THERMAL SPACERS IMPROVE ROOF INSULATION

PERFORMANCE OF METAL BUILDINGS

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Pre-engineered metal building systems are being increasingly used to construct the one and two story commercial structures of less than 150,000 square feet of floor area. Metal building manufacturers have doubled their share of this market since 1964, when it was 24%. This market share grew to 37% in 1973, and in 1978 stood at 47%.

The conventional way to insulate metal buildings has been to stretch a faced blanket insulation over the exterior of the structural framework and mechanically fasten the exterior metal skins through the insulation to this framework. See Figure 1.

For many years, the accepted method for calculating the heat transmission through a building section has been to determine the laboratory measured value of the thermal resistances of each building component, individually, add the resistances together, and invert the total value to arrive at "U" value. This approach has had a logical foundation: the sum of the parts should equal the whole.

However, the escalating cost of energy in recent years has caused greatly increased research into the various mechanisms affecting heat transfer. The result of this further research is now calling into question the adequacy of the conventional calculation method, for it is becoming evident that with certain building components, the sum of the parts may be less than or more than the whole.

The cause of this anomaly is the synergism which results when the components are installed full size in the walls or roofs of actual buildings, and are measured while working together in response to actual weather conditions in the real world. Only a moment's reflection is needed to recognize the truism that this synergism can never be detected when the same components are measured in a laboratory as small, separate samples.

A comparison of calculated "U" values versus measured "U" values for a conventional ribbed metal roof system is shown in Table 1.

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The actual tested results were obtained at Butler Research in a guarded hot box conforming with ASTM C236. The calculated values do not account for insulation compression or loss at fasteners and panel/insulation joints. The slope of the roof was flat in the tests. Under winter conditions, the heat flow is up, and under summer conditions, the heat flow is down. All blanket insulation is 0.6 lbs/cu ft density fibrous glass blanket with a three mil vinyl facing.

The calculated value versus the tested varies from 20% to 50%, a considerable variance from what the owner thought he had purchased. The insulation is not only compressed directly over the purlins, but also a distance on each side of the purlins. Other things also occur such as compression of blankets from the top side by the metal sheets. Another variable is how taut the workmen install the blankets. Most situations lead to a condition where the sum of the parts are less than the whole.

The conventional system for metal buildings has been shown wherein a pre-engineered blanket insulation is installed over roof purlins and the exterior metal skin fastened through the insulation with metal screws.

Now, a floating roof system (also known as standing seam) will be shown with special clips that create a space between the exterior skin and the purlins, utilizing a thermal spacer of rigid insulation. This creates a situation where the sum of the parts is better than the whole.

A standing seam roof (SSR) is constructed using a concealed clip fastening system which substantially reduces fastener penetration through the roof covering. See Figure 2.

The metal roofing surface is never penetrated since each panel is fastened directly to the structural (purlin) support by a clip concealed between the panel's male and female interlocking ribs. This minimizes the effects of expansion and contraction in that the slotted clip with its retaining washer allows the roof covering (panel) to move independently of any differential movement of the structural framing.

To minimize the thermal conductivity through the roof panel into the structural framing, a thermal spacer is provided continuously on top of each supporting purlin after the blanket insulation is installed. The improved thermal value of the thermal space balances that which is lost by compressing the blanket insulation at the purlin. The thermal spacer and concealed clip can accommodate a variety of flexible blanket insulation thicknesses from 1-1/2" through 4". The thermal spacer is fabricated with a slot or notch to position it directly over a purlin and to keep it from moving out of position. Blanket insulation with its vapor barrier toward the interior is placed over and on the purlin and under the thermal spacer. Panels are installed resting on the thermal spacer with ribs up and are attached to supporting members by the concealed clip as previously described.

Compared with the conventional ribbed roof system, fastener penetration is reduced approximately 75% in a standing seam system. Reduction of fastener penetrations through the roofing minimizes the possibility of water leaks.

All joints and end laps are sealed or flashed or both. After roof panels are placed, a roof seaming machine is used to continuously seam the interlocking ribs of the roof panel. At the same time, the tab of the concealed clip that secures the roofing system to the structural framing is folded into the seam.

Most of the thermal spacers are made of extruded polystyrene foam which is combustible and may constitute a fire hazard if improperly installed. It should always be installed above the blanket insulation. The total square footage of thermal spacer in a building is normally less than 5% of total wall and roof surface. The thermal spacer does not contribute to the structural integrity of the building.

