PAPER NUMBER 9

BLISTERING OVER URETHANE

Hollis Porcher
Sechrist-Hall Company

INTRODUCTION

Membrane blistering over urethane board insulation has been the source of roofing industry concern for several years. There has been a great deal of speculation concerning its causes. At times, in fact, it appeared that opinions would be so diverse as to be hopeless; and yet today, manufacturers and contractors are working with a unity of effort to find a permanent solution to the problem.

One industry-sponsored program has recently provided at least a tentative hypothesis explaining this phenomenon, and the National Roofing Contractors Association (NRCA) has issued two technical bulletins with recommended procedures for preventing this blistering.

This hypothesis, formulated after extensive laboratory and field testing, attributes urethane blistering to two basic factors:

- urethane board's extremely low thermal conductivity
- its low vapor permeability in comparison with more porous traditional insulating materials.

Low thermal conductivity raises the transient peak mopping asphalt temperature at the asphalt-insulation interface, thereby increasing the pressure of heated water vapor. Low permeability obstructs the water vapor's dissipation downward through the insulation, diverting it back into the asphalt film, where it forms bubbles or channel voids that later grow into blisters when the sun heats the membrane.

The NRCA-recommended preventive remedy is to either (a) interpose a porous insulating material between the urethane board and the membrane, or (b) install a base sheet so as to allow for venting. Both have the same purpose of relieving vapor pressure within the roof system.

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In order to develop a fuller understanding of the nature and magnitude of this particular phenomenon of blistering, we must go back to a starting point. At least a starting point in so far as the phenomenon becoming wide spread knowledge within the roofing industry. This point would be with the establishment of National Roofing Contractors Association's Project Pinpoint, a program designed to accumulate and evaluate types and numbers of roof problems. This program was established in 1974 and Table I shows how blistering over urethane has become an increasing problem since that time. This table was prepared from data available through Project Pinpoint and is stated as an accurate indication of roof problems to within 5%. Table II, also from Pinpoint data, shows the trend toward using more insulation within the roof assembly.

In particular it indicates an increase of 100% in the use of urethane and urethane composite insulations within the last two years as compared to the previous four. From this we must surmise that the need for a highly efficient thermal insulation is so pressing it justifies taking risks in using the material. And so, there is even more reason to find a permanent solution.

Credit for some of the earliest efforts to find a cause and solution for the problem must go to the Western States

SYMPTOMS	1979	1978	1977	1976	1975	1974	TOTAL
Blistering	44 (25) 57%	26 (7) 27%	22 (7) 32%	46 (16) 35%	8 (2) 25%	34 (2) 6%	**180 (59)** **32%**
Other	46 (7) 15%	29 (9) 31%	21 (1) 5%	39 (4) 10%	17 (2) 12%	37 (3) 8%	**189 (26)** **13%**
TOTAL	**90 (32)** **35%**	**55 (16)** **29%**	**43 (8)** **18%**	**85 (20)** **23%**	**25 (4)** **16%**	**71 (5)** **7%**	**369 (85)** **23%**

90 (32) indicates a total of 90 jobs of which 32 had urethane.
% figures shown are approximate.

TABLE I
Problem jobs reported to Pinpoint.

INSULATION USED	1974-77	1978	1979
None	31%	23%	20%
Fiberboard	10%	7%	7%
Perlite	27%	26%	23%
Fiberglass	18%	17%	19%
Cellular Glass	1%	1%	1%
Urethane	4%	8%	7%
Polystyrene	3%	5%	7%
Other (mostly composite)	6%	13%	16%

% shown is percentage of total roofing jobs.

TABLE II
Relative use of roof insulations in roof assemblies

Roofing Contractors Association. This association could not accept the explanation that poor workmanship was the cause of the blistering. In July of 1978 they started a testing program based on installations of roof assemblies under actual field conditions. Four locations were chosen for variations in climatic conditions. The test roofs in Tucson, Arizona, Salt Lake City, Utah and Seattle, Washington have all shown blistering. The last one at Oakland, California has not been in place long enough for data to have been evaluated. The test was documented on film during installation and thermocouples were strategically placed for future study. All of these roofs are being observed and monitored and will continue to yield valuable data. WSRCA should be commended for their initiative.

It was in mid 1978 that the Thermal Insulation Manufacturers Assn. (TIMA) also began investigating the blistering phenomenon. Through their Roof Insulation Committee (RIC) test programs were conceived and implemented. In particular, the Technical Subcommittee of RIC/TIMA was assigned the task of developing qualified laboratory procedures and coordinating the work of various member labs. NRCA was invited to participate in the program and a liaison group was formed.

