CHAPTER 5 THERMAL INSULATION IN INSTALLATIONS
THERMAL INSULATION IN INSTALLATIONS

- The thermal insulation for installations are classified as technical insulation and industrial insulation.

- The problems such as condensation are result of mistakes during the selection of type of insulation material and its thickness.

- The thermal conductivity of the selected insulation material is very important such in the selection of the proper material with proper diffusion resistance coefficient (µ).

- The condensation occurs if an insulation material which has lower diffusion resistance coefficient is used for thermal insulation of installation.

- If the installations in colder environment are not insulated, the freezing problem can occur.
THERMAL INSULATION IN INSTALLATIONS

THE REQUIRED PROPERTIES OF THE INSULATION MATERIALS USED IN INSTALLATIONS

• The thermal insulation is required in order to save energy, to prevent heat loss and heat gain due to the temperature difference.

• The thermal insulation is applied to:
  - Buildings and constructions
  - Installations
  - Industrial applications

• The installations are classified into three categories according to the temperature of fluid which flows through the pipes;
  - **Cold Lines**: The lines in which the fluid temperature is below 6 °C
  - **Warm Lines**: The lines in which the fluid temperature is between 6 °C and 100 °C
  - **Hot Lines**: The lines in which the fluid temperature is above 100 °C

• The thermal insulation is carried out for hot lines in order to prevent heat loss; and for cold lines in order to prevent heat gain.

• The thermal insulation materials used in installations are generally Polyethylene Foam, Glass Wool, Cellular Glass, Calcium Silicate, Rubber Foam and Polyurethane.
THE REQUIRED PROPERTIES OF THE INSULATION MATERIALS USED IN INSTALLATIONS

- The required properties that should be taken into consideration during the stage of the thermal insulation of the installations;

1) Thermal conductivity coefficient \((k)\)
2) Water vapor diffusion resistance coefficient \((\mu)\)
3) Fire endurance
4) Resistive to corrosion
5) Ease for usage
6) Economical aspect

1) THERMAL CONDUCTIVITY COEFFICIENT \((k)\)
   - In the selection of insulation material, the most important parameter is the thermal conductivity coefficient.
   - The lower the thermal conductivity coefficient, the higher the thermal resistive to heat transfer.
   - The most important to take into consideration here is the type of the insulation material and its thickness.
For example, in the central heating system (in which the fluid temperature is 90 °C and room temperature 22 °C)

- At 60 mm (2") pipe; 83.4% energy gain for 20 mm insulation - 87% for 30 mm insulation
- At 89 mm (3") pipe; 83.9% energy gain for 20 mm insulation - 87.7% for 30 mm insulation
- At 114 mm (4") pipe; 84.1% energy gain for 20 mm insulation - 88% for 30 mm insulation
- At 169 mm (6") pipe; 84.2% energy gain for 20 mm insulation - 88.3% for 30 mm insulation

In practical applications, the insulation material thickness is generally selected as 20 mm for small diameter pipes, and 30 mm for large diameter pipes.

2) WATER VAPOR DIFFUSION RESISTANCE COEFFICIENT (µ)

- As is seen in heat transfer, the water vapor tends to transfer from the higher partial vapor pressure to lower one.
- If the water vapor transfers completely, µ=1; and if no water vapor transfers, µ=∞.
- The outer surface temperature of the pipes in which low-temperature fluid flows is generally below the environment temperature. If the outer surface temperature of the pipeline decrease below the sweating temperature, the condensation starts.
- If there is no insulation, the condensation occurs on the outer surface of the pipeline
- If there is an inadequate insulation, the condensation occurs on the outer surface of the insulation material.
THERMAL INSULATION IN INSTALLATIONS

• Especially in cold pipe lines, the water vapor diffuses into the fibrous insulation material ($\mu \approx 1.1$) which is not covered any vapor barrier and the vapor condenses inside the insulation material. The condensed water sometimes can freeze.

