, in addition to rigid insulation, should be used in areas that may get walked on during either shutdowns or normal operations.

Offshore Applications. Use Type 304 stainless steel weatherjacketing. Coated aluminum can be used in areas not subject to mechanical damage. Coated aluminum is an attractive choice because it is only half the cost of stainless. One major drawback is that the coating may be damaged, and bare aluminum does corrode in marine environments.

Comparison of Weatherjacketing Materials

Aluminum resists atmospheric corrosion quite well and can be used in almost all locations, except in some corrosive chemical plant environments where painting may be required. De-icing salts have also caused corrosion of weatherjacketing that is close to a road. Only the aluminum alloys best suited for atmospheric corrosion resistance are recommended. Alloy 3003 or 5052 has good atmospheric corrosion resistance and has been used with good success. Copper-bearing alloys such as 2024 should not be used. Aluminum sheets should not be installed directly over calcium silicate (because of alkaline reaction) unless sheets contain a kraftpaper/ polyethylene moisture barrier.

Steel weatherjacketing coated with a baked vinyl organosol is also available. This product (one trade name is “Steel Jack”) costs about 40% more than aluminum weatherjacketing.

Stainless steel (Type 304) is used for weatherjacketing in corrosive environments too severe for bare aluminum or coated steel. This is the case offshore where we recommend stainless steel weatherjacketing on the basis of favorable experience at locations such as Ninian.

123 Offshore Insulation

Because the environment is more demanding offshore than onshore, several design considerations should be addressed:

- Fiberglass and mineral wool are attractive materials because: 1) short piping runs are easier to insulate and 2) temperatures are typically below 300°F where fiberglass and mineral wool have the largest advantage in K-factor. However, both mineral wool and fiberglass will retain water if the weatherjacket leaks. The cost of replacing insulation should be weighed against the higher cost of using foamglas or calcium silicate in areas where it is likely the weatherjacket will be damaged.
- Weatherjacketing must be stainless steel (Type 304) because aluminum will corrode rapidly in marine environments. Coated aluminum could be used in areas not subject to mechanical damage. Coated aluminum is attractive because its cost is only half that of stainless steel, but if the coating is damaged, it will corrode.
- Sealing and caulking of the weatherjacketing is critical due to constant exposure to washdowns, rain, or fog (IRM-MS-1381-J, Section 3.5.)
- For flexible-removable insulation, Teflon-coated fiberglass cloth is preferred over other cover materials to prevent water intrusion (IRM Section 150; IRM-MS-4197-A; IRM Standard Drawing GD-N1138).
- Careful attention should be paid to selection of insulation. For example, high vibration areas should not be treated with calcium silicate. Instead, mineral wool or fiberglass is adequate and does not have the disadvantages of the rigid calcium silicate.
- Priming of steel under insulation is very important in the prevention of corrosion once the insulation gets wet. Polyamide epoxy (Code P-15, *Coatings Quick Reference Guide*) is used for equipment running under 200°F. For equipment running over 200°F, an organic zinc is recommended. Corrosion under insulation is addressed in greater detail in Section 600 of the *Corrosion Prevention and Metallurgy Manual*.

124 Insulation for Special Applications

Odd-shaped Equipment. Flexible reusable insulating covers are preferable to permanent insulation for 2-inch and larger flanged valves and piping and equipment flanges. These covers are also recommended for large hot pumps and turbines. Covers are fabricated from ceramic fiber or fiberglass encapsulated with various materials to form a weathercoat. See Section 150, Removable Covers, for more information.

Insulation for Pipelines. Refer to Insulation References [6] and [7] and the *Pipeline Manual* for more information on insulating pipelines.

130 Tank Insulation

131 Insulation Materials

Fiberglass semirigid board (block) is the most widely used insulation for tanks within the Company. The maximum service temperature is limited by the thermosetting resin binder at 450°F. However, this is not a concern for the majority of tanks as they are rarely heated above 200°F.

Typical blocks are 2 × 4 feet, from 1 to 4 inches thick, depending on the economic thickness determined.

Mineral wool semirigid board (block) is competitive with fiberglass. The two materials have similar properties except mineral wool is good up to 1100°F.