The first test program to be performed was designated the short range (laboratory) test program. It was designed to test the various components of a roof system after each had been conditioned to one of three stages of moisture content. The three conditions were extremely wet, ambient, and dry. Samples were incorporated in a roof assembly approximately two feet square. In all there were 108 sample assemblies representing every possible combination of the conditioned materials. Some eighty-one of these assemblies were cycled under heat lamps simulating solar conditions during a four day period. During this time blister formation was recorded as to size and location. The final step was to chill the samples down so they could be split and blister locations determined. This part of the test program was completed in early 1980 and test data and conclusions made available soon thereafter.

While the short range program was in progress a group within the committee was making plans for the first phase of the long range (field) test program. This test involved installing representative insulation material (from member firms with TIMA) on a roof located within a certain geographical area of the country. There were three different built-up roof specifications used over each manufacturer's insulation. Members of NRCA's liaison group were invited to participate in developing specifications for the project. Once this was completed a project near Atlanta, Georgia was selected and arrangements made for the installation. This was completed in April of 1980 and is currently being monitored by an independent witness. Preliminary reports indicate no blistering had occurred within the first ninety days after completion.[1]

In June of 1979 a testing program was sponsored by NRCA and Midwest Roofing Contractors Association through the facilities of Southwest Research Institute (SwRI) in San Antonio, Texas. This program was conducted along test procedures developed by Dr. Lawrence J. Parker.[2] The test was to be impartial in that it would provide data on the effects of applying hot asphalt to all standard types of roof insulation. Purposes of the tests were to determine what phenomena occur as a result of the hot asphalt application, i.e. such as gases that may be released and changes in physical dimension of the material. Test apparatus was developed similar to Dr. Parker's and consisted mainly of a closed speciman chamber and a gas collection chamber. Gas specimens were collected and then analyzed by gas chromatography.

Midway through the program it was decided that a full scale test simulating field conditions might be of considerable value. The primary purpose of this type of testing would be to allow visual observation of the foaming action as hot asphalt is applied as well as its effects on the dimensional stability of the material. A procedure was quickly developed and insulation materials were gathered. This field test consisted of mopping felts over a representative selection of roof insulations. Thermocouples were placed above and beneath the facer felt on one of the urethane insulations and temperatures monitored. A base ply felt and three #15 asphalt organic felts were mopped in place. This entire procedure was observed by representatives of NRCA and MRCA, along with SwRI technical staff. When foaming occurred it was measured for its severity by recording the size range and number of bubbles per square foot of surface. Table III gives the observations and measurements for each material.

It was noted that the first mopping over the insulation produced the most prolific bubbling with little or no bubbling evident when subsequent plies were mopped over the base ply. After the field samples had cooled sufficiently they were cut into strips and placed in a −18°C (0°F) environment. After being chilled they were split to observe the voids created by the foaming action. The last column of Table III lists the percent of channeling found for each sample. Figure 1 is a schematic of the channeling found under the base ply felt. There was no channeling or void system found above the base ply. It was also noted that the voids were almost always found totally encapsulated within the asphalt and not as a result of felts not being coated.

The conclusion of the report submitted by SwRI in January 1980 addressed itself primarily to two essential aspects of the problem. The first was to define the source of the gas which was creating the foaming action and resultant void system. The second was to define the transient temperature distribution in the asphalt and surface of the insulation.

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[1] RIC/TIMA, "Review, Conclusions and Discussion of RIC/TIMA Testing Program," RSI Publication, August, 1980 issue.

[2] President of Shelter Insulation, Inc., San Antonio, Texas.

SAMPLE	DESCRIPTION	OBSERVATION IMMEDIATELY AFTER APPLICATION	AVERAGE DIA. OF BUBBLES	% CHANNELING* UNDER FELT
A-1	Baseline; 2" Wood Fiberboard	Smooth Surface; No Bubbling	None	5%
B-1	Baseline; 1" Perlitic	Smooth Surface; No Bubbling	None	5%
C-1	Baseline; 15/16" Fibrous Glass & Felt	Smooth Surface; No Bubbling	None	5%
E-1	1.5" Urethane/Perlitic Composite; Asphalt Top Skin	Slow Formation of Bubbles	1/8"	20%
F-1	15/16" Urethane/Fibrous Glass Composite	Immediate Bubbling and Foaming	3/8"-1/2"	80%
G-1	1.2" Urethane; Asphalt Outer Skins	Slow Formation of Bubbles	1/8"-3/4"	40%
I-1	1.2" Urethane; Asphalt Outer Skins	Slow Formation of Bubbles	1/8"-1/4"	50%
J-1	1.2" Urethane; Asphalt Outer Skins	Slow Formation of Bubbles	1/4"-1/2"	40%

*Ratio of void area to total area.

