# Technical Newsletter

2026, Feb

## Vapor Barriers in Petrochemical Furnaces for Chemical Protection.

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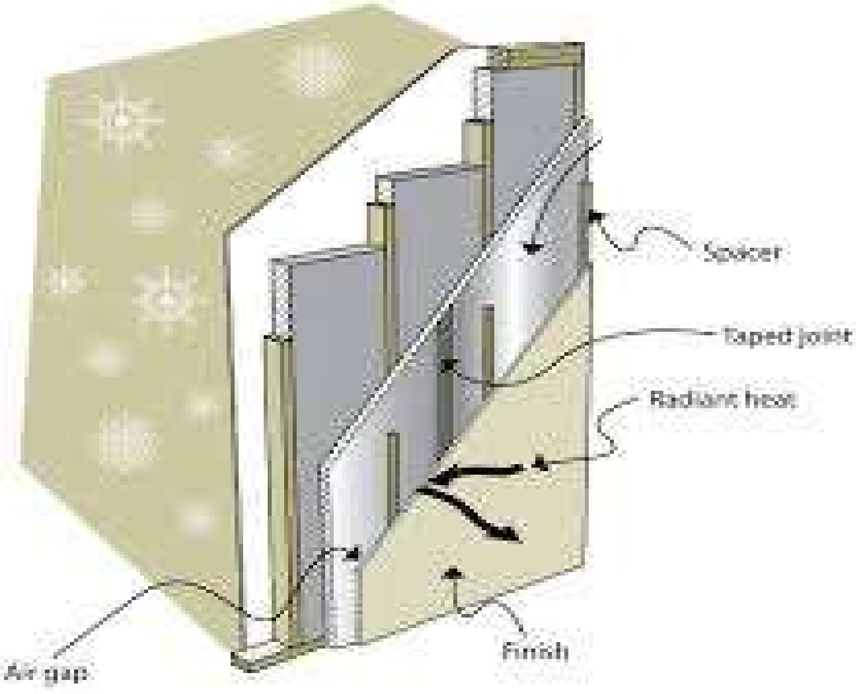

**Generic example of the use of a vapor barrier**

# 1. Introduction

The presence of **moisture and corrosive vapors under thermal** insulation in process equipment, such as petrochemical furnaces, generates a phenomenon known as **corrosion under insulation (CUI)**. This type of chemical attack affects the mechanical integrity of the metal casings of furnaces and heaters and can cause premature failures, production losses, and safety hazards if not properly controlled.

The use of **vapor barriers** is an essential design strategy to **prevent moisture or condensate from penetrating the base metal through the insulation**. This report analyzes the problem, the mechanisms of attack, materials, and design methods for vapor barriers in petrochemical furnaces.

# 2. Problem Description

## 2.1 What is Corrosion Under Insulation (CUI)?

**Corrosion under insulation (CUI)** is a type of localized corrosion that occurs when **moisture, condensation, and corrosive agents become trapped between the metal surface and the thermal insulation**, without proper drainage or ventilation. This includes environments where water vapor condenses along with aggressive gases such as **SOx, NOx, or acidic compounds formed by the combustion of sulfur-containing fuels**.

In petrochemical furnaces, the external walls of the metal shell are usually covered by several layers of insulation and protection; however, if the insulation does not have an **appropriate vapor barrier**, condensed water can remain in contact with the metal during heating and cooling cycles, **accelerating corrosion**.

## 2.2 Consequences

- Loss of metal thickness
- Degradation of the mechanical capacity of the furnace.
- Formation of localized pits and cracks.
- Risk of catastrophic failures and downtime.

# 3. Chemical Attack Mechanism

## 3.1 Formation of Condensates and Corrosive Agents

Furnace combustion vapors are rich in **water and acidic byproducts**, particularly when sulfur-containing fuels are used. These vapors can condense when the surface temperature of the furnace walls drops at points in the insulation.

When condensed water vapor combines with contaminants such as **sulfur dioxide ($SO_2$), nitrogen dioxide ($NO_2$)**, or other acidic gases, corrosive liquid solutions are formed. **These wet electrolytes facilitate the electrochemical reaction of the casing metal**, accelerating corrosion.

### 3.2 Chemical Reaction with Iron

The main reactant is **liquid water** (or a wet film) that dissolves oxygen, chloride ions, and contaminants. The corrosion of iron is classically explained by the reaction:

$$\mathrm{Fe} + \frac{1}{2}\mathrm{O_2} + \mathrm{H_2O} \rightarrow \mathrm{Fe^{2+}} + 2\mathrm{OH^-}$$

In the presence of chloride ions or acids, these products can accelerate localized corrosion and cause deep pitting. In humid environments, localized corrosion can quickly outpace simple uniform corrosion.