This is what happens to the "U" value of these various roof systems with and without thermal spacers. See Table 2.

The same inconsistency in calculated versus tested U values exists as was noted in the ribbed roof examples. However, most important is the tested U value comparisons of the various roof systems.

A standing seam roof with 3" blanket insulation and without a thermal spacer results in about a 20% difference ($\frac{.11 - .09}{.11} \times 100$) in tested "U" value. A standing seam roof with 4" blanket insulation with a thermal spacer gives about a 33% improvement ($\frac{.12 - .08}{.12} \times 100$) over a conventional ribbed roof with 4" blanket insulation. Comparing thermal spacers used with a 3" or 4" blanket in a standing seam roof system as shown in Table 2, a 3" blanket with thermal spacer delivers the same performance as a 4" blanket without thermal spacer. Since this work was done, The Dow Chemical Company has conducted additional tests to show that the tested results for the standing seam with thermal spacers shown in Tables 1 and 2 are conservative.

The following test specimen was constructed and tested at the Butler Research facility in an ASTM C236 guarded hot box assembly.

- Standing seam roof deck
- 4" foil-scrim-kraft (FSK) faced Pre-engineered (PEB) blanket insulation
- With and without 1" x 5" thermal spacers (T.S.) of extruded polystyrene foam insulation
- 8" Z-shaped purlin
- Fasteners - 2' O.C.

Results are as shown in Table 3.

The overall insulation value of the roof is increased by about 30%. As a result, buildings are more energy efficient.

This is one of the most cost effective ways to improve the insulation value of a metal building roof. Thermal spacers can pay for themselves in as short a period as 18 months using a simple payback method. Some variation in test results does exist in the industry on the effectiveness of thermal spacers. "U" values quoted for 4" pre-engineered blanket insulation under a standing seam roof with and without 1" thick thermal spacers at 45^{o} mean temperature winter conditions are typically advertised as shown in Table 4.

Variations in results can be due to differences in standing seam roof types mostly due to configuration, type and weather tightness. Some of the testing was in the vertical rather than the horizontal position and translated to the horizontal. Rounding off of results to two places, which is probably more than the precision and accuracy of most tests, more investigation needs to be done to analyze all the potential variables.

Thermal variables exist due to characteristics of the thermal spacer. The "k" factor of the thermal spacer material has proven not to be a significant variable. The depth of the spacer is important. A 1" space was determined to be the best. The improved thermal value is mainly due to the separation of the exterior skin from the structural member, the configuration of the through metal clips and the fact that the blanket fluffs up on the top side. The depth will probably be limited to a maximum 2" or some other similar depth for structural or application reasons.

The shape of the thermal spacer may be a factor wherein one is rectangular and another is tapered to fill the expected gap area. See Figure 3.

A comparison was made of the width variable from the normal 5" with a continuous run of rigid insulation board above the blanket. See Figure 4.

The improvement at 45^{o}F was $\frac{.069-.064}{.069}$ x 100 = 7.25%. The cost of 5' wide insulation versus 5" wide thermal spacer isn't justified. Apparently what happens is that a continuous width rigid insulation does not allow the blanket insulation to fluff up. However, additional work needs to be done on 6", 7", 12", etc. width spacers.

The heat loss or heat gain benefits of a small thermal spacer have been discussed in detail. This small piece of rigid foam insulation has a number of side benefits. It reduces condensation at fasteners on the interior that can result in dripping. It reduces the snow melting and icing condition that may occur over purlins in the winter. By offering a rigid support for the metal panel, it helps minimize damage from foot traffic during installation. Rigid foam spacers may help alleviate a problem where screw down at eaves is necessary.

A thermal spacer needs to be moisture resistant. It should not be friable. The strength of a rigid foam needs to be great enough to withstand foot traffic. Its compressive and flexural strength should be sufficient to compress a blanket to 1/8" thickness over a 2' width without compressing itself or breaking.

In summary, full-scale testing has revealed that when certain insulation components were measured in an assembly, their performance may differ substantially from calculated values. The difference in efficiency can be large enough that it should stimulate insulation and building manufacturers to do full-scale testing in order to gain a more accurate understanding of the total performance of their various products and systems.

The recent trend toward the setting up of energy codes which require minimum R values for walls, ceilings and floors of new and retrofitted structures forces manufacturers of insulation products to confront the problem of determining what R values in their products are needed to provide in place performance equivalent to the code requirements.