Calcium silicate block-type insulation is stronger than either fiberglass or mineral wool but has not seen much service on tanks below 450°F due to high installation costs.

Foamglas is generally used for cold insulation. Its cost makes it uncompetitive with other insulation materials in hot services. It is sometimes used on the lower foot of an insulated shell to prevent wicking of water.

Polyurethane (PUF). Sprayed or poured-in-place PUF insulation is not recommended for the following reasons:

- PUF is difficult to apply properly. Even under optimum conditions with experienced applicators and Company supervision, PUF has proven to be difficult to apply (it bubbles, blisters, and cracks).
- PUF is expensive. While installed costs may at first appear attractive, a careful review of the actual lifetime costs which include maintenance costs will be more than that of competing systems. A 1984 CRTC study found that the initial cost of a spray-applied PUF system should be multiplied by a factor of 2.5, to economically compare it to competing insulation systems such as fiberglass blocks. [3]

- PUF can cause corrosion. PUF will hold moisture because it is not 100% closed cell. The water reacts with constituents in the foam and forms acids. Even with epoxy primer, the presence of acids means a constant threat of corrosion.

A preformed, double-laminated (with aluminum foil) polyurethane board insulation is available. This product is satisfactory for many plant applications such as tanks.

Polyisocyanurate Rigid Foam (Trymer), manufactured by Dow Chemical Company, can be formed to fit pipes, tanks, spheres, etc. The Company has experienced cost savings with this system instead of the fiberglass semi-rigid board because the Trymer sheets come in bigger sizes (4 by 8 feet as opposed to 2 by 4 feet for the fiberglass semi-rigid sheets). The benefits of the larger, stiffer sheets include 1) shorter erection time, 2) less manpower required, and 3) less banding needed. This material is good for roof installations because it has high compressive strength and no edges to be caught and blown off by high winds. The polyisocyanurate also has a lower K factor per inch of thickness than do other insulation materials.

Bakersfield has written a good specification [1] for the use of this product on tanks cooler than 225°F.

132 Tank Roof Insulation

Floating roof tanks usually do not have roof insulation largely because these tanks are not often heated over 180°F due to the temperature limitations of the elastomeric vapor seals. Also, single-deck floating roofs require expensive weather coatings, and the insulation can become waterlogged and cause the floating roofs to collapse.

Floating roof tanks lose much more heat than do cone roofs, because the lower deck is in direct contact with the heated stock. If possible double-deck floating roofs should be installed on heated tanks. The dead air space (inside the pontoon) serves as an insulation layer. Inexpensive fiberglass blocks similar to home attic insulation can be installed in pontoons and no weather coat is required.

Fixed roof tanks typically have fiberglass roof insulation. Owens Corning markets a higher density fiberglass insulation called Roof Deck, which supposedly has a higher compressive strength and is able to withstand abuse from foot traffic.

As mentioned above, polyisocyanurate rigid foam has many of the same advantages of Roof Deck and is being used more often now.

Fixed-roof insulation for services up to 150°F is, at best, marginally economical.

133 Tank Weather Jackets

Shells. Aluminum sheet is commonly used over fiberglass and mineral wool insulation on tanks. Aluminum has good atmospheric corrosion resistance and can be used

at almost all locations except coastal regions, where coated aluminum or coated steel must be used.

Aluminum sheets should have a moisture barrier backing and must not be used over calcium silicate unless the sheets are backed.

Corrugated sheets with 2½-inch corrugations are recommended for shells. The corrugations are vertical and accommodate expansion and contractions. They should be seamed along the vertical edges with sheet metal screws to prevent slipping.

Roofs. An effective roof weathercoating system is very important. Wet insulation can cause very high external corrosion rates on tank roofs. It can also cause “cool spots” on the tank roof which cause high internal corrosion rates.

In the past an elastomeric coating, such as tar paper, was placed over Roof Deck insulation on fixed roofs and covered with a layer of small rocks to provide slip resistance, strength, and UV protection. This system has been prone to cracking and separation around the circumference and protrusions, allowing entry of water. Often, failure can occur in one to two years for the tar and gravel built-up systems. We no longer recommend tar paper.