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## 4. Typical Case of Chemical Attack

### 4.1 In Petrochemical Furnaces

A common scenario occurs when **the sulfur content of the fuel exceeds a certain threshold**, generating sulfuric acid in the presence of condensed water. This acid is particularly aggressive towards the carbon steel used in furnace shells.

**API Standard 560: Fired Heaters for General Refinery Service** specifies that when the sulfide content exceeds **500 ppm (by mass)**, a **304 stainless steel foil vapor barrier** must be installed to prevent condensation and corrosive products from reaching the metal surface. Furthermore, this barrier must be positioned so that **the outside temperature remains at least 100 °F (≈ 37 °C) above the calculated acid dew point** under all operating conditions.

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## 5. Vapor Barriers: Materials and Thicknesses

### 5.1 Standard materials

1. **Stainless steel sheet (SS 304/316) foil type**
    - High corrosion resistance and thermal durability.
    - Recommended when acid gases or high sulfur content are present.
2. **Aluminum sheets or aluminum foil with polyethylene**.
    - They function as physical barriers to vapor.
    - They are commonly used in multi-layer thermal insulation.
3. **Polymeric barriers coextruded with metal**
    - Laminates (foil + LDPE/HDPE) with low vapor permeability .
    - Typical total barrier thickness: 1.5 mm (foil + polymer layer).

### 5.2 Thicknesses and Performance

- Metal foil thickness: typically **0.05 mm to 0.2 mm** for barrier metal foil.
- Total barrier (metal + polymers): **up to 1.0 – 1.5 mm** to ensure an effective barrier against vapor and pressure.

*Note: Thicknesses should be selected based on **operating temperature, vapor diffusion, chemical compatibility, and mechanical rigidity**.*

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## 6. Vapor Barrier Location Calculation

### 6.1 Thermal Considerations

A vapor barrier is placed **between the metal surface and the main thermal insulation**, or **applied directly to the base metal before insulation**. Its purpose is to **minimize the conduction of moisture from the environment to the hot metal surface**.

### 6.2 Typical Criterion (API 560)

For the design of barriers in furnaces, API 560 specifies that the barrier should be located so that **the surface where it is located** maintains a temperature **≥ 100 °F (≈ 37 °C) above the acid dew point under all operating conditions**.

**Simplified Formula for Barrier Distance**

Although there is no single universal formula, the criterion is:

$$\text{Tbarrier} = \text{T Dew point} + 37°\text{C}$$

Donde:

- Tbarrier : It is the temperature at the surface of the metal where the vapor barrier rests.
- Tacid dew point: It is calculated based on the **composition of combustion gases and water content**.

The effective distance from the metal depends on **the thermal conductivity of the insulation materials**, and will be obtained through detailed thermal analysis (e.g., cumulative thermal resistance of each layer).

### 6.3 - Dew point of the main corrosive gases in petrochemical furnaces

We summarize here the main corrosive gases present in petrochemical furnaces, especially those derived from sulfur and nitrogen, and their approximate acid dew points. The condensation of these compounds on metal surfaces is one of the most significant causes of external corrosion of furnace shells, which is why vapor barriers are installed.

| Chemical Species | Condensantion Product | Dew Point approx. (°C) | Technical Notes |
|---|---|---|---|
| $SO_3$ (Sulfur Trióxide) | $H_2SO_4$ (Sulfuric Acid) | 115 – 150 | The main cause of acid dew point corrosion. It depends on $SO_3$ and humidity. |
| $H_2SO_4$ (steam face) | $H_2SO_4$ (líquid) | 100 – 150 | Highly corrosive; may condense at elevated temperatures. |
| $SO_2$ (Sulfur Dioxide) | $H_2SO_3$ / oxidation a $H_2SO_4$ | < 100 | Indirect corrosiveness; it becomes critical when oxidized to $SO_3$. |
| $NO_2$ (Nitrogen dioxide) | $HNO_3$ (Nitric Acid) | 30 – 60 | Condensation at moderate temperatures; corrosive to carbon steels. |
| $HNO_3$ (steam face) | $HNO_3$ (liquid) | 50 – 60 | Severe chemical attack in the presence of moisture. |
| HCl (Hydrogen chloride) | HCl (liquid) | ≈ 42 | Very aggressive even at low temperatures, common with chlorinated compounds. |

