SECTION 3: SYSTEMS DESIGN

SECTION 3

INSULATION SYSTEMS DESIGN

3.1 GENERAL

An insulation system is the combination of insulations, finishes and application methods which are used to achieve specific design objectives. Among these are:

1. Energy Savings
2. Reduced Operating Costs
3. Condensation Control
4. Chemical compatibility with the metals being insulated, the atmosphere to which the system will be exposed, and the various components of the insulation system itself.
5. Protection of mechanical and insulation systems from mechanical abuse and atmospheric damage.
6. Personnel protection
7. Fire safety
8. Sound control
9. Future requirements for access to piping, fittings, etc.
10. Accommodation to limited clearances or work space
11. Reduce emissions of pollutants to the environment

While there are several choices of insulation materials which meet basic thermal and cost effective requirements of an installation, choices become more limited with each additional design objective that comes into play.

In some cases the choice of outer coverings, accessories and installation methods is more affected by design objectives than the actual insulation material used. For instance, glass fiber pipe insulation is available with a variety of factory-applied jackets designed to resist different types of mechanically and chemically abusive atmospheres.

The choices are endless and require a working knowledge of insulation material properties as well as a firm grasp of the basic function of each insulation treatment, and the design conditions under which it must operate. Section 3 is presented as a guide to the general design objectives of both commercial and industrial installations.

3.2 COMMERCIAL INSTALLATIONS

Insulation in commercial buildings such as schools, shopping centers, warehouses, hospitals, hotels and other public buildings is designed primarily to reduce energy consumption and/or prevent condensation. The types of mechanical systems commonly insulated in commercial installations vary only slightly from project to project, and involve a relatively narrow temperature range. Typical mechanical systems include:

1. Plumbing (13°C to 80°C)
2. Ducts and housings (15°C to 43°C)

3. Steam and condensate (100°C to 185°C) *upper limit will vary with the pressure of steam

4. Outdoor air intake (seasonal outdoors temperature range)

5. Roof drains (1°C to 15°C)

6. Hot water heating (80°C to 100°C)

7. Chilled water (5°C to 13°C)

8. Engine exhaust (approximately 675°C)

9. Kitchen exhaust ducts (approximately 1100°C)

10. Refrigerant suction (-40°C to 10°C)

Care should be taken in designing commercial insulation systems to specify the thickness, material and finish necessary to accomplish the purpose of the application. Commercial buildings are designed to accommodate either human comfort or materials storage. Generally these purposes are achieved through the proper design of the heating/ventilating/cooling and plumbing systems. The purpose of the insulation system design is to enhance the efficiency of these systems, reduce energy consumption, help prevent damage from condensation, improve sound control and prevent fire.

3.2.1 DESIGN OBJECTIVES

The insulation system designer must be aware of the objectives of the installation and the amount and type of equipment planned to achieve these objectives. In some cases, as with steam heating, proper insulation planning can reduce the required capacity of the generating system. In the case of fruit and vegetable or refrigerated meat storage, temperature maintenance and condensation control objectives will supersede economic thickness design. Appearance and hygiene factors can also affect the choice of finishes in exposed areas and/or areas where food is being prepared or stored.

Condensation control on ducts, chillers, roof drains and cold piping is a basic function of insulation in commercial buildings. Design objectives here are to choose materials and application methods which will achieve the best vapour retarder seal possible, and to calculate the thickness of insulation necessary to prevent condensation.

Insulation chosen for personnel protection and/or fire protection must be able to withstand high temperatures without contributing to a possible fire hazard. Engine exhausts which can reach temperatures of 455°C to 675°C should be insulated sufficiently to reduce surface temperatures exposed to personnel or flammable materials to under 60°C. Kitchen exhaust ducts which are subjected to flammable grease accumulation fall within the same design criteria.

3.2.2 MATERIALS

The insulation materials most widely used on commercial installations are:

1. Glass and Mineral Fiber (pipe insulation, flexible blanket and board):

    - available with various jacketing materials

    - accommodates general commercial temperature range

    - meet code requirement for flame spread and smoke developed

2. Elastomeric (pipe covering and sheets):

- no additional vapour retarder or finish usually required

- used on plumbing piping, chilled water piping, suction piping, flexible lines and cold surfaces

- check manufacturers data for flame and smoke developed

3. Calcium Silicate (pipe covering and block):

   - necessary for higher temperature commercial and industrial installations needing high compressive strength such as high pressure steam, diesel exhaust, kitchen exhaust and breechings

4. Urethane, Polisocyanurate, Phenolic Foam (blocks and pipe covering):

   - necessary where a denser, less absorbent material is required

   - accommodates the general commercial temperature range

   - check code requirements for flame spread & smoke developed

5. Perlite (pipe covering and block):

   - necessary for higher temperature commercial and industrial installations needing high compressive strength such as high pressure steam, diesel exhaust, kitchen exhaust and breeching.