• The water inside an insulation material damages the system in two ways;
  ❖ The water increases the thermal conductivity coefficient of the insulation material.
  ❖ The water inside the insulation material causes the corrosion and may cause the insulation material and sometimes the pipeline to be changed with new ones.

• There are two ways to prevent these problems;
  ❖ The closed porous materials which have high water vapor diffusion resistance coefficient should be used for thermal insulation.
  ❖ For especially insulation of cold lines, a perfect vapor barrier material should be used if open porous (fibrous) insulation materials are used.

• As a result, the closed porous insulation materials such as Polyethylene Foam, Rubber Foam should be used in cold lines.
3) FIRE RESISTANCE
The values of fire-resistance which are used in insulation should be given with respect to the norms.

4) LOW CORROSION RISK
Because of having chemical agent, thermal insulation material which is applied to the metal surfaces should not cause the corrosion. In addition to this, it must resist to the water vapor passing. Because the water vapor passing can cause corrosion in the metal surfaces.
5) **EASE OF APPLICATION**
It should be applied easily, hermetical (tam sızdırmaz) and not forming a heat bridge. The insulation material which is selected according to nature of the work to be done should be lightweight, easy to convey, store and cut, also it must have features which requires minimum labor.

6) **ECONOMY**
The cost of insulation material which is applied must be low.
THE INSTALLATION PLACES THAT CAN BE INSULATED

• Insulation is technical issue in installation. For this reason it must be well known under what conditions, and which materials to be selected.

• Improper (bilinçsiz) installation of insulation may be extravagance (boşa yapılan harcama). Because of this, different materials are used according to the pipe’s condition such as hot, warm or cold.

• In addition, the critical insulation thickness must be account before insulation.

INSULATION IN PIPES

Pipe insulation can be examined in various types.

1. Cold water pipe insulation (cold lines)
2. Hot water and heating pipes insulation (warm lines)
3. Steam, hot water, etc. pipes insulation (hot lines)
Thermal insulation materials which are used in pipe insulation:

- Prefabricated Rubber foam
- Prefabricated Polyethylene foam
- Prefabricated Glasswool - Rockwool - Cellular Glass
- Prefabricated EPS - XPS
- Prefabricated Polyurethane - Phenol foam
- White Glasswool or Rockwool Mattress (Şilte)
- Injected Polyurethane
- Calcium Silicate

In Turkey, pipe insulation is widely carried out by means of Bakalite Roll Glasswool whose thickness is reduced when it is rolled tightly, and it is not hard enough when it is rolled loosely.

**So, the usage of Glasswool in Turkey has not yet understood. And its usage is wrong.**

- It should be rolled around a pipe tightly, however, the necessary thickness should be satisfied by rolling the same insulation material over and over until the required thickness is obtained.
- However, its cost becomes higher and so, the usage of Bakalite Roll Glasswool is not so suitable for pipe insulation when compared with the prefabricated pipe glasswool.
1. Cold Water Pipe Insulation

• Due to the flow of cold liquid in the pipe, surface of the pipe is cold.

• Water vapor in the air which contacts with the cold surface becomes a liquid after condensing as soon as contacting.

• Condensation can cause corrosion and energy loss. This situation can be eliminated with correct application.

• For cold water pipe insulation; Prefabricated Fiberglass, Prefabricated Glasswool and Prefabricated Styropor insulation materials which are based on polyurethane and synthetic rubber are used.

• These materials are coated with aluminum foil when the necessity of vapor barrier.

• In our county, synthetic rubber based insulation materials are widely used for cold water pipes insulation.