Two effective insulation and weatherjacketing systems for hot storage tank roofs are recommended: the **Thermacon Roof Insulation System** and the **Owens Corning Roof-Deck/Belzona Membrane System**. Although these specialized systems cost more than the conventional built-up systems, they provide truly effective weather barriers [14].

Thermacon's Roof Insulation System uses a weather-tight metal roofing system which can move independently of the tank. This reduces the potential of damage due to high winds or temperature variations. The roof system is available as a radial design which may be installed on any shape roof over many suitable insulation materials including mineral wool, fiberglass, calcium silicate or perlite.

The design Thermacon uses is proprietary and details are not included in Company specification of drawings for hot storage tank insulation. Specification IRM-MS-3865 lists the Thermacon system as acceptable for Company use. Please contact Materials Engineering, CRTC, for more information on this system.

The Owens Corning Roof Deck/Belzona Membrane system has been used on eight tanks in Richmond Refinery. A hot sulfur tank (T-3141) has had this system in service the longest, for about two years as of Spring, 1990. The system exhibits no significant visual deterioration and appears to be adhering well to penetrations through the insulation and weather barrier. This system has replaced the tar and gravel system in Specification IRM-MS-3865 and Drawing GD-N99995, Detail 7.

The Belzona Membrane is an acrylic ester copolymer with pigments for UV resistance. It is reinforced with a fabric and has a total thickness of 16 mils. It is applied over the Roof-Deck board insulation. This insulation has a “prefelted primed” side that will accept the membrane without wicking. Several high density board (block) insulations are acceptable beneath the Roof-Deck insulation, which is usually one inch thick.

The main disadvantage to both systems is a tendency not always to seal effectively around penetrations. Care must be taken and enforced during installation to use proper design, procedures and materials for sealing around penetrations. These are outlined in IRM-MS-3865. Overall Company experience with both systems has been favorable.

Another tank roof insulation jacket system, called Tufseam, has been used successfully at El Segundo Refinery.

134 Attaching Tank Insulation

Shells. The least costly system is the lay bar and banding system. This system uses horizontal bands between lay bars which hold the insulation in place, and additional bands and lay bars hold the corrugated aluminum weather jacket sheets.

A more secure attachment of insulation is the impaled stud system. This system is preferred in high wind applications. In this system, insulation is impaled over metal spikes that stick out from the tank wall. The tips of the studs are hammered flush with the insulation before weatherjacketing is installed.

Both of the above systems are detailed on Standard Drawings GD-N1081 and GD-N99995.

Several refineries have used the Thermacon insulation system by Thermacon Industries Inc. The sidewall system consists of foil-faced isocyanurate foam insulation boards laminated to painted aluminum outer sheets. These insulation panels are factory curved to the tank or sphere's radius, which enables much quicker and easier installation. The system uses 3-inch wide stainless steel or aluminum bands at 2-foot vertical spacing to secure the panels to the tank. The design also accommodates expansion and contraction better than corrugated aluminum weatherstripping does.

Roofs. Insulation blocks are best held in place by impaling. Adhesives suitable for the maximum temperatures are also used successfully.

140 Inspecting and Retrofitting Existing Insulation

141 Inspecting Existing Insulation

Insulation can absorb water and crack or disintegrate during service, losing its insulating ability. Most often the insulation is covered by weatherjacketing, making the insulation impossible to visually inspect unless the weatherjacketing is removed. Infrared thermography is commonly used to measure the surface temperature of vessels, piping and equipment and is useful in finding breaks or failures in insulation.

A heat flow meter is also a valuable field tool to judge insulation performance. The meter is used to measure heat loss over time and monitor damage to insulation. This method is more accurate than guessing insulation effectiveness from appearance of the weather jacket.

Visual appearance of weatherjacketing is not always an accurate indicator of the condition of insulation. Rigid insulation such as calcium silicate can crack (leaving gaps for heat loss) but retain its shape under weatherjacketing. Studies have also shown that crushing of non-rigid insulation, less than 30%, does not significantly change the heat loss rate [8]. Also, the visual appearance of the weatherjacketing gives no indication whether or not the insulation is wet.

