Technical Guide

FOAMULAR® Extruded Polystyrene Insulation

For Cold Storage Applications

FOAMULAR extruded polystyrene insulation is suitable for virtually all cold storage insulating needs, including floors, walls and roofs. FOAMULAR insulation is adaptable to all types of wall construction including tilt-up, precast concrete, prefabricated metal-faced panels and concrete masonry unit construction. It is suitable for use in conjunction with single-ply roofing membranes, modified bitumen and built-up roofing membranes over virtually any type of roof deck, including steel or concrete. Durable FOAMULAR insulation also performs well under cold storage concrete floor slabs.

Superior Performance, Compressive Strength and Applications

FOAMULAR extruded polystyrene insulation is a closed-cell insulation made using Owens Corning's exclusive HYDROVAC® manufacturing process. FOAMULAR insulation's resistance to water absorption and water vapor transmission allows it to maintain low thermal conductivity in the presence of the severe water vapor characteristics of cold storage applications. FOAMULAR extruded polystyrene insulation is manufactured to comply with ASTM C 578. See FOAMULAR Insulation Physical Properties chart below.

Owens Corning offers a variety of FOAMULAR products for use in cold storage applications depending on the specific needs of the design and engineering process.

FOAMULAR 150, 250 and LT30 insulations with minimum compressive strengths of 15, 25 and 30 psi are suitable for use in insulating cold storage facility floors with modest loading requirements. FOAMULAR LT40, 400 and 600 insulations with minimum compressive strengths of 40 and 60 psi are capable of accommodating the more normal floor loads of cold storage facilities.

THERMAPINK® extruded polystyrene insulation, with long-term, reliable R-value, high moisture resistance and good dimensional stability, is the preferred roof insulation for cold storage applications. A sampling of in-service cold storage roofs by Owens Corning, in conjunction with the Army Corps of Engineers/Cold Regions Research and Engineering Laboratory, demonstrated that extruded polystyrene resists moisture build-up better than other types of insulation commonly used. The R-value of the building envelope is critical to the efficient operation of low-temperature buildings. THERMAPINK insulation provides reliable R-value for the building envelope with closed-cell moisture resistance. In the design of cold storage roofs, it is critical to assess thermal and moisture performance, and specify materials that are able to perform in high vapor drive applications. High quality vapor-retarding layers may be required in the roofing assembly to limit the amount of moisture migrating to dew point temperatures in the roofing assembly. Often, the insulation needs to resist vapor intrusion from outside.

In ballasted roofing systems, THERMAPINK insulation can be 10" thick when installed directly over steel roof decks without a gypsum board thermal barrier. Wet pipe sprinkler protection may be required in some locations, and by some insurance carriers. Contact your Owens Corning representative for more information including a copy of the U.S. Army Corps of Engineers report cited above.

FOAMULAR Insulation Physical Properties*

Property	ASTM Method†	Product/ASTM C 578 Type					
		FOAMULAR-150	FOAMULAR-250/THERMAPINK 25	FOAMULAR LT30	FOAMULAR-LT40	FOAMULAR-400	FOAMULAR 600
		Type X	Type IV	Type IV	Type IV	Type VI	Type VII
Thermal conductivity – "k" (BTU x in/°F x ft^2 x h)*							
@ 75°F mean temperature	C 518	0.20	0.20	0.20	0.20	0.20	0.20
@ 40°F mean temperature		0.18	0.18	0.18	0.18	0.18	0.18
Thermal resistance "R-value" per inch, min (°F x ft2 x h/BTU)*							
@ 75°F mean temperature	C 518	5.0	5.0	5.0	5.0	5.0	5.0
@ 40°F mean temperature		5.4	5.4	5.4	5.4	5.4	5.4
Compressive strength minimum (specification) value (lb/in^2)‡	D 1621	15.0	25.0	30.0	40.0	40.0	60.0
Flexural strength (lb/in^2 min)*,§	C 203	60	75	100	100	115	140
Water absorption, max (% by volume)*	C 272	0.10	0.10	0.10	0.05	0.05	0.05
Water vapor permeance, max (perm)*,◊	E 96	1.1	1.1	1.1	1.1	1.1	1.1
Water affinity*	–	hydrophobic					
Water capillarity*	–	none					
Dimensional stability, max (% linear change)*,#	D 2126	2.0	2.0	2.0	2.0	2.0	2.0
Linear coefficient of thermal expansion, max (in/in/°F)*	–	2.7 x 10^{-5}	2.7 x 10^{-5}	2.7 x 10^{-6}	2.7 x 10^{-5}	2.7 x 10^{-5}	2.7 x 10^{-5}
Flame spread*,**,††	E 84	5	5	5	5	5	5
Smoke developed*,**,††,‡‡	E 84	45-175	45-175	45-175	45-175	45-175	45-175
Oxygen index, min*,**	D 2863	24	24	24	24	24	24