## Technical notes

- The values shown are typical ranges used in furnace and boiler engineering..
- The actual acid dew point depends on the partial pressure of the acid, the water vapor content, and the overall composition of the gases..
- **In conservative design, it is recommended to keep the temperature of the casing and external insulation above the highest expected acid dew point (generally that of sulfuric acid).ico).**

## 7. API References and Related Standards

### Relevant API Standards

| API Standard | Main Application |
|---|---|
| **API Standard 560** | Design and specifications of process furnaces (Fired Heaters) in general refinery services; includes criteria for steam barrier when there is a high sulfur content. |
| **API RP 583** | Recommended practice for corrosion under insulation and fireproofing; guide for material selection and design of insulation systems to mitigate CUI. |
| **API 510 / API 570 / API 574** | Inspection and management of ción y gestión de integrity of containers and pipes under insulation. |

### ASTM complementaries

- **ASTM C1136, ASTM E96** for measuring vapor permeability and barrier characteristics.

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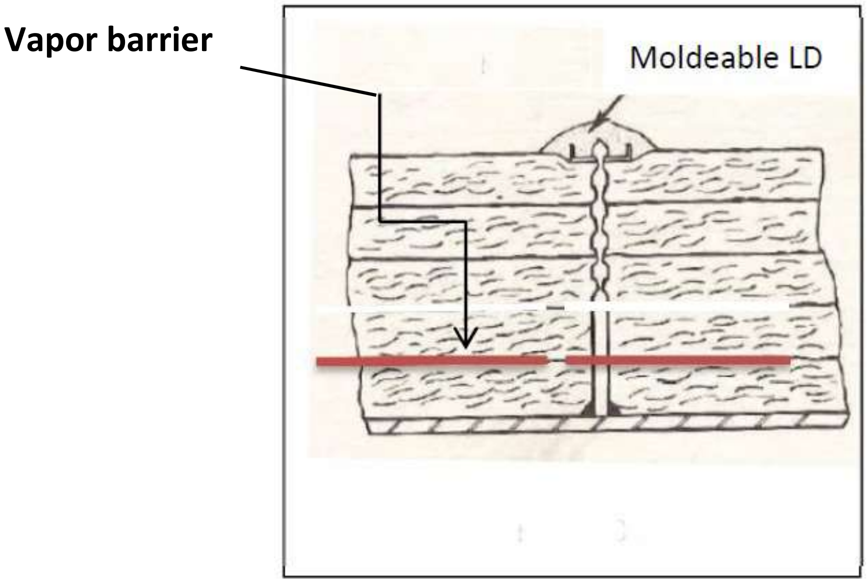
## 8. Illustrations and examples:

8.1: Example of a vapor barrier in a “multilayer” ceramic fiber insulation (one layer of fiber on top of another).

Materials:
Ceramic Fiber 8 lb/pie3 de 1 “
Ceramic Fiber 8 lb/pie3 de 2 “
Ceramic Fiber 4 lb/pie3 de 1 “
Aluminum Foil 60 microns, 95 kg
Performance foil : 6.2 m2/kg.



