APPLICATION OF EPS INSULATION FOR OPTIMUM PERFORMANCE IN BUR AND SINGLE-PLY ROOFING SYSTEMS

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I. Introduction

Expanded polystyrene insulation (EPS) is well suited for use in single-ply roofing systems, a rapidly expanding segment of roofing technology. This compatability has accelerated recognition of its many advantages as an insulating material for built-up roofs as well.

When choosing insulation material, however, the prudent designer must have at his command full knowledge of its advantages and disadvantages. For this reason, The Society of the Plastics Industry, the trade association for EPS, entered into a joint testing program with NRCA and MRCA in April, 1982. The two-year program seeks to clarify many significant issues with regard to application guidelines for EPS roof insulation.

This paper discusses the current state of the art in EPS roof insulation. It accordingly reports on three major areas of interest:

1. Positive performance characteristics of EPS roof insulation
2. Areas targeted for further study
3. Design of problem-free roof systems with EPS insulation

II. Positive Performance Characteristics of EPS Roof Insulation

- High Insulation Value — EPS at 1.25 pcf density has an R value of 3.92 for one inch at a mean temperature of 75°F; R=4.25 at 40°F.
- Permanent R Value — Since EPS does not use low conductivity blowing agents to enhance R value, dissipation of these agents with aging does not reduce R value.
- Low Density — In the 1 pcf density typically applied, EPS adds less weight per board foot and per unit of R value than any other roof insulation. This translates to lower deck loading and greater ease of handling.
- Low Water Absorption — EPS at 1 pcf density or higher absorbs less than 2.5% by volume.
- Water Vapor Permeability — The vapor transmission properties of EPS insulation vary with density. By selecting the proper density, you can achieve the vapor permeability desired for most roofing applications. Yet even at higher densities, EPS insulation is not a complete vapor retarder. It breathes and as a result will allow moisture vapor to pass through.

  In tests conducted by the U.S. Army Cold Regions Research and Engineering Laboratories[1], EPS outperformed all other insulation products under typically severe exposure conditions (85°-70% R.H. inside, 40°-75% outside). In a second test, inside R.H. was increased to 100% in order to force water vapor into the insulation (unusually severe conditions). Under these circumstances, EPS maintained more of its R value than most other insulation products tested. Even at 10 times dry weight or 1,000% water pickup, EPS retained 80% of its R value.
- High Strength — For a lightweight product, EPS has high strength. Under 10 psi (1440 psf) compressive stress, EPS will deform only 10%. (This deformation is not permanent. The EPS board recovers when the weight is removed.) Flexural, tensile and shear strengths are also high enough for most job site conditions. As noted in the application section, however, some job site conditions exceed even these strength properties. Care must be taken to avoid or to compensate for those occurrences.
- Versatility — EPS insulation is the most versatile and custom-designable board stock insulation available for roofs.

Density:	1-3 lbs. pcf in any increment
Sizes:	Any size up to 20″ x 4′ x 16′
Laminates:	Virtually all materials in solid form, including all currently marketed roof insulations, may be laminated to improve or modify performance characteristics.
Custom Shapes:	Tapered cuts for positive slope-to-drain, shiplap, tongue and groove, channels for special roofing systems, and even custom cuts to fit contoured deck configurations are normally available.

- Ease of Application — No special tools are required for field cutting of EPS. Knives or saws are sufficient. A recent development is rooftop hot wire cutting equipment. Lifting to the top of high-rise buildings presents no problems.
- Resistant to Attack — As an inert organic material, EPS provides no nourishment to animals, plants, fungus or micro-organisms and will not rot.

- Certified Physical Properties — Current plans for a nationwide, third party certification program are nearing completion. This program, supported by The Society of Plastics Industry, EPS Division and conducted by NAVLAP Approved Laboratories, will be introduced early in 1983. It will certify to the roofing contractor, architect, and building owner that the product delivered is the same as the product specified. Tests will be conducted on a regular basis on samples obtained through unannounced visits. Certified properties will include density, thermal resistance (R value), flexural strength, dimensional tolerances, flame spread, and smoke development.

III. Areas Identified for Further Study by the NRCA/MRCA/SPI Joint Task Group

EPS was first introduced as a roof insulation in the 1950s. Some areas of the country were virtually unaware of its existence until the 1960s but in other areas, particularly the upper Midwest, tapered EPS board was widely used to assure roof drainage on dead-level decks. In most cases, built-up roofs were applied directly to higher density (1.25 pcf) EPS with drum-type felt layers.

