

CONTEC

Comissão de Normalização
Técnica

SC-09

Thermal Insulation and
Refractories

Design of Cold Insulation

Revalidation

Revalidated em 08/2018.

Design of Cold Insulation

Procedure

This Standard replaces and cancels its previous revision.

The CONTEC - Authoring Subcommittee provides guidance on the interpretation of this Standard when questions arise regarding its contents. The Department of PETROBRAS that uses this Standard is responsible for adopting and applying the sections, subsections and enumerates thereof.

Technical Requirement: A provision established as the most adequate and which shall be used strictly in accordance with this Standard. If a decision is taken not to follow the requirement ("non-conformity" to this Standard) it shall be based on well-founded economic and management reasons, and be approved and registered by the Department of PETROBRAS that uses this Standard. It is characterized by imperative nature.

Recommended Practice: A provision that may be adopted under the conditions of this Standard, but which admits (and draws attention to) the possibility of there being a more adequate alternative (not written in this Standard) to the particular application. The alternative adopted shall be approved and registered by the Department of PETROBRAS that uses this Standard. It is characterized by verbs of a non mandatory nature. It is indicated by the expression: **[Recommended Practice]**.

Copies of the registered "non-conformities" to this Standard that may contribute to the improvement thereof shall be submitted to the CONTEC - Authoring Subcommittee.

Proposed revisions to this Standard shall be submitted to the CONTEC - Authoring Subcommittee, indicating the alphanumeric identification and revision of the Standard, the section, subsection and enumerate to be revised, the proposed text, and technical/economic justification for revision. The proposals are evaluated during the work for alteration of this Standard.

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Introduction

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Foreword

This Standard is the English version (issued in 01/2013 of PETROBRAS N-894 REV. E 06/2012. In case of doubt, the Portuguese version, which is the valid document for all intents and purposes, shall be used.

1 Scope

1.1 This Standard sets out the conditions required in the design of thermal insulation of equipment and piping operating at low temperature. However, it does not apply to services with operating temperatures below -100 °C.

1.2 This Standard applies to the material selection and sizing of thickness of thermal insulation material, according to the following criteria:

- a) condensation control of moisture on the outer surface of the thermal insulation;
- b) conservation of heat energy;
- c) stabilization of industrial process phases;
- d) personnel protection or comfort.

1.3 This Standard applies to designs started from its issue date as well as to existing facilities/equipment, at the time of maintenance or repair.

1.4 This Standard contains Technical Requirements and Recommended Practices.

2 Normative References

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document applies.

PETROBRAS [N-896](#) - Installation of Cold Insulation;

PETROBRAS [N-1618](#) - Thermal Insulation Material;

ASTM [C 795](#) - Standard Specification for Thermal Insulation for Use in Contact With Austenitic Stainless Steel;

ASTM [C 534](#) - Standard Specification for Preformed Flexible Elastomeric Cellular Thermal Insulation in Sheet and Tubular Form;

ASTM [C 1728](#) - Standard Specification for Flexible Aerogel Insulation.

NOTE For documents referred in this Standard and for which only the Portuguese version is available, the PETROBRAS department that uses this Standard should be consulted for any information required for the specific application.

3 Terms and Definitions

For the purposes of this document, the following terms and definitions apply.

3.1

low temperature

operating temperature equal to or less than the average of the maximum ambient temperatures in the two hottest months of the year

3.2**thermal insulation material**

material used to reduce the heat transfer

3.3**thermal insulation**

set of materials that, when applied, reduces the heat transfer

3.4**economic thickness**

thickness obtained taking into account the costs of absorbed energy, the investment in thermal insulation and maintenance, aimed at minimizing the total cost

3.5**energy conservation**

criteria for establishing the economic thickness of insulation material(s), taking into account the costs of loss energy, the investment in thermal insulation and maintenance, aimed at minimizing the total cost

3.6**condensation control of moisture on the outer surface of the thermal insulation**

criteria for establishing the thickness of the insulation material(s) that ensures non condensation of air humidity on the surface of the thermal insulation of piping or equipment

3.7**stabilization of industrial process phases**

criteria for establishing the thickness of insulation material(s), taking into account the maximum allowable value for heat loss (heat flow), based on the needs and limitations of a particular industrial process

3.8**personnel protection or comfort**

criteria for establishing the thickness of the insulation material(s) that aims to prevent damage or personnel discomfort

4 General Conditions**4.1 Sizing Criteria**

4.1.1 The basic criteria for determining the thickness of the thermal insulation consists on the use of concepts of energy conservation and condensation control of moisture on the outer surface of the thermal insulation.

4.1.2 When there is more than one reason for sizing, the thickness shall be calculated in accordance with the corresponding criteria and the one that presents the highest value shall be used.