* Properties shown are representative values for 1" thick material based upon most recent product quality audit data. † Modified as required to meet ASTM C 578. ‡ Value at yield or 10%, whichever occurs first. § Value at yield or 5%, whichever occurs first. ◊ Actual water vapor permeance for 1" thick material, value decreases as thickness increases. # Value ranges from 0.0 to value shown.
** These laboratory tests are not intended to describe the hazard presented by this material under actual fire conditions. †† Data from Underwriters Laboratories, Inc. Classified. See Classification Certificate U-197. ‡‡ ASTM E 84 is thickness-dependent, therefore a range of values is given.

Excellent Resistance to Freeze/Thaw Cycling

FOAMULAR extruded polystyrene insulation has been tested for its ability to retain critical structural properties in a severe freeze/thaw environment. It has been demonstrated that FOAMULAR insulation retains its load carrying ability (minimum compressive resistance) after 1,000 freeze/thaw cycles. (See Table 1.)

Recommended FOAMULAR Insulation Thicknesses for Cold Storage Applications

The selection of insulation thickness is based upon variable design factors, such as:

- Cold storage inside temperature
- Outside maximum temperature
- Cooling equipment capacity, which is based on:
  - Mechanical efficiency
  - Design heat flow rate
  - Commodity being cold-stored
  - Air infiltration rates

Determining Thickness

Thickness of insulation, which determines heat flow rate, can be determined using the FOAMULAR Insulation Thickness graph to the right and the temperatures found in the Summer Design Temperatures for Selected U.S. Cities chart below.

Summer Design Temperatures for Selected U.S. Cities

City	Median of Maximum Annual Temperature (°F)
Atlanta	96
Boston	96
Charlotte	98
Chicago	96
Cleveland	95
Houston	99
Los Angeles	98
Memphis	98
Miami	93
Minneapolis	97
New York	95
Omaha	100
Phoenix	113
Portland	98
St. Louis	99

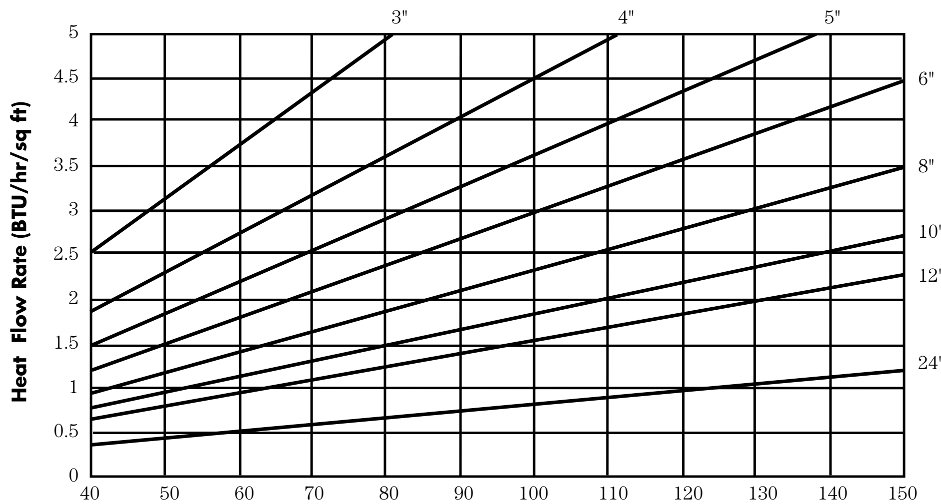
Note: Design temperatures taken from the 1989 ASHRAE