Much controversy exists as to whether or not this was a proper application technique. Some roofing contractors and consultants claim to have experienced problems as a result of these designs. Many others have said these problems were a result of application technique and not of design. One company achieved a Factory Mutual Class I rating with this system and the vast majority of these systems are still performing, with no major problems.

Due to the controversy and the lack of scientific data regarding these systems, most industry representatives today recommend adhering an overlayment board to the EPS by means of the mop-and-flop method before the built-up membrane is applied. Many EPS manufacturers factory-laminate the overlayment board before shipment. Insulation board joints are taped to prevent melt due to hot asphalt.

A scientific answer to the core question, however, has yet to be provided. That is: Were the problems, relatively few in number, attributable to the design, application, the material itself, or to some combination of factors?

In the 1970s when single-ply roofing came into this unsettled arena, the advent of loose-laid, ballasted single-ply roofing systems was an ideal candidate for EPS. The very basis of this system is freedom from fear of the effects of component movement. For this reason, when specifying and applying these systems, designers and contractors in rapidly increasing numbers have chosen the most cost-effective insulation available — EPS.

But what about full adhered or partially adhered single-ply systems? And how should modified bitumen systems be approached? Each time the question of attachment arises, uncertainty grows.

Out of this uncertainty, in late 1980, came preliminary meetings between NRCA, MRCA, and The Society of Plastics Industry (SPI) as represented by its EPS Division. From these meetings emerged the joint task force previously mentioned. A contract was signed in April, 1982 with Structural Research, Inc. (SRI) of Madison, Wisconsin, SRI, represented by Dr. Rene M. Dupuis, has identified three general areas of concern regarding the use of EPS. They are:

1. High thermal coefficient,
2. Dimensional instability (shrinkage),
3. Low melting point.

With several million squares of EPS destined for installation before the research program's completion, the industry confronts an obvious question: What to do in the meantime? Since Dr. Dupuis' research is central to the question of EPS performance and the construction industry needs some guidance on how the systems should be applied, preliminary answers to the questions asked in the SRI program will be provided in the same spirit as NRCA's recent Bulletin #12, which recommends interim use of an overlayment of fiberboard, fibrous glass, or perlite board insulation, with staggered joints over the EPS board underneath and consideration of joint taping.

The opinions expressed are based on state-of-the-art technology and may or may not be confirmed by the results of the research. Some questions will be impossible to answer until the research is complete. These are identified where appropriate. Methods of "designing around" these problem areas are discussed in the final section of the paper.

1. Can a fully-adhered membrane (BUR or single-ply) ever be applied directly to EPS?

   In the case of BUR systems, the answer is yes. Millions of squares have been applied both in the U.S. and Europe and 20-year histories of problem-free performance are common. The caveat is that these systems are not particularly forgiving and care must be exercised in following specifications.

   In fully adhered single-ply systems the answer at this writing is no. The high solvent content of adhesives (or the heat of torches used in some modified bitumen systems) are not compatible with EPS. Some recently introduced adhesives have both compatibility **and** sufficient uplift resistance. Not enough experience with these adhesives exists, however, to recommend their use for membrane attachment.

   Overlayment boards of 1/2" wood fiberboard, 3/4" perlite or the like are a common means of solving these design problems. Any compatible adhesive (field-applied asphalt or factory-applied latex or urethane) that has passed Factory Manual I 90 wind uplift requirements can be trusted fully by the designer/applicator in adhering these overlayment boards to EPS.

2. Can partially adhered, elastomeric single-ply roof membranes be mechanically attached through EPS without an overlayment?

   Some tested systems have achieved attachment very successfully. Long-term performance of these systems, however, has yet to be sufficiently evaluated. In addition, the expense of these systems in most cases would approach that of systems using overlayments. That being the case, some sort of overlayment (including successfully tested and recently introduced kraft linerboards) should be used to prevent pullthrough. These overlayments will also prevent any weakening of the wind uplift resistance of the EPS due to possible effects of horizontal shear.

3. Is moisture a problem in the use of EPS roof insulation?

Yes, moisture is a problem in the use of **all** roof insulation. If design considerations call for levels of interior relative humidity of 45%, the prudent designer should consider a vapor retarder. This 45% R.H. guideline is especially critical where the average January mean temperature is below 40°F (in the northern hemisphere).

