DETERMINING INSULATION THICKNESS

by Roger Morrison, PE, RRC
NCFI Polyurethanes
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Four Methods to Determine Insulation Thickness

1. Economic Thickness
2. Building Code Requirements
3. Avoiding Condensation
4. Minimum Practical Thickness

The best method of determining insulation thickness is to determine the thickness by all four methods and apply the greatest thickness.

R-value Basics

Component		R-Value
	Exterior Air Film	0.17
	Exterior Sheathing	0.64
	Spray Polyurethane Foam	13.6
	Air Space	1.45
	Sheetrock	0.32
	Interior Air Film	0.68
	Total	16.86

Total R-value is equal to the sum of the R-values of the individual building assembly components.

1. Economic Thickness

It doesn't pay to keep adding insulation thickness because the cost of the insulation will be more than the energy saved. This is an example of the Law of Diminishing Returns.

Law of Diminishing Returns: The incremental return on an investment decreases with added investment.

The first half-inch of SPF gives you the most bang for your buck.
At some point, it doesn't pay to add more insulation.

Insulation Efficiency Based on ½-inch Plywood = 0 %

Inches of SPF	R-Value	Efficiency
0	0.64	0.0%
0.5	3.99	84.0%
1	7.34	91.3%
1.5	10.69	94.0%
2	14.04	95.4%
2.5	17.39	96.3%
3	20.74	96.9%
3.5	24.09	97.3%
4	27.44	97.7%
4.5	30.79	97.9%
5	34.14	98.1%
5.5	37.49	98.3%
6	40.84	98.4%

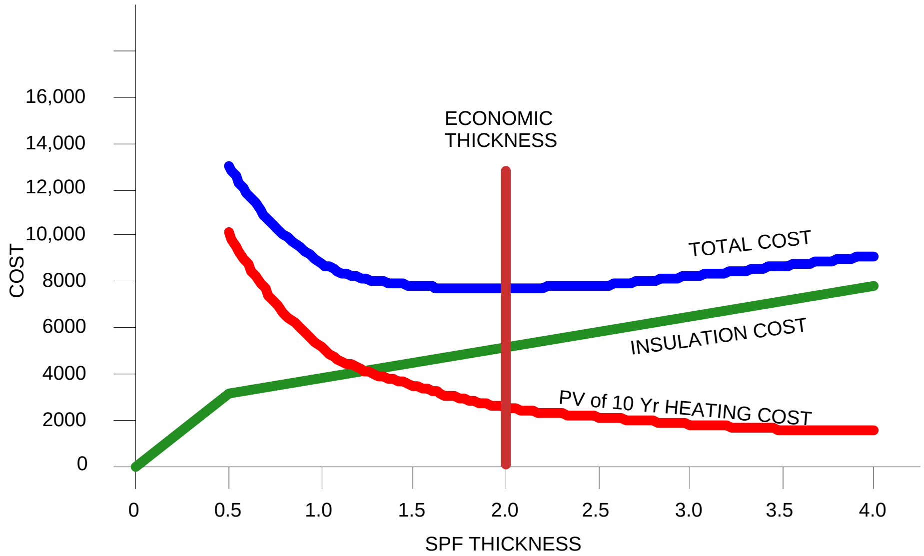
Economic Thickness determines what SPF thickness costs the least for the customer by comparing future energy dollars to current insulation dollars. This involves complex financial calculations.

Example Calculation

Project:	Fire suppression water storage tank
Location:	Fargo, ND (cold climate)
Size:	20 ft high by 20 ft diameter
Temperature:	Maintain water at 45^{o}F or higher
Cost of Capital:	3 % per year
Fuel Inflation:	10 % per year
Heating:	Steam heat from #2 fuel oil @ $2 per gallon

Annual Cost to Heat Tank:	$15,800 per year
Present Value of 10 years:	$210,000
Cost of Insulation:	First 1/2-inch + coating= $3,060; $700 per add'l half-inch

Economic thickness is the SPF thickness that minimizes the customer's total cost. In the case of this example, 2 inches of SPF offers minimizes the customer's cost.



Economic Thickness Summary

- Method is highly mathematical (spreadsheet application)
- Based on many assumptions about the future
- Provide the best economical choice for the customer
- Best used with simple structures such as tanks, roofs, freezers and coolers.