Table 1

Retention of Compressive Strengths (PSI)	FOAMULAR 250	FOAMULAR 400
Minimum specifications	25.0	40.0
Initial Actual	32.2	52.0
After 1,000 freeze/thaw cycles*	29.6	52.0

* ASTM C 666 Procedure A: Freeze/thaw cycles alternated with the test specimen totally submerged in water and exposed to freezing temperatures.

FOAMULAR Insulation Thickness Graph



Temperature Differential (ºF)
(Difference in maximum outside temperature versus inside operating temperature)

1) Heat Flow Rate (HFR) = "C" x temperature differential. 2) HFR impacts necessary refrigeration equipment size, efficiency and energy usage, (i.e., cost). Lower HFR is better but must balance against cost of insulation and total construction cost. 3) "C" is for insulation only. 4) Final estimates of HFR must be based on "U" of total construction assembly. 5) FOAMULAR R = 5.4/in @ 40ºF mean.

	3"	4"	5"	6"	8"	10"	12"	24"
R	16.2	21.6	27.0	32.4	43.2	54.0	64.8	129.6
C	.062	.046	.037	.031	.023	.019	.015	.008

To determine thickness:

1. Determine the appropriate temperature differential by subtracting the inside operating temperature from the maximum outside temperature. (See the Summer Design Temperatures for Selected U.S. Cities chart.) The project designer must specify inside operating temperatures.
2. The designer must specify the optimum heat flow rate for the project – often in the range of 2 to 4 BTU/hr/sq ft.
3. Locate the point on the FOAMULAR Insulation Thickness graph where the HFR and the temperature differential lines intersect and compare to the diagonal lines. These indicate the thickness of FOAMULAR extruded polystyrene insulation required to provide the specific HFR at the given temperature differential.

Example:

A cold storage facility in Cleveland, OH, intends to operate with an inside temperature of 20°F and with a design heat flow rate of 2.0 BTU/hr/sq ft.

- 95°F - 20°F = 75°F (temperature differential)
- From the graph, FOAMULAR insulation thickness of 7.0" is needed.

Heat Flow Rate (HFR) has been detemined using the following formula:

HFR = C x Temperature Differential

- C = reciprocal of total R for a given thickness of FOAMULAR insulation.
- Temperature Differential = outside maximum temp. – inside operating temp.
- HFR is in BTU/hr/sq ft.
- The R-value for FOAMULAR insulation at 40°F mean temp., 5.4/inch, was used.

Design of Concrete Slabs on Grade Supported by FOAMULAR Insulation

Insulated concrete slabs are common in cold storage facilities. These slabs and the layers below must be capable of supporting the live and dead loads imposed by vehicles, stationary and/or moving equipment, loaded storage racks and pedestrian traffic. FOAMULAR extruded polystyrene insulation provides support beneath insulated concrete floor slabs. The slab and supporting layers must be designed with consideration given to the rigidity of each layer. Proper design avoids excessive deflection which can result in cracking. *Note: It is recommended that final concrete slab design be specified by a professional architect or engineer.*

Allowable Stress on FOAMULAR Insulation Layers

A concrete slab must be capable of distributing loads over an area of sufficient size so that pressure on underlying layers do not exceed allowable limits. When FOAMULAR extruded polystyrene insulation is used below the slab, allowable stress limits are defined based upon a percentage of FOAMULAR insulation's minimum compressive strength as shown in Table 2.

Determining Stress

Use the following charts and formulas to determine the stress present on the concrete slab and insulation layers. To determine the stress that FOAMULAR insulation will experience, you will need to know the deflection of the concrete slab (see Concrete Slab Design Formulas) as well as the foundation modulus.

Foundation modulus is a measure of how much a substrate deflects under a given load, expressed as inches deflection per inch of thickness or "pci." The foundation modulus for various thicknesses of FOAMULAR insulation can be found in Table 3.