TABLE 1

Calculated and Tested U Values* of Ribbed Roof System

ROOF PANEL TYPE	INSULATION THICKNESS (inches)	CALCULATED "U" VALUE		TESTED "U" VALUE	
		WINTER 45^{o} Mean	SUMMER 75^{o} Mean	WINTER 45^{o} Mean	SUMMER 75^{o} Mean
Ribbed	1-1/2"	0.16	0.17	0.20	0.22
	2	0.12	0.13	0.19	0.21
	3	0.08	0.09	0.14	0.15
	4	0.06	0.07	0.12	0.13

*Units for "U" values throughout the presentation are $Btu/h \cdot ft^{2} \cdot {}^{o}F$

TABLE 2

Calculated and Tested U Values* of Metal Roof System

ROOF PANEL TYPE	INSULATION THICKNESS (inches)	CALCULATED U VALUE		TESTED U VALUE	
		WINTER 45^{o} Mean	SUMMER 75^{o} Mean	WINTER 45^{o} Mean	SUMMER 75^{o} Mean
Ribbed	1-1/2"	0.16	0.17	0.20	0.22
	2	0.12	0.13	0.19	0.21
	3	0.08	0.09	0.14	0.15
	4	0.06	0.07	0.12	0.13
Standing Seam w/o Thermal Spacer	1-1/2"	0.16	0.17	0.17	0.18
	2	0.12	0.13	0.14	0.16
	3	0.08	0.09	0.11	0.12
	4	0.06	0.07	0.09	0.10
Standing Seam w/Thermal Spacer	1-1/2"	0.16	0.17	0.15	0.16
	2	0.12	0.13	0.12	0.13
	3	0.08	0.09	0.09	0.10
	4	0.06	0.07	0.08	0.09

TABLE 3

Tested "U" Values* by The Dow Chemical Company

SSR DECK (standing seam)	WINTER TESTED "U" AT 45 F	SUMMER TESTED "U" AT 75 F
4" FSK faced fibrous glass blanket only	0.10	0.113
4" FSK faced fibrous glass blanket plus 1" x 5" thermal spacer	0.069	0.082
therefore:	31% improvement	27.4% improvement

TABLE 4
"U" Values* from Industry

COMPANY	PEB	SSR w/o SPACER	SSR w/SPACER	PERCENT CHANGE
"A"	4"	.09	.08	+11.1
"B"	4"	.081	.078	+ 3.7
"C"	4"	.12	.11	+ 8.3
"D"	4"	.100	.069	+31.0

TABLE 5

Comparing the Thermal Spacer Width Variable

SSR DECK	WINTER TESTED "U"* AT 45°F	SUMMER TESTED "U" AT 75°F
4" FSK-PEB w/ 1"x5" T.S.	.069	.082
4" FSK-PEB w/ cont. T.S.	.064	.070