TABLE III

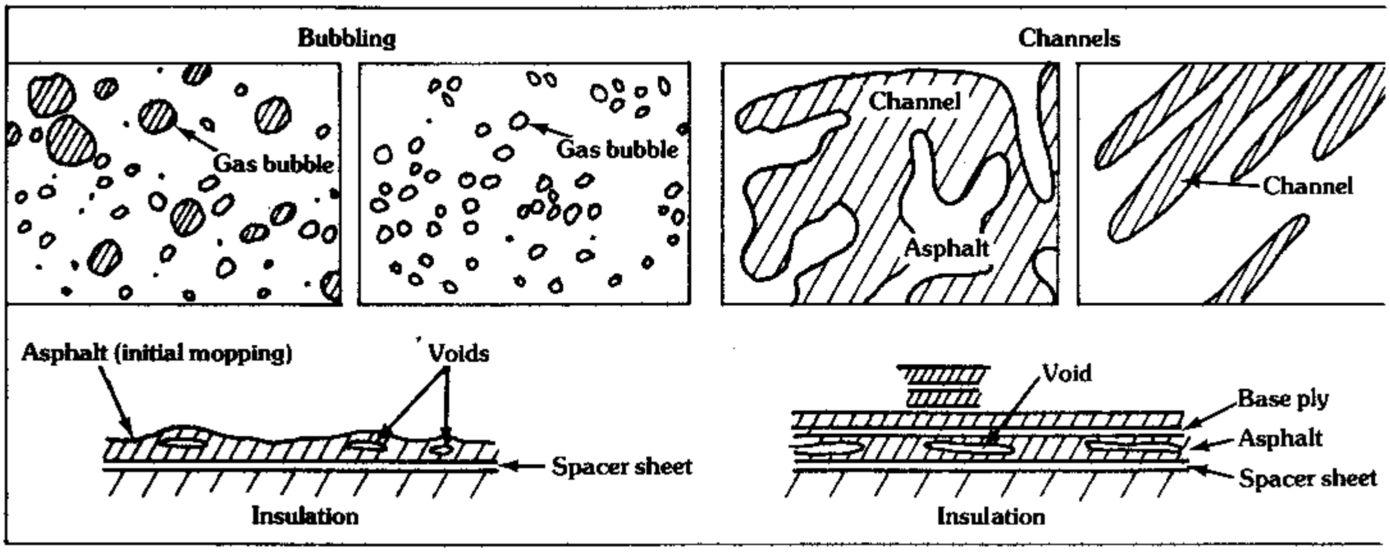

FIGURE 1
Schematic of bubbling and channeling.

Gas chromatography was used to identify the gases that evolved during application of hot asphalt. While the experiment was not considered conclusive in this matter, there was strong evidence that water on or near the surface was the most likely source of gas generation. Diffusion of gases from within the insulation material, such as Freon 11, would be highly unlikely since it would have to occur against a strong temperature and pressure gradient. This was supported by the data gathered. Surface moisture, on the other hand, will be available on the surface of all insulations and within facer sheets when they are present.

After application, the transient temperature of the asphalt will depend strongly on the heat transfer properties of the insulating material. The difference in heat capacity and thermal conductivity of the urethane versus other insulation materials may be a causative factor in the differences in blistering observed.

The report concludes that the most probable mechanisms controlling initial bubble formation during hot mopping of urethane foam insulation are the availability of moisture an the transient temperature distribution in the asphalt an substrate.

After studying the SwRI report submitted in January, th liaison group from NRCA and MRCA decided a supplementary report expanding on conclusions of the first report woul be of some value to the roofing industry. This grou requested Dr. Ulric Lindholm[3] of SwRI to study the te results with the objective of developing more comprehensiv conclusions. His report was completed and submitted to th liaison group in June 1980.

Dr. Lindholm's report began with certain basic assumptions; he developed a model for blistering during th applications of hot asphalt that, under normal condition moisture would be present on the surface of all insulation

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[3] U. S. Lindholm, Director, Department of Materials Science SwRI, San Antonio, Texas.

and that this moisture would vaporize upon contact with hot asphalt. The migration of the vapor from the insulation surface will then depend upon the temperature gradient across the interface. The vapor permeability of the urethane core is very low, by comparison, and the temperature gradient across the interface remains high. Because of urethane's exceptionally low thermal conductivity value, water vapor generated at the interface would be driven into the asphalt rather than the urethane. This would explain the foaming action observed when hot asphalt is applied to urethane. By this same reasoning, water vapor generated at the face of baseline insulations would be driven into the more permeable material and there should be little, if any, foaming at the surface.

Using a temperature profile computed by Dr. Herb Busching for a plywood substrate, Dr. Lindholm developed hypothetical curves for fiberboard, urethane and an "ideal" insulation (perfect insulator). Figure 2 shows the comparison of these transient temperature distributions.