   - lightweight

   - moisture resistant to 315°C

A variety of weather and vapour retarder jackets and mastics is available to aid insulation materials in meeting and designing objectives such as fire safety, appearance and system abuse protection.

3.2.3 SPECIFICATIONS

Because commercial installations involve relatively limited materials and applications choices, with few variations to the mechanical systems receiving insulation treatment, there is a tendency to prepare general specifications which are often insufficient for proper installation or bidding. For example, a specification which states that "chillers or all cold surfaces of chillers will be insulated..." can be interpreted several ways especially if it hasn't been designated as to whether or not the chiller has been factory insulated.

All materials, thicknesses, finishes, securements and design objectives should be carefully communicated to the insulation contractor.

3.3 CHECK LIST - MECHANICAL SYSTEMS RECEIVING INSULATION TREATMENT

The following list is prepared for the convenience and guidance of specifiers. It may be used as a reminder to specify the treatment each individual component of general mechanical system will receive.

A. HVAC AND CHILLED WATER SYSTEM COMPONENTS

[ ] 1. Ductwork

[ ] a. High Pressure Supply

[ ] b. Low Pressure Supply

[ ] c. Return Air

[ ] d. Mixed Air

[ ] e. Plenums and Housings

[ ] f. Variable Air Volume and Terminal Units, and Mixing Boxes

[ ] g. Drops to Diffusers and/or Flexible Ducts

[ ] h. Exhaust (from dampers to outside louvers)

[ ] 2. Piping/Fittings/Valves, Etc.

[ ] a. Chilled Water Supply/Return

[ ] b. Refrigeration Suction

[ ] c. Hot Water Heating Supply/Return

[ ] d. Cooling Tower

[ ] e. Condensate Drain Lines

[ ] 3. Equipment

[ ] a. Chillers

[ ] b. Converters/Heat Exchangers

[ ] c. Pumps (chilled/hot)

[ ] d. Expansion Tanks

[ ] e. Air Eliminators

B. STEAM AND CONDENSATE SYSTEMS COMPONENTS

[ ] 1. Piping/Fittings/Valves, Etc.

[ ] a. Steam (High, Medium and/or Low Pressure)

[ ] b. Condensate (from trap to receiver tank)

[ ] c. Pumped Condensate (from receiver to boiler or feed water heater)

[ ] d. Boiler Feed Water

[ ] e. Cold Water Make-up

[ ] 2. Equipment

[ ] a. Boilers

[ ] b. Generators

[ ] c. Converters

[ ] d. Pumps

[ ] e. Breechings/Flues

[ ] f. Flash Tanks

[ ] g. Condensate Receivers, Deaerator and Feed Water Tanks

C. DOMESTIC HOT AND COLD WATER SYSTEMS COMPONENTS

[ ] 1. Piping/Fittings/Valves, Etc.

[ ] a. Cold Water

[ ] b. Hot Water

[ ] c. Hot Water Circulating

[ ] d. Soft Water

[ ] e. Soil, Waste, Vent and/or Drain Lines (condensations, sound control and fire protection).

[ ] 2. Equipment

[ ] a. Hot Water Generator

[ ] b. Hot Water Storage Tank

[ ] c. Water Softeners

[ ] d. Cold Water Storage Tanks

[ ] e. Heat Recovery Storage Tanks

D. OTHER

[ ] 1. Horizontal Suspended Roof Drain Piping and/or Roof Sumps

[ ] 2. Kitchen Exhaust (fire hazard)

[ ] 3. Emergency Generator Exhaust (personnel and fire protection)

[ ] 4. Refrigeration Piping, Drains and Equipment

[ ] 5. Sterilizer Steam (piping & equipment)

NOTE: If any of the above items are factory insulated, it should be so noted in the insulation specification.

3.4 INDUSTRIAL INSTALLATIONS

Conditions exist in industrial installations such as power plants, chemical plants, petroleum refineries, steel, pulp and paper mills, meat packing plants, food, soap, and cosmetic process plants, marine work, etc., which require that the insulation systems designer be involved in the project during the design phase. Depending upon the industrial process of function of the installation, these conditions include:

1. Stringent control of extreme temperature parameters.

2. Corrosive atmospheres resulting from the presence of process chemicals or the location of equipment and piping outdoors.