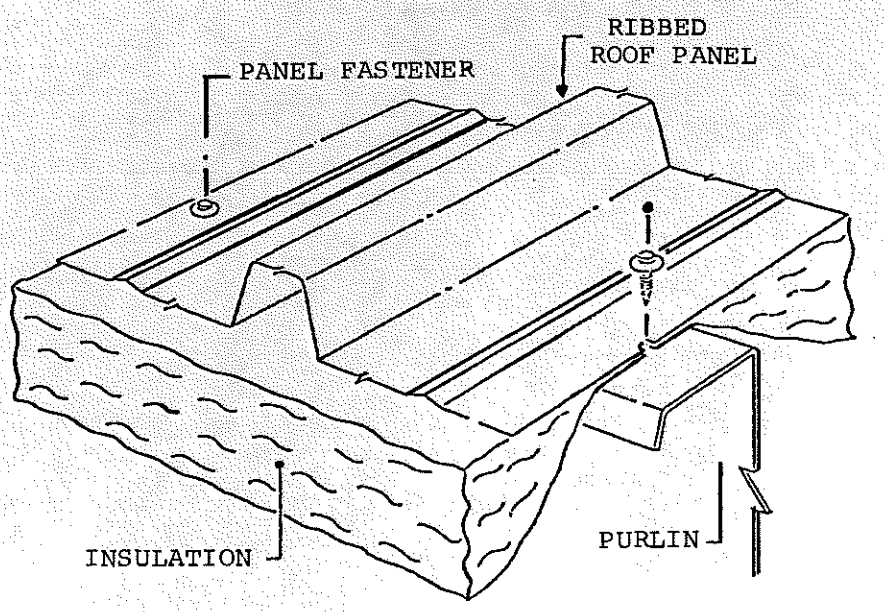

Fig. 1 Conventional ribbed roof system

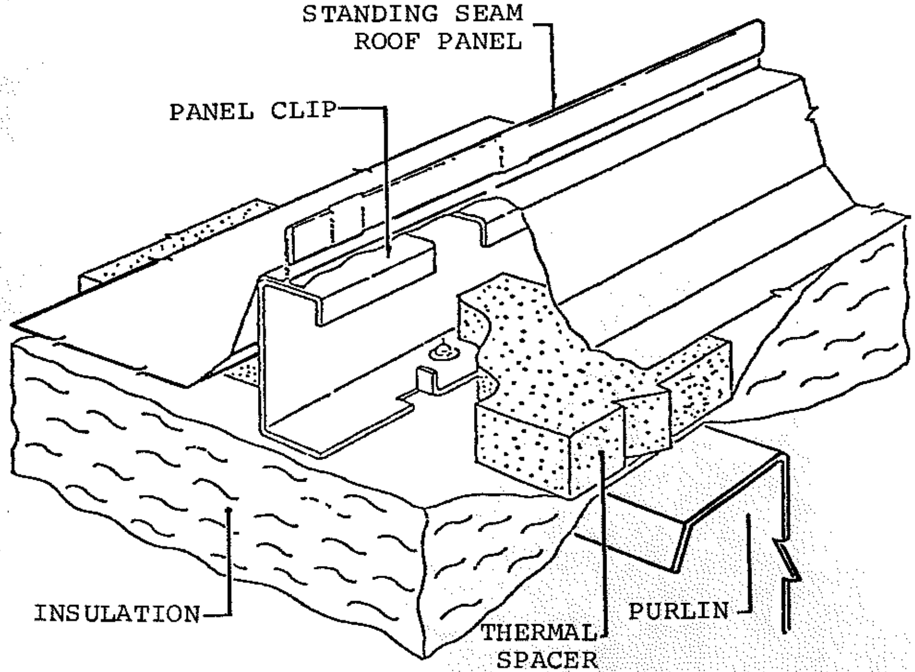

Fig. 2 Standing seam roof system

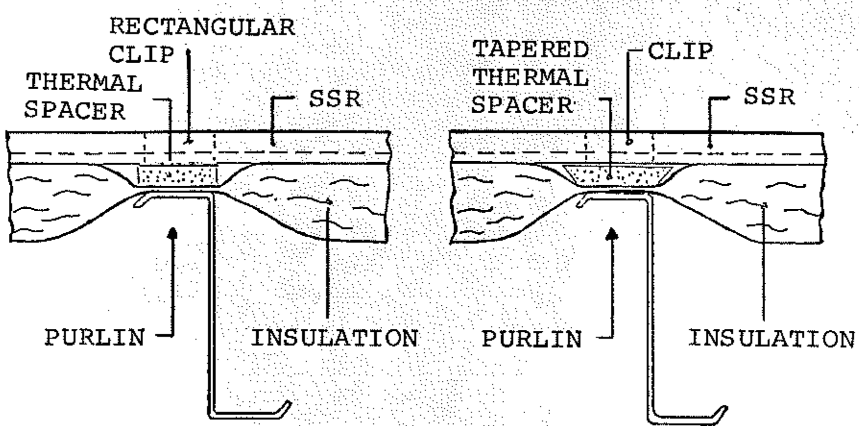

Fig. 3 Shape of thermal spacer

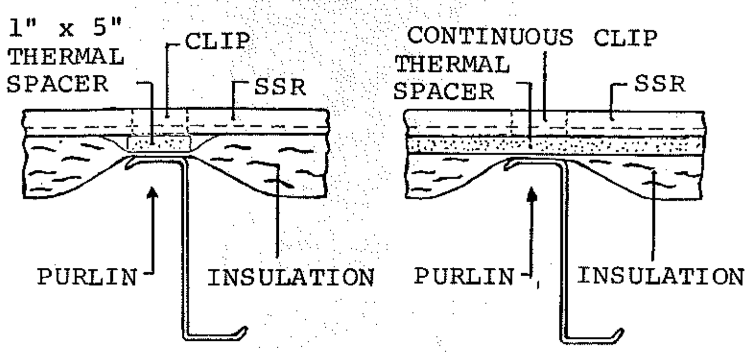

Fig. 4 Comparing the thermal spacer width variable