• The advantage of insulation of cold lines is to protect the performance of system extending the life of mechanical systems.
Elastomeric Rubber Foam Sheets
Elastomeric Rubber Foam Sheets
Elastomeric Rubber Foam Sheets
Custom Aluminum Coated Elastomeric Rubber Foam Insulation Application
Special aluminum-coated Elastomeric Rubber Foam
2. Hot Water and Heating Pipe Insulation

- Commonly used materials for insulation of these types of pipes are generally high temperature resistant materials such as Glass Wool Mattress, Rock Wool Mattress, Prefabricated Polyethylene, Rubber Foam which are polyurethane based thermal insulation materials.
- The important thing is to prevent penetration of the outdoor air through the inside in these types of insulation.
Insulation of Hot Water Pipes with Cellular Glass
Pipe Insulation with Glass Wool

Insulation of Hot Water Pipes with Prefabricated Aluminum Foil Coated Glass Wool
Insulation of Hot Water Pipes with Prefabricated Foil Glass Wool

Insulation of Vessel
Insulation Applications with Elastomeric Rubber Foam
3. Steam, Hot Water, etc. Pipes Insulation

• **Prefabricated Glass Wool** are used in pipe insulation whose operating temperature does not exceed the +250 °C.

• From +250 °C to +550 °C temperatures, **White Glass Wool** or **Rock Wool** which are wrapped with cardboard (mukavva) or galvanized wire are used. The outer surfaces of these materials are coated with galvanized steel, aluminum or PVC.

• If Carboard-Glass Wool is used for insulation, the flammability of the cardboard should be considered and insulation surface temperature must not damage to the cardboard.
Rock Wool Mattress covered with Galvanized Metal Sheet
Insulation Application with Multilayer Materials
Insulation with Prefabricated Polyurethane
Insulation for Valves and Armatures

• The valves, nonreturn valves (Çek valf), silt traps (pislik tutucu) and flanges in hot and cold installations have a great heat transfer surfaces.

• Generally, these installation equipments are unfortunately not insulated.

• The fundamental reasons for no insulations of valves and armatures can be given as;
  ❖ The heating of boiler room (kazan dairesi) by means of armatures are not desired.
  ❖ The difficulty of re-insulation of armatures during the maintainance of the armatures.
  ❖ It increases cost.
  ❖ The cost of metal sheet coverage is high.
  ❖ The applications are not esthetic and there is a detail problem.
  ❖ No importance (önem) is given for the insulation.
The Problems Rised Due to No Insulation in Heating Pipe Systems

• The increase in energy (heat) loss and operating cost (işletme maliyeti)
• Damage of other equipments due to excessive heating of a boiler room. For example, the decrease in efficiency of pressurized air compressor.
• Risk of industrial accidents due to high surface temperature of valves and armatures.
• No esthetic view among insulated pipes and uninsulated valves and armatures in a same line.

The Problems Rised Due to No Insulation in Cold Pipe Systems

• The increase in energy (heat) loss and operating cost (işletme maliyeti)
• Corrosion due to condensation

The application of Valve Jacket

• In Our Country, the insulation of armatures in hot and cold lines is carried out by means of Rubber Foam, Polyethylene, Glasswool and Rockwool.
• Also, valve jackets are used for insulation.
• The valve jackets are comprised of three layers.
The application of Valve Jacket

• The inner and outer layers of a jacket are made of silicone coated glass fabric (cam kumaşı) which resist up to 250 °C.
• The middle layer is made of 5-cm thick Rabitz wire-wound (Rabitz tel sarılı) Rockwool which resists up to 750 °C.

• The advantages of valve jackets are;
  ❖ It is nonflammable due to no having carbon or hydrogen itself.
  ❖ It is resistive to water, oil, weak acids and all air conditions. So, it can be used inside or outside of facilities.
  ❖ Its assembly is so easy.
  ❖ It can be easily removed during the repairment.
    And it can be recovered easily after repairment.
  ❖ No heat bridges occur due to the valve flanges also being covered by the jacket.
  ❖ It provides high energy saving.
  ❖ It provides an esthetic view.
  ❖ It is a long-life material.
**Insulation in Air-Conditioner Ducts**
- The insulation of heating, ventilation and air-conditioner ducts are given as follows;
  - Thermal Insulation
  - Insulation due to Condensation
  - Sound Insulation

**Thermal Insulation in Air-Conditioner Ducts**
- For the thermal insulation of the rectangular ducts, sheet-type Elastomeric Rubber Foam, Folio-Coated Polyethylene Foam, Folio-Coated Glasswool are used.
- For insulation of outside applications, the insulation material should be covered with aluminum or galvanized metal sheets.