4.2 Materials

4.2.1 The insulation material normally used is the expanded polyurethane (pre-molded, sprayed or injected) or polyisocyanurate (pre-molded). Granular expanded perlite, elastomeric foam, cellular glass and aerogel may be used according to specific design.

4.2.2 The insulation materials used shall be in accordance with PETROBRAS [N-1618](#), including the following materials:

- a) elastomeric foam, according to ASTM [C 534](#);
- b) aerogel, according to ASTM [C 1728](#).

4.2.3 The thermal insulation shall be applied according to PETROBRAS [N-896](#). For applications not foreseen in PETROBRAS [N-896](#), a procedure of specific installation shall be presented according to the instructions of the manufacturer and assembler.

4.2.4 For the same type of material, it is recommended that the distribution of layers of rigid thermal insulation material is made in accordance with Table 1. **[Recommended Practice]**

Table 1 - Thickness Distribution of Pre-Molded Rigid Insulation Materials

Total thickness mm (in.)	Layers mm (in.)	
	1 st	2 nd
25 (1")	25 (1")	-
38 (1½")	38 (1½")	-
51 (2")	51 (2")	-
63 (2½")	38 (1½")	25 (1")
76 (3")	38 (1½")	38 (1½")
89 (3½")	51 (2")	38 (1½")
102 (4")	51 (2")	51 (2")
114 (4½")	63 (2½")	51 (2")
127 (5")	63 (2½")	63 (2½")
139 (5½")	76 (3")	63 (2½")
153 (6")	76 (3")	76 (3")
165 (6½")	89 (3½")	76 (3")
178 (7")	102 (4")	76 (3")
191 (7½")	102 (4")	89 (3½")
204 (8")	102 (4")	102 (4")

4.2.5 Expansion-contraction joints shall be provided for the rigid thermal insulation, in accordance with PETROBRAS [N-896](#).

4.2.6 For piping or equipment of 300 and 400 series stainless steel, the maximum content of chlorides and fluorides in thermal insulation shall comply with the criteria of ASTM [C 795](#), in order to minimize the possibility of stress corrosion cracking.

4.2.7 When the equipment or piping is subjected to high and low temperature conditions, it shall be used, firstly, a layer of rigid thermal insulation for high temperature, sized so that the maximum temperature of its outer surface is less than 80 °C.

NOTE 1 The sizing of the thickness of thermal insulation material for low temperature shall not consider the influence of the thermal conductivity of the rigid thermal insulation material for high temperature.

NOTE 2 If the piping or equipment is also subjected to high temperature conditions and there is a need for personal protection (hot), the maximum temperature of its outer surface, considering the last layer of thermal insulation, does not exceed 60 °C.

4.3 Equipment and Piping

4.3.1 Except as otherwise recommended by the system designer or if there is risk of freezing, it shall not be insulated:

- a) if the gain of heat is necessary in view of process requirements;
- b) piping and equipment sporadically cooled, such as:
 - relief valves and release systems;
 - vents and drains;
 - flare system;
 - drainage system;
- c) hoses.

4.3.2 The insulation of interference parts of piping, equipment, handwheels and valve stems shall comply with the provisions of PETROBRAS N-896.

4.3.3 The materials applicable for equipment and piping insulation are shown in Table 2.

NOTE A technical and economic analysis shall be performed in order to select the best material and method of application.

Table 2 - Selection of Thermal Insulation Material to be Used

Material/ method of application	Piping and accessories		Tanks			Towers (Note 4)		Exchangers and vessels (Notes 2 and 4)		Rotating equipment	Spheres
	Aerial	Buried	Roof	Wall	Bottom	Small	Medium and large	Small and medium	Large		
Injected polyurethane	X	X	X (Note 1)	X (Note 1)		X	X	X	X	X	X (Note 1)
Sprayed polyurethane (Note 5)			X	X			X		X		X
Pre-molded polyurethane	X	X	X	X	X (Note 3)	X	X	X	X	X	X
Pre-molded polyisocyanurate	X	X	X	X	X (Note 3)	X	X	X	X	X	X
Granular expanded perlite				X		X	X	X	X		
Cellular glass	X	X	X	X	X	X	X	X	X	X	X
Elastomeric foam	X	X	X	X		X	X	X	X	X	X
Aerogel	X	X	X	X		X	X	X	X	X	X

NOTE 1 It is allowed the injection of polyurethane on the roof and wall of tanks and spheres, since it is applied with removable forms to enable the execution of a steam barrier.

NOTE 2 For Cold Box, only granular expanded perlite shall be used.

NOTE 3 Admitted only to support blocks of the bottom tank annular plate.