142 Retrofit Insulation

A Materials Engineering study found that retrofitting new insulation over existing insulation can pay out rapidly with rates of return of 55 to 85%, regardless of the insulation material used, and regardless of moderate crushing from foot traffic [8]. Retrofitting is about twice as cost-efficient as applying new insulation (30 to 45% rates of return).

150 Flexible Removable Insulation Covers

151 Background

It may be economically feasible to insulate hot flanges, valves, vessel manways, and heat exchanger covers. Removable insulation covers are a safe way to insulate this equipment, though they are expensive. The major advantage of covers is that they are reusable from one shutdown to the next. In fact, crafts such as pipe fitters and instrument mechanics can often re-install them. Insulation crafts may or may not be required, depending upon the plant situation.

The Company Specification IRM-MS-4197 was developed as a result of the many cover improvements made during construction of the Pascagoula Residuum Conversion Project (PRCP) and the Richmond Lube Oil Project (RLOP). These two major projects purchased over 20,000 covers at an expenditure of several million dollars.

Insulation cover materials and design vary substantially. This section presents specific information on how removable covers should be made. The following contractors were used to supply flexible insulation covers for RLOP and PRCP:

Insulation Technology, Inc.
5645 West Howard Street
Niles, Illinois 60648
(312) 647-1500

Energy Control Systems
Route 4
P.O. Box 380B
Gonzalez, Louisiana 70737
(514) 644-8435

152 Description of Covers

Removable insulation covers can be either flexible pads or rigid boxes. The flexible pads are more common. PRCP used the rigid box-type construction primarily, as it was both cheaper and was considered more durable than pads. However, it was economics of scale, inexpensive labor, and a talented contractor that made the rigid construction economical. Most users will find the flexible-type cover to be the more economical.

Both types of covers have a core insulation which provides the primary thermal barrier. The insulation should be either ceramic fiber or fiberglass. The core insulation is encapsulated in a jacket. Flexible covers use either silicone-impregnated or Teflon-coated fiberglass fabrics for the jacket, while rigid covers use a metallic insulation jacket.

153 Insulation of Hot Flanges

In general, all flanges over 100°F should be insulated for the following reasons:

- For heat savings
- For personnel protection
- To prevent large thermal gradients across the flange under inclement weather conditions. This can cause distortion of the flange and ultimately a flange leak.

However, if the flanges and insulation are improperly designed, the following problems can occur:

- If flange and bolts are not of similar materials, differential thermal expansion at the operating temperature can unseat the gasket or yield the bolts or flange.
- The bolts will relax and stretch if the internal operating temperature is above the creep stress limit of the bolts. This stretching can cause leakage and possible auto-ignition because of the high temperatures.
- Improperly designed insulation will “soak up” any leakage, again leading to a possible auto-ignition problem.

To prevent these problems, the following criteria should be used for design and insulation of flanges:

- The flanges and bolts should be of similar material, i.e., B7 or B16 studs for carbon steel or low alloy flanges. If the flanges and bolts are of dissimilar materials, an analysis should be done to confirm that differential thermal expansion at maximum operating temperature will not unseat the gasket or yield the bolts.
- Flange and bolt materials should be chosen for the maximum internal design temperature and corrosive nature of the process fluid. In other words, the stress in flange and bolt material must be kept below the creep stress limits at the maximum internal design temperatures.

Temperature limits for commonly used studs are:

less than 750°F A193 B7

750°F to 950°F A193 B16

Above 950°F Consult CRTC Engineering Analysis and Materials Engineering on a case-by-case basis.

- Use insulation covers designed for safe leakage. Refer to the Specification IRM-MS-4197 for the design and manufacture of leak-safe, removable insulation covers.
- Apply insulation when the flange is cold (after hydrotest and before startup) to minimize startup stresses. Insulation may be temporarily removed after startup to allow inspection for leaks.

A practical problem in the plants is the mixing of B7 and B16 studs, especially during plant shutdowns when a great deal of bolting and unbolting is being done. If a location cannot guarantee that these studs will be totally segregated, then another option is to leave flanges over 750°F uninsulated and use a weathercover over them to protect against wind and rain.

Bolt-up. Bolt-up procedures should follow Bolting-Up Practice found in Section 600 of the *Piping Manual*.