**Insulation due to Condensation**
- In order to prevent the condensation at the outer surfaces of cold lines in hot environment, One-Surface Aluminum Folio-Coated Polyethylene Sheet or Rubber Foam is used.

**Sound Insulation**
- The inner surface of a duct is covered with sound insulation material.
- A nonflammable, acoustic foam is ideal for sound insulation.
- By means of acoustic foam, the thermal insulation is simultaneously satisfied.
Insulation of Industrial Equipments

• The most proper material for the insulation of boilers and tanks having temperatures between 250 °C and 500 °C is **Wired** (telli) **Glasswool** or **Wired Rockwool**.

• For the insulation of the tanks or boilers having operating temperatures above 500 °C, **Rockwool** or **Ceramic Fiber** (Seramik Elyaf) is used.

• **Rockwool** can be used up to 750 °C.

• **Ceramic Fiber** can be used up to 1250 °C. It is used in industry for very high temperature oven, furnace and stove (etüv).

• Also, **firebrick** (ateş tuğlası) is used for the outer wall of these high-temperature oven, furnace etc. These firebricks can be covered with **Rockwool** or **Ceramic Fiber** if necessary.
CONDENSATION IN INSTALLATIONS

CONDENSATION

Condensation is a process in which water vapor (gaseous state) turns into water droplets (liquid state), when it comes in contact with a cooler surface.

Condensation Parameters

1. Ambient temperature \((T_a = ^\circ C)\)
2. Relative humidity rate \((\varphi = \%)\)
3. Fluid temperature \((T_m = ^\circ C)\)
4. Cell structure of the material
5. Surface air convection coefficient \((h)\)
6. The thermal conductivity coefficient \((k)\)
7. Water vapor diffusion resistance coefficient \((\mu)\)
How does the condensation occur?

In cold lines, if insulation material absorbs water and precautions are not taken against vapor passing or a sealed application cannot be done, for example using insulation materials which has low water vapor diffusion resistance coefficient ($\mu=1.1$) such as fibrous materials cannot cause condensation on the surface, but water vapor enters and condenses inside the insulation material, then it converts to the water.

**The Results due to Condensation**

Condensed water increases the thermal conductivity coefficient of insulation material and decreases the insulation property. In some cases, thermal conductivity coefficient of insulation materials such as glass wool can worse two-three times.

*Examples of Disrupted Insulation which affected by Condensation*
<table>
<thead>
<tr>
<th></th>
<th>Glass Wool</th>
<th></th>
<th>Polyurethane</th>
<th></th>
<th>Rubber Foam</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Dry State</strong></td>
<td>(20°C)</td>
<td>(20°C)</td>
<td>(20°C)</td>
<td></td>
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<td></td>
</tr>
<tr>
<td></td>
<td>$k=0.040$ W/mK</td>
<td>$k=0.038$ W/mK</td>
<td>$k=0.040$ W/mK</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Insulation thickness</strong></td>
<td>Heat Loss</td>
<td>“$k$” Value</td>
<td>Heat Loss</td>
<td>“$k$” Value</td>
<td>Heat Loss</td>
<td>“$k$” Value</td>
</tr>
<tr>
<td>25</td>
<td>-17.10</td>
<td>1.20</td>
<td>-18.20</td>
<td>1.30</td>
<td>-18.20</td>
<td>1.30</td>
</tr>
<tr>
<td>4.0</td>
<td>-12.10</td>
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<td>0.86</td>
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<tr>
<td>50</td>
<td>-10.40</td>
<td>0.74</td>
<td>-10.30</td>
<td>0.74</td>
<td>-9.80</td>
<td>0.70</td>
</tr>
<tr>
<td><strong>Wet State</strong></td>
<td>(20°C)</td>
<td>(20°C)</td>
<td>(20°C)</td>
<td></td>
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<td></td>
</tr>
<tr>
<td></td>
<td>$k=0.075$ W/mK</td>
<td>$k=0.050$ W/mK</td>
<td>$k=0.038$ W/mK</td>
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<tr>
<td>25</td>
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<td>1.90</td>
<td>-21.80</td>
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<td>-12.00</td>
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<tr>
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<td>1.26</td>
<td>-13.20</td>
<td>0.94</td>
<td>-9.80</td>
<td>0.70</td>
</tr>
</tbody>
</table>