Analysis of Unreinforced Concrete Slab and FOAMULAR Insulation Foundation Interaction under a Static Point Load

The following design examples illustrate the interrelated performance of the floor slab and its underlying insulation layers. They show that changes in one component must be examined for their impact on other components. These examples also show that the tensile strength of concrete slab is more often a limiting factor than is the compressive strength of the insulation. The explanations to the right refer to information in Table 4 on page 4.

Table 2
FOAMULAR Insulation Recommended Stress Limits (psi)

Recommended	FOAMULAR 250	LT30	LT40	FOAMULAR 400	FOAMULAR 600
Minimum compressive strength	25.0	30.0	40.0	40.0	60.0
Live Load (<.20 of minimum)	5.0	6.0	8.0	8.0	12.0
Dead Load (<.33 of minimum)	8.3	10.0	13.3	13.3	20.0

Table 3
FOAMULAR Insulation Foundation Modulus "K" (psi)

	Thickness					
Insulation	1"	1.5"	2"	2.5"	3"	4"
250	750	710	675	595	565	510
LT30	NA	850	700	NA	NA	515
LT40	NA	NA	850	640	580	550
400	1100	1000	900	780	680	650
600	1520	1400	1275	1150	1040	790

Notes: For multiple layer insulation systems, assuming layers are identical, the foundation modulus for the system (KT) equals the foundation modulus for one (1) of the layers (K1) divided by the total number of layers (L). KT=K1/L. For insulation systems which utilize a variety of thicknesses, the system foundation modulus (KT) is determined by adding the reciprocal of the foundation modulus for the individual layers (1/K1). The total is the reciprocal value for the foundation modulus of the entire insulation system.

Concrete Slab Design Formulas

- **Stress Under Point Load in Field of Slab**

$$f_b = 0.316 \frac{P}{h^2} \left[\log h^3 - 4 \log \left(\sqrt{1.6a^2 + h^2} - 0.675h\right) - \log k + 6.48\right]$$

- **Deflection**

$$D = \frac{P}{8\sqrt{K \dfrac{Eh^3}{12(1-\mu^2)}}}$$

Nomenclature

- a Radius of load contact area (in)
- D Deflection (in)
- E Modulus of Elasticity, concrete (psi) $E \approx 57{,}000 \sqrt{Fc}$
- fb Tensile stress, bottom of slab (psi)
- Fc Concrete compressive strength min (psi)
- ft Tensile stress, top of slab (psi)
- Ft Concrete tensile strength, allowed (psi) $Ft \approx 4.6 \sqrt{Fc}$
- h Slab thickness (in)
- K Insulation foundation modulus (pci)
- L Radius of relative stiffness (in) $L = \sqrt[4]{\dfrac{Eh^3}{12(1-\mu^2)k}}$
- P Load (lb)
- μ Poisson's Ratio, .20 for concrete

Estimating Stress in FOAMULAR Insulation Layer

The stress that FOAMULAR insulation will experience under a concrete slab can be estimated by multiplying the insulation's foundation modulus (K) by the deflection of the concrete slab (D).

F (Stress)= K x D

Deflection of the concrete slab can be determined by using the Concrete Slab Design Formulas to the left.

Discussion of Design Examples

Example 1 – The conditions listed result in a stress of 3.42 psi on the insulation layer. The stress is acceptable when related to the live or dead load recommendations for the chosen insulation. The actual stress in the concrete slab is also below that which is allowed.

Example 2 – Changing the insulation layer from Example 1 results in reduced stress on the insulation layer. However, the increased insulation layers are prone to more deflection and are less capable of supporting the load. Therefore, deflection in the concrete slab increases, which results in a concrete stress that is too high.

Example 3 – Increasing the thickness of the concrete slab in Example 2 reduces the concrete stress under the point load to an acceptable level. Other variable changes that reduce concrete slab tensile stress to acceptable levels include reducing load, increasing area of load contact, using a stronger concrete, adding steel reinforcements or increasing the insulation foundation modulus.