3. Increased fire hazard caused by high temperatures and the presence of volatile substances.

4. Presence of operating personnel. (personnel protection)

5. Sanitary and contamination requirements for food, meat packing, soap, cosmetic, dairy and brewery processes.

6. Additional mechanical abuse to insulations from excessive handling, foot traffic on vessel tops and lines, and the added movement of expansion, contraction and vibration.

7. Necessity for easy removal of insulation for predictable maintenance areas.

8. Critical clearance and space limitations coupled with the need for greater thickness of insulations.

9. Complex construction and installation schedules.

10. Radiation hazards in nuclear facilities.

11. Work accessibility requiring scaffolding, cranes, etc.

Pertinent data concerning the installation design objectives, the materials being processed or used, applicable government regulations or codes, operating data and temperature parameters must be determined far enough in advance of final specification preparation to insure the design of a properly functioning insulation system.

3.5 DATA REQUIRED FOR INDUSTRIAL INSULATION SYSTEM DESIGN

3.5.1 NATURE OF THE PROCESS

The possibility of spillage, leaks and accidental contamination of process chemicals and products is always present in industrial installations. Insulations should be chosen which do not react to the chemicals contained in the vessels or piping to which they are applied. Such a reaction may lower the ignition temperature of the process chemical or insulation material, contributing to fire hazard conditions.

Special care should be taken to use non-absorbent insulations in the presence of combustible or toxic liquid. Spontaneous combustion of a combustible liquid absorbed over the large surface area of insulation may occur as it oxidizes. Absorbent insulation may contribute significantly to an accidental fire by storing up the spilled or leaked combustible materials.

Stainless steel is the most appropriate of the metal jacketing materials, having high resistance to corrosives and bacterial growth as well as high mechanical strength. High cost of stainless steel usually limits its use to fire protection and corrosive environments. Aluminum may erode in wash down areas or where strong cleaning chemicals are used. The use of weather and vapour retarder coatings, reinforced with glass cloth or mesh, provides a mechanically strong and sanitary finish for equipment and other irregular surfaces. Many are also resistant to chemicals.

3.5.2 SPECIFIC TEMPERATURE PARAMETERS OF PIPING AND EQUIPMENT

In addition to the reduction of energy usage, industrial insulation systems must maintain controlled temperatures required for process materials being transported from one point in a facility to another.

Temperature control may be continuous, intermittent, cyclic or rapidly changed due to weather conditions or the necessity of steam cleaning and wash down periods.

An insulation of high thermal diffusivity, low specific heat and low density is desirable in installations which require rapid heat-up or cool-off of insulated surfaces. A process changing from hot to cold every few minutes requires an insulation that has the ability to change temperature quickly and has very low mass to retain heat.

The temperature of an insulation's outer surface must be considered where insulation is used for personnel protection or to protect the jacket or mastics or where excessive surface temperatures might cause ignition of fumes or gases. On low temperature installations, surface temperatures must be above dew point to prevent condensation and drip. The emissivity property of insulation finishes is significant in these cases. High emissivity is recommended on finishes used for personnel protection treatments.

On installations where temperatures must be maintained at specific levels, it must be decided in the design phase whether added insulation thickness or heat tracing or both would provide the most efficient service. This decision is based on data other than the conventional economic thickness considerations.

Extreme temperature surfaces in industrial process and power facilities may require the use of materials and application methods which can absorb expansion, contraction and vibration movement. Stainless steel banding or expansion bands are recommended for applications with extreme expansion movement or on large diameter surfaces. Because most high temperature insulations shrink while the metal surface expands, methods such as double layer - staggered joint construction, the design and placement of cushioned expansion joints and/or the use of high rib lath between insulation and metal surfaces may be employed to protect the insulation seal.

Awareness of the nature of the process, its components, the relative temperatures of piping and equipment and the general location of such equipment and substances, aids the specifier in determining areas where excess heat or chemicals may create fire hazards or personnel hazards.

3.5.3 METAL SURFACES RECEIVING INSULATION TREATMENT

A selected insulation should not be chemically reactive to the metal over which it is applied. Basically, insulation installed on steel should be neutral or slightly alkaline. That installed on aluminum should be neutral or slightly acidic.