Spray Shields. Insulation covers for hydrocarbon service over 400°F should have a spray shield installed between the cover and the flange being insulated. A spray shield is a preformed sheet metal cover wrapped around the flange. The spray shield should have a gap or a funnel at the bottom to provide a channel for safe leakage through the insulation.

The spray shield and leakage port keep the insulation cover from becoming soaked with hydrocarbon in the event of a leak. Insulation covers soaked with hydrocarbon are poor insulators and can cause fires by auto-ignition.

Removal of Covers

Caution should be used when removing the cover from a hot flange to avoid the possibility of being sprayed with hot material.

160 Insulation Test Criteria

CRTC Materials Engineering has developed acceptance criteria for the major types of insulation materials. These criteria incorporate ASTM testing procedures and industry-accepted standards.

161 K Factor

The K factor relates to the efficiency of the insulating material. A low K value is a better insulator, and a high K value a poorer insulator. The K factor for a material should be measured by either ASTM C-177 (Guarded Hot Plate Test) or ASTM C-335

(Guarded Hot Pipe Test) and certified by an independent testing laboratory. K values do not vary much within a generic class. If test results showed otherwise, we would suspect that the test, not the insulation, is faulty because these tests are manipulated easily.

Over the lifetime of an insulation, mechanical or thermal abuse will lower the efficiency of the insulation, though the K factor will remain close to the original value. Expect a 10% variance during normal use.

162 Compressive Strength

Compressive strength should be measured according to ASTM C-165.

163 Chloride Content

Insulation materials can contain enough chlorides to cause chloride stress corrosion cracking in steels and austenitic stainless steels. Therefore, all insulation materials must meet the criteria set forth in ASTM C-795, “Wicking-Type Thermal Insulation for Use Over Austenitic Stainless Steel.” This specification requires that an insulation fall within the acceptable range shown in Figure 1 of ASTM C-795, which plots ppm chloride versus ppm sodium plus silicate. ASTM C-795 also requires that the pH be greater than 7 but less than 11.7. ASTM C-871 shall be used to measure chemical content.

164 Flammability

Calcium silicate, perlite, and Foamglas have no organic components and will not burn, but binders used in mineral wool and fiberglass will burn and could cause a fire hazard. Hence, mineral wool and fiberglass insulation must meet ASTM E-84, “Surface Burning Characteristics of Building Materials,” with a flame spread index (FSI) of 25 or less, a fuel contribution of 50 or less, and a smoke development of 50 or less. Calcium silicate should have a rating of 0/0/0.

Fire-resistant urethane foams which have a flame spread index of 25 or less as tested per ASTM E-84 are sometimes specified for new construction to provide some fire resistance. However, polyurethane foams are organic and can burn. So-called “self-extinguishing” polyurethane foams meeting ASTM D-1692 are available but are not recommended for new construction. This is because large-scale tests have shown that some D-1692 foams will significantly feed a fire; hence, the E-84 test criteria are recommended instead.

170 Company Specifications and Drawings

The specifications and standard drawings named below deal with insulation for hot systems. Except where noted, they are in the gray tabbed sections of Part 1.

IRM-MS-1381	Hot Lines, Vessels and Equipment
IRM-MS-3354	Polyurethane Insulation of Hot Storage Tanks (<i>Not recommended, see commented Specification.</i>)
IRM-MS-3865	Hot Storage Tanks
IRM-MS-4197	Flexible Removable Insulation Covers
BF-S-1639	Polyisocyanurate Foam Board Insulation for Hot Storage Tanks, <i>available from CUSA Production Western Region</i>
GD-N1081	Standard Insulation and Aluminum Weatherproofing Assembly Details for Heated Tanks
GD-N1137	Fabrication and Installation Details for Flexible Removable Insulation Covers
GD-N1138	List of Materials and Approved Brands for the Fabrication of Flexible Removable Insulation Covers
GD-N99783	Standard Insulation for Hot Piping
GD-N99785	Standard Insulation for Hot Vessels, Heat Exchangers and Hot Equipment
GD-N99993	Standard Insulation Item Numbers
GD-N99995	Standard Insulation and Aluminum Weatherproofing Details for Hot Tanks