Example 4 – Changing to an insulation with a substantially greater foundation modulus and compressive strength results in a reduction in concrete tensile stress. Note that the foundation modulus in the example increased by 75% over that used in Example 2 to cause only a 7% reduction in concrete slab tensile stress. Variation of insulation foundation modulus within a small range has little impact on the final concrete slab design.

Example 5 – Excessive stress levels in the concrete slab can also be corrected by increasing the area of load contact. Note the decrease in concrete slab tensile stress from Example 2, which results from distributing the load over a larger area.

Example 6 – All of the previous examples focus on reducing the tensile stress in the concrete slab to an acceptable level. This example shows the effect of increasing the load to a level which places maximum allowable compressive strength on the insulation. Note the excessive tensile stress which results on the concrete slab.

Table 4

Variable Input	Design Examples 1	2	3	4	5	6
Point load (lb)	7200	7200	7200	7200	7200	24600
Radius of Contact area (in)	5	5	5	5	5.75	5
Concrete Properties						
Compressive Strength (min psi)	4000	4000	4000	4000	4000	4000
Tensile stress, allowable (psi)	291	291	291	291	291	291
Modulus of elasticity (psi)	3.6×10^6	3.6×10^6	3.6×10^6	3.6×10^6	3.6×10^6	3.6×10^6
Slab thickness (in)	5	5	5.5	5	5	5
Insulation Properties						
"K" (pci)	565	282	282	520	282	282
Number of layers	1	2	2	2	2	2
Thickness per layer (in)	3	3	3	3	3	3
FOAMULAR-product	250	250	250	600	250	250
Calculations						
Concrete slab deflection	.0061	.0086	.0074	.0063	.0086	.0293
Concrete tensile stress, actual (psi)	286	313	269	289	289	1071
Insulation compressive stress, actual (psi)	3.42	2.42	2.09	3.28	2.42	8.26

Steel reinforced concrete slabs will distribute imposed loads differently than unreinforced slabs; therefore, the calculation techniques used to estimate stresses are different than shown in this section.

However, the concept of balancing stress levels between concrete and the insulation is the same.

Many types of concrete slab exist for different purposes, and design techniques for each vary greatly. This section discusses one aspect, the FOAMULAR insulation layers and their effects on slab thickness in the design of a simple, type "a", plain concrete slab. It is not the intent of this section to provide comprehensive design guidance. Rather it is to demonstrate the importance of the relationship between a concrete slab and its supporting underlayers, and to identify FOAMULAR insulation's physical properties – which will be important to the slab designer – regardless of the type of slab involved. In all cases, Owens Corning recommends that final concrete slab design be specified by a professional architect or engineer. The professional architect or engineer will assess the need for steel reinforcement due to structural shrinkage or temperature requirements, the need for expansion or contraction joints, and other important concerns relating to slab durability.

The examples in this section relate to interior slab loadings only, which are loadings placed on the surface of the slab in a position removed from free slab edges. Edge loading design becomes more complicated because it requires consideration of bending stresses in the top of the slab as well as the effects of slab edge curling. The interaction between the slab and the insulation below is similar regardless of load location, although rarely does interior loading govern design.