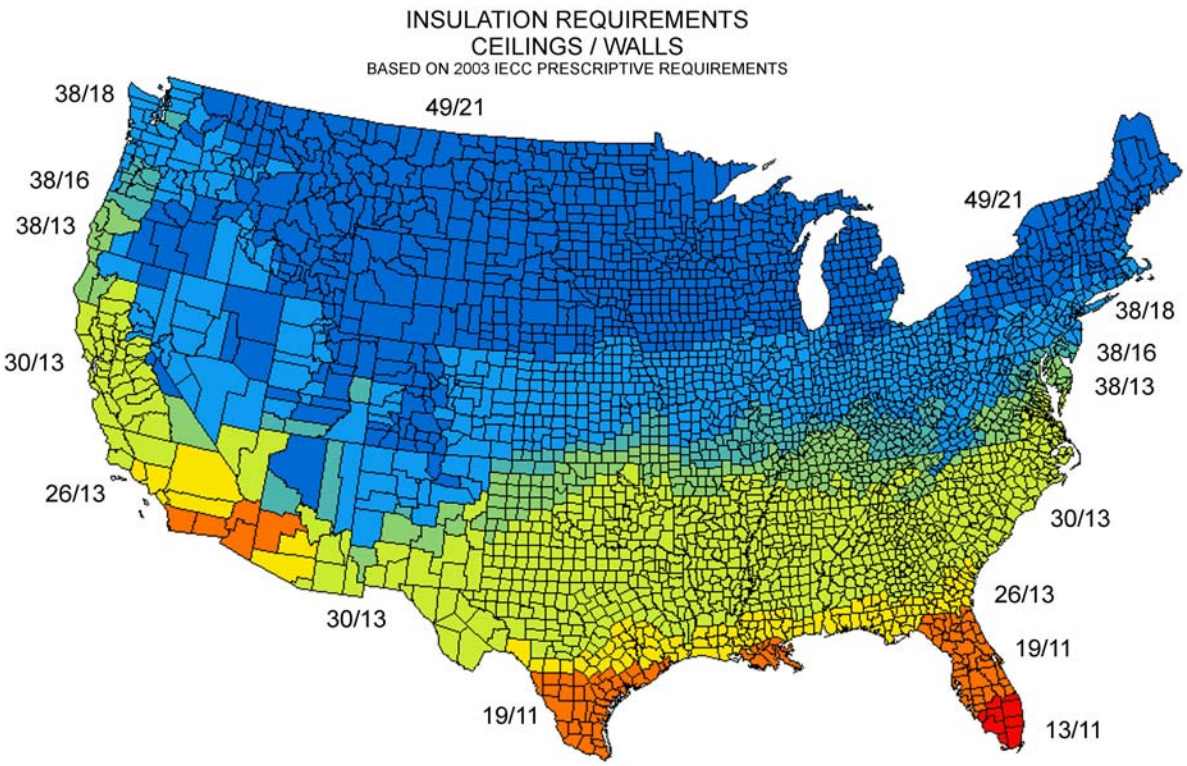
2. Building & Energy Code Requirements

Building and energy codes require that buildings meet certain minimal energy consumption standards.

Generally, codes provide two methods to meet their standards:

- **Prescriptive Requirements**
- **Performance Requirements**

Prescriptive Requirements: See map below for typical requirements.



Performance Requirements: Also called "Trade-Off Approach." Designers can vary the R-value of the insulation provided the overall energy usage of the building meets code requirements.

For example, a designer can install more/larger windows by compensating with greater insulation thickness.

- Involves HVAC sizing and efficiency
- Requires a design professional
- Computer programs, such as REScheck are usually used to compare alternatives

Energy Star / Green Building Rating

Buildings may be certified as Energy Star or Green Building Rated. The energy efficiency of these certified buildings must be greater than code requirements. These buildings typically use more insulation.

Building and Energy Code Summary

- Appropriate for most building structures
- Good for complex structures
- Code generally require more insulation than is economically desirable
- Prescriptive approach is easy
- Performance approach is complicated

3. Condensation Control

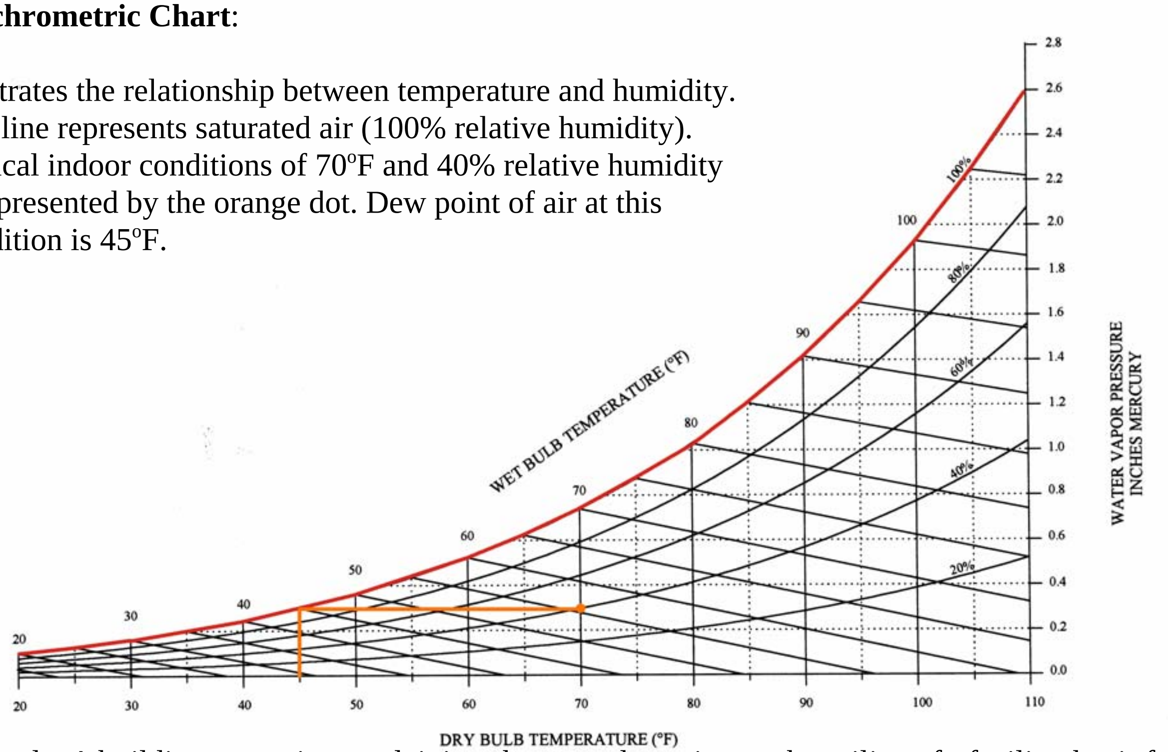
When the temperature of humid air drops below its dew point, condensation occurs. Design the building assembly to prevent condensation.