4. Is mechanical damage to EPS under ballasted single-ply membranes a problem?

   Yes. The same can be said about most roof insulation products. The guideline here should be that if noticeable crushing of EPS takes place there will be an adverse affect on R value. The contractor should not allow this to happen. If unavoidable, an additional thickness increment of insulation should be specified to compensate for lost R value.

5. Which adhesives are compatible for use with EPS?

   Any adhesive that has been tested and found to be compatible with EPS is safe to use. This would include latex, most urethanes, and some cold-applied modified bituminous adhesives, which are now becoming available. This does not necessarily mean these adhesives will perform under severe wind uplift conditions. That can only be determined through accepted wind uplift testing procedures.

6. Is dimensional stability a problem? (Internal expansion or contraction due to any cause)

   EPS cured for a minimum of seven days after molding and prior to application will have negligible amounts of expansion, contraction, or shrinkage. It will not adversely affect loose-laid systems or any other system where an overlayment board is applied. As with any insulation, individual boards should be tightly butted for optimal thermal performance.

7. Is mechanical puncture of membranes a particular problem with EPS?

   This question involves a wide range of variables, i.e. type of membrane, density of EPS, etc. EPS has less compressive strength than most commonly used roof insulations. Some have said this compressibility improves puncture resistance. Only the results of the test program can adequately answer that question.

IV. Design of Roof Systems with EPS Insulation to Avoid Potential Problem Areas

It is not possible to provide a complete set of guide specifications for EPS roof insulation within the confines of a technical paper. Guide specifications are generally available from your local EPS supplier.

These guidelines pertain to roofing systems that meet Factory Mutual fire and wind uplift requirements and have been approved as Class I Systems. Where Factory Manual requirements do not have to be met, lower cost substitutions may be made. These substitutions meet most building code requirements and can substantially reduce the cost of the installed system. Materials shown in brackets below indicate commonly used substitutions.

Concrete decks satisfy Factory Manual requirements without modification. Wood decks on the other hand are difficult, if not impossible, to build in a system with EPS which will pass Factory Mutual requirements. Thus the following designs assume steel deck construction.

• BUILT-UP ROOFS

A. **New Roofing**

After completion of a properly designed and installed steel deck, the first layer typically consists of 5/8″ Type C or XXX fiberglass-reinforced gypsum board. (1/2″ unreinforced gypsum board, 3/4″ perlite and 1″ wood fiberboard normally can be used where building code approval is required and Factory Mutual approval is not.) This thermal barrier is attached to the deck by means of mechanical fasteners, ribbons of hot asphalt, or approved cold adhesive.

The next layer consists of the EPS insulation which may be 1.00 pcf density, tapered for positive slope-to-drain or flat, and up to 8″ in thickness. (No limit on non-FM systems.) It is commonly attached to the substrate with a full mopping of hot asphalt, which is allowed to cool to less than 250°F but not less than 225°F.

Next a top covering of 1/2″ wood fiberboard or 3/4″ perlite is attached via the mop-and-flop method, again utilizing the 225°-250° range.

(**NOTE**: Roofing contractors, familiar with EPS, experience little trouble in determining this temperature range. Those using EPS for the first time may wish to first experiment with small amounts of EPS to find the shortest possible cooling period that does not melt the EPS.)

Finally the built-up membrane is applied. Asphalt at typical equiviscous temperature (EVT) will melt EPS. To eliminate this possibility, joints of overlayment board may be taped to prevent drippage of the hot asphalt. The roofing membrane can then be applied in accordance with the membrane manufacturer's specifications.

Many built-up roofing manufacturers furnish guarantees over EPS. Those who do not should be asked their reasons and urged to do so, as there is no logical justification for this denial.

A time-saving alternative to the above construction is to loose-lay underlayment, insulation and overlayment. The entire assembly is then fastened to the deck with mechanical fasteners.

Many EPS manufacturers now offer prelaminated composites of EPS with underlayment, overlayment or both. Consult your local EPS manufacturer for availability of these time and labor saving composites, which may be adhered to the deck with mechanical fasteners or Factory Mutual approved adhesives or asphalt.