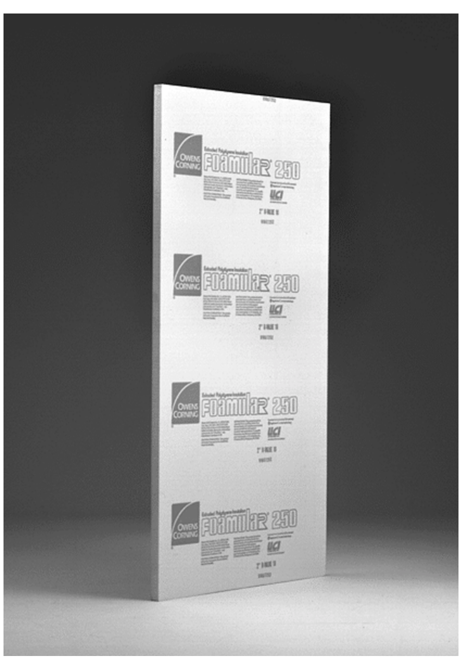
Cold Storage Design Notes

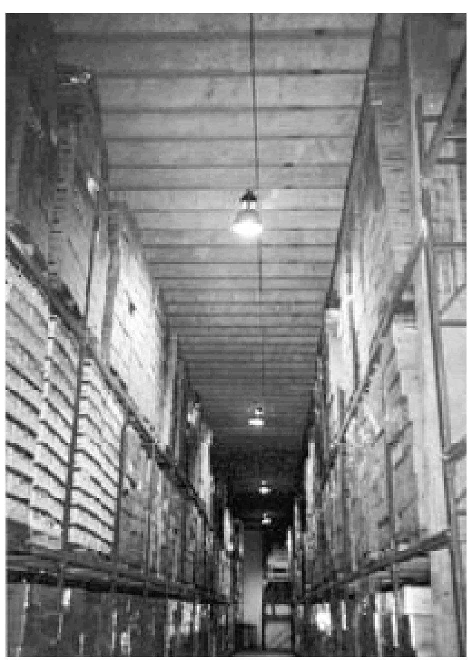
- Cold storage facility temperatures should be lowered gradually to the operating temperature range to minimize the possibility of damage to the structure. Doors should remain partially open during temperature reduction to relieve internal pressure. Complete any necessary joint caulking after temperature reduction to allow for surface contraction.
- Cold storage facilities designed to operate below freezing should have an installed heat source below the facility floor to protect from frost heave. Heating capacity must be designed based on the heat flow rate of the floor slab assembly, the operating temperature inside the facility and the efficiency of the heating source.
- Cold storage building envelope assemblies should be evaluated for effectiveness and location of vapor retarders to avoid condensation and subsequent deterioration of insulation performance.
- Install multiple layers of FOAMULAR insulation with joints staggered and edges tightly butted.
- Select primers, sealers, caulking and adhesives with care. Coal tar pitch sealants should not be used with FOAMULAR insulation.
- Avoid penetrating the FOAMULAR insulation envelope around the facility with steel beams, large pipes, or conduits. Where penetration is necessary, insulate the intruding object as fully as possible to avoid creating excessive thermal shorts through the FOAMULAR insulation envelope.
- FOAMULAR extruded polystyrene insulation is suitable for cold storage building roofs but should be covered with roof membrane and/or ballast on the same day of installation. This will prevent potential damage from heat build-up by excessive exposure to direct sunlight.
- Combustible. FOAMULAR extruded polystyrene will ignite if exposed to a fire of sufficient heat and intensity. Although it does contain a flame retardant additive to inhibit ignition from small fire sources, this product should be installed only with a fire barrier such as 1/2" thick gypsum board, masonry or concrete coverings of 1" minimum thickness or equivalent. Cold storage facilities may be subject to special allowances which permit the use of metal facings as fire barriers. Consult your local building code authority or property insurer for specific information.
- FOAMULAR insulation should be covered to prevent discoloration caused by excessive exposure to direct sunlight.
- FOAMULAR insulation is not recommended for use where sustained temperatures exceed 165°F. Do not use in contact with chimneys, heater vents, steam pipes or surfaces with temperatures over 150°F.

More Information

For more information on FOAMULAR, please contact your Owens Corning representative to request the following publications:

THERMAPINK Product Data Sheet	5-FO-23546
DURAPINK® Product Data Sheet	15-FO-23550
DURAPINK PLUS Product Data Sheet	5-FO-23551





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Disclaimer of Liability

This FOAMULAR insulation technical guide is not intended to be a cold storage design manual. The examples discussed herein focus on a limited number of design considerations regarding insulation. Total construction and system detailing of a building requires the attention of a professional architect or engineer to ensure that all building components are functionally compatible and appropriate for the given application. We shall not be liable for incidental and consequential damages, directly or indirectly sustained, not for any loss caused by the application of these goods not in accordance with current printed instructions or for other than intended use. Our liability is expressly limited to replacement of defective goods. Any claim shall be deemed waived unless made in writing to us within thirty (30) days from date it was or reasonably should have been discovered.