First and After 1 Years Situations of Elastomeric Foam Rubber, Polyurethane and Glasswool Materials
Thermal insulation material which is used in cold lines:

- Using "Vapor Barrier" is certainly insufficient for both open porosity and low μ value.
- For closed porosity and low μ value, "Vapor Barrier" is necessary.
- It is not necessary to use "Vapor Barrier" for enough high μ value.

Precautions and Solutions against Condensation

- Selecting suitable heat insulation material.
- Minimum insulation thickness must be calculated correctly for preventing to condensate.
- Coefficient of water vapor diffusion resistance must be high enough.
- Thermal bridges must not occur during insulation and sealing application should be done correctly.
PROBLEMS FOR INSULATION OF INSTALLATION

Insulation and installation cannot be thought separately. Unfinished insulation of air conditioning systems, heating and cooling systems cannot be put into use. Materials for using insulation of installation can be separated from each other according to the plumbing temperature, thermal conductivity, vapor diffusion. 

- Material selection according to the fluid temperature
- Lack of necessary thickness to prevent condensation in pipe, air duct, armature etc. and wrong material selection
- Ignoring the thickness of pipe and armature against freezing
- Disregarding the insulation of cold-hot pipes which are inside concrete and soil
- Taking not enough precautions to prevent heat and sound bridges in the installation
- Ignoring the insulation of valves and armatures

are the major problems.
<table>
<thead>
<tr>
<th>Thermal Insulating Material</th>
<th>Maximum Operating Temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ceramic Wool</td>
<td>1800</td>
</tr>
<tr>
<td>Rock Wool</td>
<td>750</td>
</tr>
<tr>
<td>Cellular Glass</td>
<td>430</td>
</tr>
<tr>
<td>Glasswool (Bakalite)</td>
<td>250</td>
</tr>
<tr>
<td>Polyurethane</td>
<td>110</td>
</tr>
<tr>
<td>Rubber Foam</td>
<td>105</td>
</tr>
<tr>
<td>Polyethylene Foam</td>
<td>105</td>
</tr>
<tr>
<td>Expanded Polystyrene</td>
<td>75-80</td>
</tr>
<tr>
<td>Extruded Polystyrene</td>
<td>75-80</td>
</tr>
</tbody>
</table>

*Insulation Materials which are used in terms of maximum fluid temperature*
Additional Heat Losses Due to Pipe Installation Elements

1. Vanes and gate valves
2. Types of flange
3. Pipe clamps
4. Metal pipes
No Insulation or Wrong Material Selection for Sound Insulation in Air-Conditioner Ducts

In sound insulation of air-conditioner ducts, it is not necessary to use sound absorber due to selecting a suitable material and required thickness. Modern products which do not affected by oil, dirt, dust particles must be used.
Taking Necessary Precautions for Preventing Vibration of Devices

Devices are fitted onto concrete many times ignoring the precautions. After that, this causes unsolvable situations.

Application of Impact Sound Absorber Material  Vibration Absorber Spring