External stress corrosion, cracking of austenitic stainless steel may result from the presence of chloride ions on its surface. Insulation containing chlorides or located in a salt-laden or chloride contaminated atmosphere must not be in direct contact with unprotected stainless steel surfaces.

In the case of stainless steel jacketing, factory-applied moisture retarders on the inner surface may be sufficient protection. Virtually all stress corrosion cracking is caused by chlorides introduced from the atmosphere or from chemical fumes and not from the insulations themselves.

3.5.4 OPERATING DATA

The location of instruments and maintenance areas where personnel will be present is significant when specifying treatments for personnel protection and materials abuse protection from foot traffic, excessive handling and operational machinery. Rigid insulation materials and jacketing are recommended in these areas. High pressure wash down areas require resistance to water and detergents as well as high mechanical strength.

3.5.5 FUTURE ACCESS AND MAINTENANCE REQUIREMENTS

Leaks are most likely to occur at valves, fittings and flanges. Low temperature insulation can be protected from leaks by sealing off adjacent insulation with vapour-retarder mastics. Removable fitting covers may be specified at predictable maintenance areas, while special leak detection mechanisms may be installed at other locations. However, on hot applications a rigid inspection and replacement program is the best prevention of large-scale insulation destruction due to leakage.

Turbines, which require easy access for inspection and maintenance, can be insulated with removable insulation blankets fabricated from stainless steel mesh or high temperature fabric filled with fibrous insulation. These are attached to turbine surfaces by means of metal eyelets built into the blankets around the edges.

The floor level of large tanks can be protected from spilled chemical or water from wash downs by using a non-absorbent insulation along the bottom skirt or support, or by sealing with caulking.

3.5.6 ATMOSPHERIC CONDITIONS

The atmosphere surrounding industrial piping and equipment presents additional problems in the selection of finishes and jacketing. Of particular concern is the presence of chemicals or humidity which act to corrode metal finishes.

Because of its excellent weather-barrier and mechanical properties, metal jacketing is widely used on industrial installations. The metals most resistant to corrosive chemicals and humidity are stainless steel and coated electro-galvanized steel. Coated aluminum can be used to combat specific conditions by selection of the exact coating required. However, the coatings are not always abrasive resistant, leaving the aluminum open to attack at fastener openings, cuts, etc.

Aluminum is weather resistant but does not always hold up in a wash down area or where strong cleaning chemicals are used. Factory-applied moisture-retarders are recommended on aluminum jacketing to prevent galvanic corrosion.

The coverings considered most resistant to corrosives and abrasive chemicals are the plastic types.

Unless protected, some PVC type coverings may break down when subjected to the effects of ozone, infra-red and ultra-violet rays. Protective paints are available for PVC coverings not manufactured for outdoor use. Weather barrier coatings offer good protection from weather as well as from the chemical attack of acids, alkali, solvents and salts, either air-borne or as a result of intermittent spillage. Glass cloth and other fabric membranes are generally used as reinforcements and add mechanical strength to the installation.

Maximum protection from chemical attack on cold and dual temperature service is achieved through the use of vapour retarder coatings. They, too, are applied with reinforcing fabric.

Stainless steel jackets and bands are recommended in areas which require superior fire resistance.

Stainless steel is recommended over the use of aluminum due to the latter's lower melting point.

Some weather and vapour retarder mastics also add fire retardant properties to an insulation system.

3.5.7 CLEARANCES

Because of the complexity of process piping and the added thickness required to control heat loss or gain, clearances often become so minimal that it can be necessary to insulate piping together in groups. This is also true in marine work.

3.5.8 SCHEDULING AND MATERIALS STORAGE

Precise industrial installation schedules and good application practice often dictate that insulation be finished as soon as possible after roughing-in. The materials chosen must have the necessary strength to resist any excessive amount of handling and moving at the installations site. Materials which are moisture absorbent must also be protected from water while being stored at the site. Storage areas should be clearly indicated for the insulation contractor in project specifications, and should be noted as covered or open.

3.5.9 SPECIFICATIONS

Contract drawings should indicate the extent and general arrangements of the yard and the process piping to receive insulation treatment. The size of piping and equipment, line origination and termination, elevations, support locations, and orientation of nozzles, fittings and valves should also be indicated and properly dimensioned.

3.5.10 QUALITY OF MATERIALS

Insulation and associated materials should be specified and ordered to meet appropriate codes and standards. Manufacturers' data sheet and test reports should be consulted in the selection process to determine conformity.