NOTE 4 For purposes of definition of large, medium and small equipment, Table 3 shall be considered.

NOTE 5 The design and performance guarantee are the responsibility of the applicator, which shall inform the design values (thickness, type and physical properties) that are checked in the acceptance of the application procedure, according to PETROBRAS N-896.

Table 3 - Classification of Equipment Size

Equipment/size	Small	Medium	Large
Exchangers	$\leq 2 \text{ m}^3$	From 2 m^3 to 20 m^3	$> 20 \text{ m}^3$
Vessels	$\leq 2 \text{ m}^3$	From 2 m^3 to 20 m^3	$> 20 \text{ m}^3$
Towers	$\leq 5 \text{ m}^3$	From 5 m^3 to 40 m^3	$> 40 \text{ m}^3$

5 Specific Conditions

5.1 Energy Conservation

5.1.1 To determine the economic thickness, a specific study that considers the updated costs of energy and the installation of thermal insulation shall be made.

5.1.1.1 The calculation route presented in Annex A can be used to determine the insulation thickness. **[Recommended Practice]**

5.1.1.2 Annex G can be used as an indicator of economic thickness, only in the quick sizing of lines or small equipment insulated with polyurethane/polyisocyanate and in accordance with the conditions specified on it. **[Recommended Practice]**

NOTE It is the responsibility of the designer to check if the energy cost calculations presented in this Standard apply to his specific case or if there are other costs to consider, such as loss of production or loss of separation efficiency.

5.2 Condensation Control of Moisture on the Outer Surface of the Thermal Insulation

5.2.1 The thermal insulation shall assure, on the outer surface, a temperature above the dew point obtained from Table F.1 in Annex F.

5.2.2 To determine the thickness of moisture control, it is recommended to use the calculation route from Annex B. **[Recommended Practice]**

5.3 Personnel Protection or Comfort

5.3.1 The thermal insulation shall assure, on the outer surface, a temperature above 0°C .

5.3.2 The thermal insulation shall be done on equipment and piping in which the outer surfaces are located at a height less than 2 m of any floor or at a lateral distance of less than 1 m of stairs or platforms for personnel transit.

5.3.3 If the thermal insulation is not allowed due to operational problems, metallic protection (screens) and even appropriate signs, limiting people's access to non insulated outer surface, shall be provided.

5.3.4 To determine the thickness for personnel protection, a specific study to consider the local environmental conditions shall be made.

5.3.5 The calculation route presented in Annex B can be used to determine the insulation thickness.
[Recommended Practice]

5.4 Stabilization of Industrial Process Phases

To determine the thickness for stabilization of industrial process phases, it is recommended the use of the calculation route in Annex C. **[Recommended Practice]**

Annex A - Energy Conservation - Calculation Route

A.1 Introduction

A.1.1 The calculation of thermal insulation thickness based on the concept of energy conservation aims, complying with the constraints of safety and process, to promote an economic benefit by reducing the heat absorbed through the walls of a piping or equipment. Because it is a calculation that involves material costs, maintenance and energy, the concept of "more economic solution" may vary over time.

A.1.2 The additional cost in material and the reduction of thermal energy cost, resulting from the increase of thickness of the thermal insulation, shall be analyzed. Therefore, it is necessary to calculate the heat absorbed for each new thickness analyzed, which requires an iterative calculation. The guide shown herein is only one way to determine the thickness. The nomenclature of the variables used is included in Table E.1 in Annex E.

A.2 Determination of the Heat Flux

A.2.1 Define a thickness configuration for the start of the analysis, for example, the value immediately above to the value obtained from another calculation criteria.

A.2.2 Estimate a value for the temperature of the outer surface of the thermal insulation, for example, the same value obtained from another calculation criteria.

A.2.3 Calculate the heat transfer coefficients appropriate to the problem, according to Annex D.

A.2.4 With the average temperature $(T_e + T_0)/2$, calculate the material thermal conductivity.

A.2.5 Calculate the new temperature of the outer surface using the equation balance of D.2.1.1 in Annex D or the equation of D.2.2 in Annex D with:

$$q = (h_c + h_r) \cdot (T_a - T_e)$$

NOTE 1 For flat surfaces, it can be expressed as:

$$T_e = \frac{(h_c + h_r) T_a + \frac{k}{L} T_0}{h_c + h_r + \frac{k}{L}}$$

NOTE 2 For cylindrical surfaces:

$$T_e = \frac{(h_c + h_r) T_a + \frac{k}{r_e \ln \left(\frac{r_e}{r_0} \right)} T_0}{h_c + h_r + \frac{k}{r_e \ln \left(\frac{r_e}{r_0} \right)}}$$