Methods of calculating the potential for condensation:

- Dew Point Analysis
    - AY 118 Moisture Vapor Transmission
    - ASHRAE
- WUFI computer simulation program
- Requires a design professional

Psychrometric Chart:

Illustrates the relationship between temperature and humidity. Red line represents saturated air (100% relative humidity). Typical indoor conditions of 70°F and 40% relative humidity is represented by the orange dot. Dew point of air at this condition is 45°F.



Example: A building owner is complaining about condensation on the ceiling of a facility that is full of tropical fish aquariums. The air in the facility is at 75°F and 85% relative humidity. The facility is located in Denver, CO. The roof/ceiling assembly consists of a modified bitumen membrane, one-inch plywood deck and 1.5 inches of cellulose insulation. The outside design air temperature for Denver is 15°F.

As a spray foam contractor, how much spray foam do you need to apply to the roof surface to stop the condensation?

From the Psychrometric Chart, the dew point of the air (75°F and 85% RH) is 68.5°F. Therefore, to prevent condensation, the underside of the deck must be kept above 68.5°.

$$T_x = T_i - \left(\frac{\Sigma R_x}{\Sigma R_{total}} \right) \left(T_i - T_e \right)$$

Using the equations from AY 118 Moisture Vapor Transmission, the underside deck temperature at the design conditions is 30°F. No wonder there’s condensation!

Further calculations indicate that by spraying 7 inches of SPF to the roof surface would be necessary in order to bring the underside deck temperature to 69°F.

However, by exploring alternatives, it can be calculated that only one inch of SPF on the roof will bring the underside deck temperature up to 70°F provided the 1.5 inches of cellulose insulation are removed. (The cellulose is acting to keep the underside deck temperature cooler and, in this case, acts to increase condensation potential.)

Therefore, as a spray foam contractor you can offer two solutions to this problem: 7 inches of SPF on the roof and keep the cellulose or 1 inch of SPF on the roof and remove the cellulose. Either solution will stop the condensation.

Condensation Control Summary

- Useful in ALL climatic zones
- Necessary for unusual conditions such as freezers, coolers, and high humidity environments
- Calculations are complicated
- Results are relative to other building assembly components (such as vapor retarders and other insulations)

4. Minimum Practical Thickness (catchall category)

Physical or other determinants sometimes limit the minimum thickness that SPF can be applied.

Examples of minimum thickness include that:

- Required to get a smooth texture or surface profile
- Recommended or permitted by the manufacturer
- Needed for sloping roof surfaces to drainage points
- Needed for air barrier application
- Required to achieve physical properties (such as 1/2-inch minimum pass thickness)

Minimum Practical Thickness Summary

- Easily determined
- No complicated calculations required
- Varies from project to project
- Varies with SPF system / type

Summary

The table below summarizes the four methods and where and when each might be applicable.
If in doubt, determine the insulation thickness by all four methods and use the result that yields the greatest thickness.

Method	Structure Type	Climate Zone / Special Conditions	Ease of Determination	Comments
Economic Thickness	Commercial & industrial applications Simple structures	All	Difficult	Best economic choice for customer.
Building / Energy Code Requirement	Residential & commercial buildings Code authority	All	Prescriptive: Easy Performance: Difficult	Easy to use for complex structures. Requires more insulation than is economically desirable.
Condensation Control	Any	Climate extremes (hot, humid, cold) Special use facilities in all climate zones (freezers/coolers, swimming pools, humid interiors)	Difficult	Determines the thickness and placement of insulation relative to other building components.
Minimum Practical Thickness	Any	Any	Easy	Varies with project and SPF system.