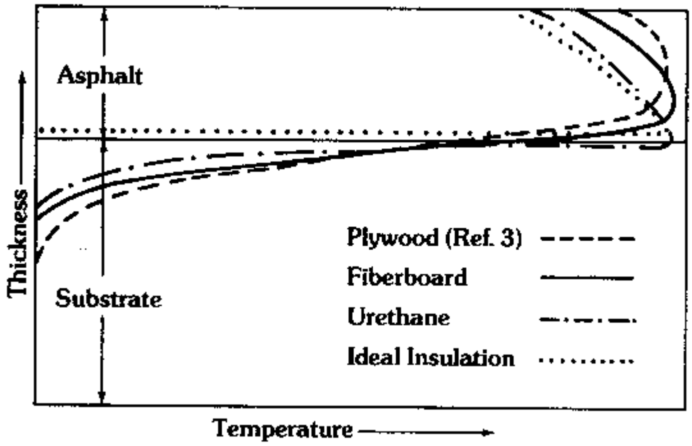

FIGURE 2
Expected temperature profiles in several substrate materials.

As the curves approach the ideal, as the one for urethane does, one can see that the maximum temperature will occur at the surface of the insulation and heat flow will be in the direction of the decreasing temperature gradient in the asphalt. Water vapor would be driven by the temperature gradient in that same direction. As the vapor is driven into the asphalt, the asphalt is cooling and becoming more viscous. As the viscosity rises it eventually reaches a point where it overcomes the driving force of the water vapor. In this way entrainment of bubbles occurs, which tends to explain the channels and other voids found when moppings were separated.

Dr. Lindholm's further concludes that vapor diffusion from within the insulation (such as Freon) would not be toward the hot asphalt and the more likely vapor source would be at the insulation surface. This would further suggest that the gas source is surface water. The very properties of urethane that make it an excellent thermal insulation, that is, low thermal conductivity and low permeability, seem to be causative factors in the blistering phenomenon which occurs at the time of application. This hypothesis appears reasonable, is based on physical arguments, and is in some ways supported by data and observations of the earlier tests. It no doubt will be challenged since it has not yet been verified in detail by experimental data and consideration should be given to further testing and/or analysis.

For the present, though, it would seem that by following the recommendations of NRCA Bulletins No. 4 and No. 7 we can avoid most of the potential blistering. These methods offer a way to provide a heat and vapor sink or otherwise vent the offending vapors. Perhaps we can receive a valuable lesson from our counterparts across the sea. Peter Kindermann[4] from Stuttgart, Germany presented a paper to the Congress of "Cellular and Non-Cellular Polyurethanes" held June 9-13, 1980 in Strassburg. In this paper he claimed that rigid polyurethane insulation had been used successfully in flat roof construction in The Federal Republic of Germany for the past fifteen years. He also stated that more than half the total rigid polyurethane foam consumed in the construction field of the Federal Republic is being utilized to insulate flat roofs. A flat roof/warm roof is interpreted to be a multi-layer roof structure with roof insulation. Special provisions are issued by the German roofers trade. Figure 3 shows a design which reflects the technical standard for a heat insulation flat roof.

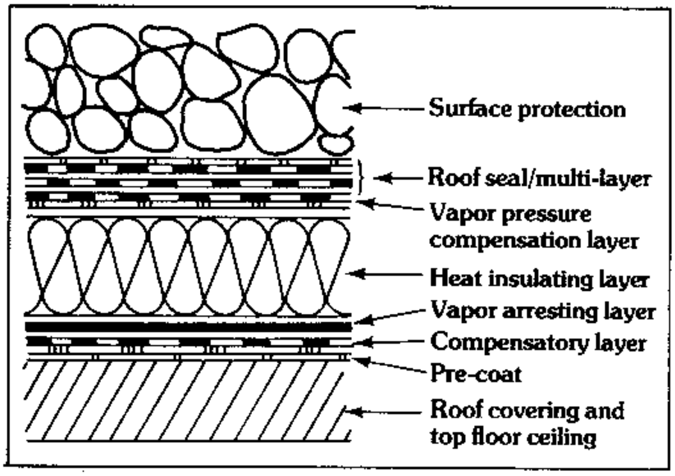

FIGURE 3
Principle of heat-insulated flat roof.

Note the "vapor pressure compensation layer." It is described as "a coherent air-layer between heat insulation layer and roof seal. It is the purpose of that layer to distribute any locally occurring vapor overpressure and to reduce transfer of movements to the roof seal."

This description could fit the thin porous layer of insulation or venting base ply that is advocated for use in NRCA's Bulletin No. 7. This writer sincerely believes that Bulletin No. 7 has the most practical solution to the urethane blistering problem, at least for the moment. This is not to say that our industry should not continually strive to improve our materials and methodology. It benefits all of us.

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[4] Dipl.-Ing. Peter Kindermann, Stuttgart, Germany.