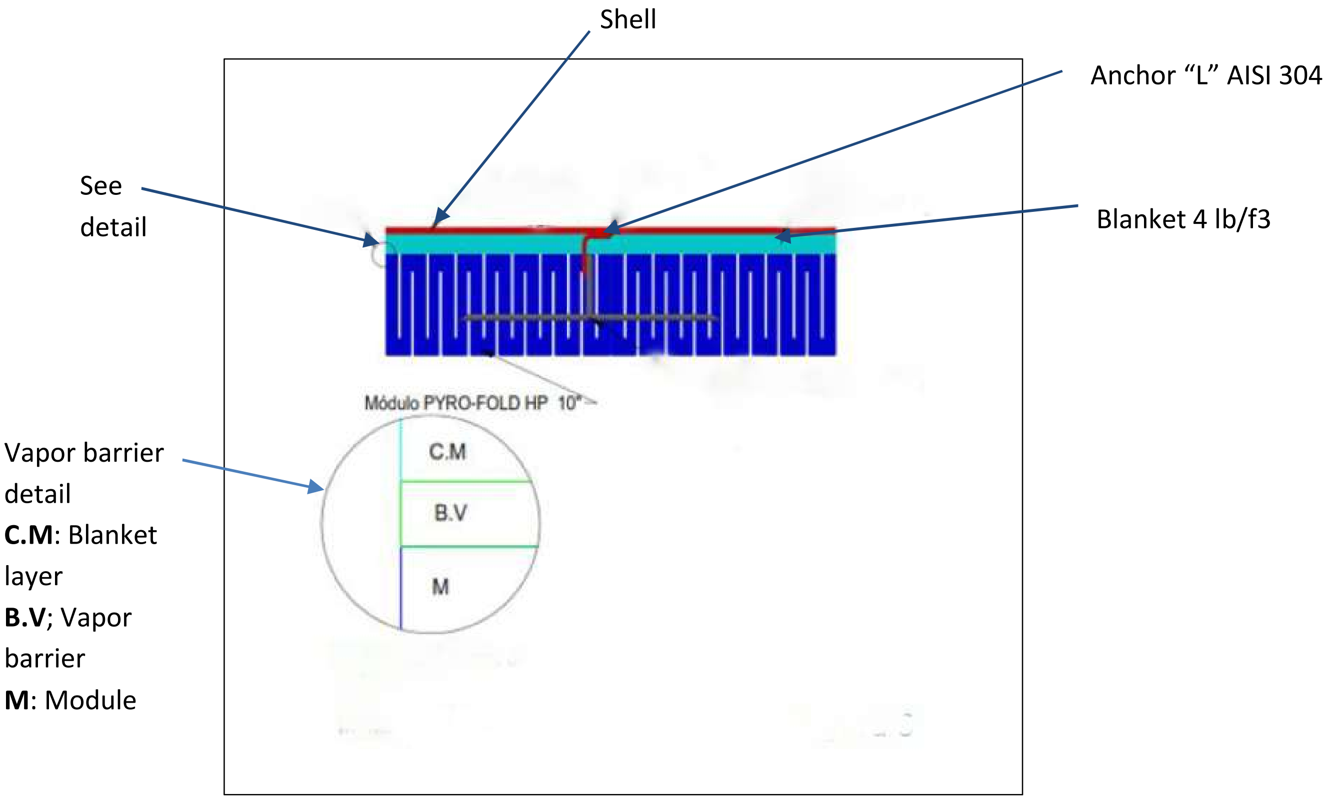
**Detail of insulation with vapor barrier over the first layer of blanket**

8.2: Example of vapor barrier in a insulation of **ceramic “modular”** (that is, with pre-fabricated ceramic fiber modules).

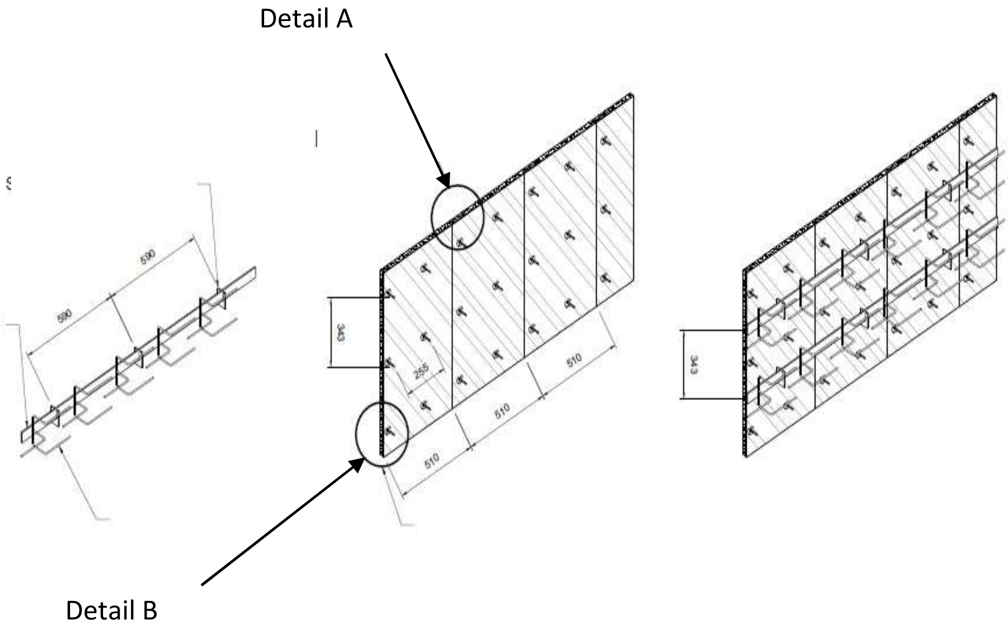
Materials:
Ceramic Fiber 8 lb/pie3 de 1 “
Fiber Modules 10 lb/pie3 de X “
Aluminum FOIL 60 microns, 95 kg
Performance foil : 6.2 m2/kg.

Vapor barrier placement: It can be placed on top of the blanket layer before installing the module (example 1). Alternatively (depending on the type of gases), it can be installed above the module (example 2).

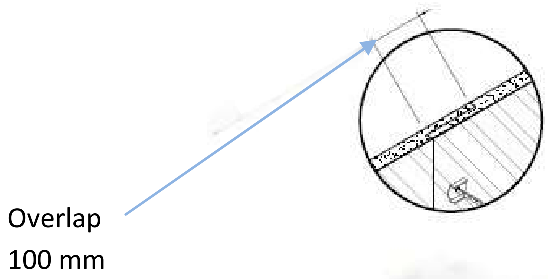
Note that the module has a combined anchoring system, while the vapor barrier has a sawtooth anchoring system. Both are made of AISI 304 stainless steel..



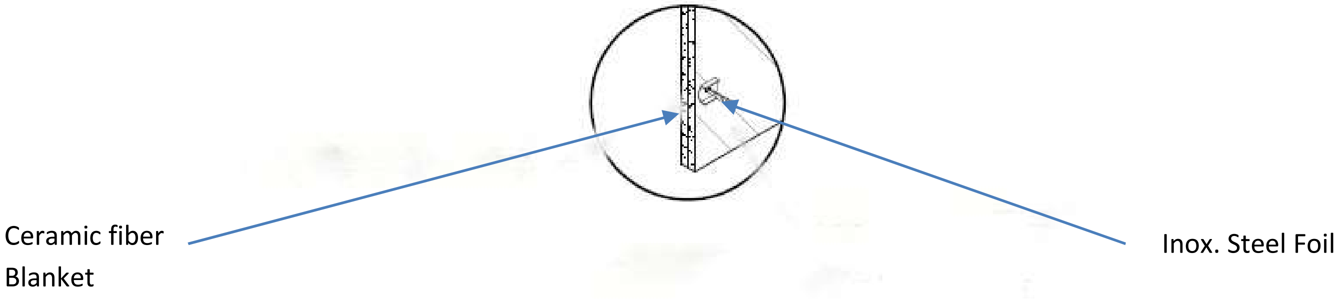
**Example 1**



**Example 2**

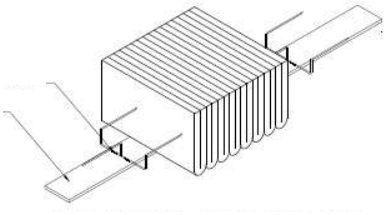


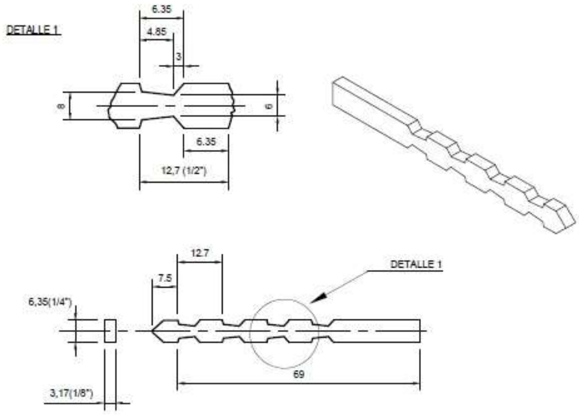
Detail A

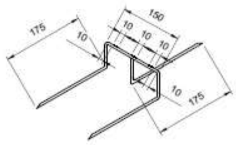


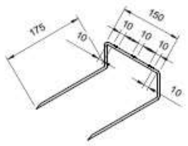
Detail B

## ANCHORING SYSTEM FOR MODULES AND VAPOR BARRIER









MATERIAL: AISI 304
SIN ESCALA

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SIN ESCALA

MATERIAL: AISI 304
SIN ESCALA

## 9. Conclusions

- **Corrosion under insulation (CUI)** is a critical risk for petrochemical furnaces due to humidity, corrosive condensates, and thermal cycling.
- **Designing vapor barriers** with appropriate materials and in thermally critical locations is essential to prevent chemical attack
- **The API standards (especially API 560 and API RP 583)** provide technical criteria for design, installation, and maintenance
- The selection of materials (stainless steel foil, metal/polymer laminates) must consider **vapor permeability, chemical compatibility, and operating temperatures**

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Note: This report is intended to illustrate all aspects and complexities of the topic covered. It should not be taken literally for final valuation decisions regarding the scope of the report. For specific calculations or decisions, we recommend consulting the relevant experts..

***All aspects concentrated in one place, our Space !!!!***

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