B. **Reroofing**

For BUR reroofing, the sequence of steps is the same as for new roofing except that thermal barriers are not normally required. In addition, two more important considerations must be noted:

1. The contractor must be completely satisfied that the old roof or insulation to be recovered is satisfactory for acceptance of the new roofing system and that the new roof system can be permanently anchored.
2. If the old membrane to be reroofed consists of coal tar pitch the following guidelines apply:
   a. The membrane must be at least five years old with no coal tar pitch repairs in that period.

b. The first layer of the new system must consist of 1/2" wood fiberboard, with joints taped securely.

c. The thickness of EPS used must be sufficient to maintain the surface of the coal tar membrane at a temperature below 130°F.

At this writing, these guidelines are in the process of being updated to allow lower cost and easier application. Check with your EPS supplier or the author for latest information.

• SINGLE-PLY ROOFS — ELASTOMERIC

A. **New Roofing**

1. **Ballasted Systems**

Ballasted roofing systems cannot, by definition, be approved for Factory Mutual Class I. (See FM Bulletin 1-29.) They are commonly approved, however, on a job-by-job basis. The following assumes an FM Class I system as outlined under "BUR" above.

For steel deck roof systems, the thermal barrier is the first layer (see "BUR" for types). In many cases, only a 3/4" perlite thermal barrier is required. Check with membrane manufacturer to be sure. The thermal barrier is loose-laid with joints tightly butted.

Following the first layer, EPS in thicknesses up to 4" is loose-laid. (No limit on non-Class I systems.) The EPS can be flat or tapered for positive slope-to-drain. Some PVC membranes require plasticizer barrier sheets above the EPS. These are commonly supplied in laminate form by the EPS manufacturer.

The membrane is then loose-laid over the EPS according to the membrane manufacturer's specifications. The entire system is then ballasted with smooth river rock at 1,000 lbs. per square. (See Section III, Item 4 for precautions.)

2. **Mechanically-Fastened and/or Partially-Adhered Systems**

These systems are applied the same as ballasted systems through the application of the EPS. After that step, 1/2" wood fiberboard, 3/4" perlite or foil-faced kraft linerboard is loose-laid over the EPS according to membrane manufacturers specifications. Next, the entire assembly is mechanically fastened with screw-type fasteners. Large surface retainer plates are used to improve wind uplift resistance.

The next step is the single-ply membrane loose-laid and adhered to the retainer plate with special adhesives. Other versions loose-lay the entire system and fasten it in place with bars or battens on 6- to 10- foot centers. These are then sealed with additional strips of membrane.

3. **Fully Adhered Systems**

In these systems composites of EPS and overlayment are most often used. They are installed over the thermal barrier (which can also be composite) and the assembly is mechanically fastened to the deck. Adhesive fastening is also acceptable with approved adhesives, though this method is not commonly used due to a lack of experience with these adhesives. The membrane is then adhered to the overlayment with a full coating of special adhesive, according to the membrane manufacturer's specifications.

B. **Reroofing**

Follow the same procedures as above, using guidelines from Built-Up Roofs — Reroofing

• SINGLE-PLY ROOFS — MODIFIED BITUMINOUS

A. **New Roofing and Reroofing**

These systems may be applied using the guidelines for fully-adhered, single-ply above (or, for that matter, the built-up roofing guidelines) with only one important additional recommendation:

- Torches melt EPS. Some adhesives attack EPS. Overlayments must be applied to the EPS insulation. Heat from torches and high solvent-based adhesives must be isolated from the EPS. Taped joints are strongly recommended. Careful indoctrination of applicators is strongly recommended.

A few additional precautions:

• **Flammability**

Like many other construction products, expanded polystyrene is combustible and should not be exposed to flame or other ignition source.

• **Job Site Solvents**

Some of the cleaning, solvent-welding and lap-sealing chemicals used in the application of single-ply membranes will attack polystyrene. Though a chemical barrier sheet between the EPS insulation and the membrane affords protection for the EPS, the contractor should exercise due care to make sure that such chemicals do not come in contact with the EPS insulation.

• **Thermal Welding**

Welding of seams in single-ply membranes should be done carefully to avoid softening or melting the EPS insulation underneath.

• **Ultraviolet Degradation**

Prolonged exposure to sunlight will cause a slight discoloration of EPS insulation and can create a friable board surface. Though the insulation properties will not be significantly affected unless exposure is so excessive that thickness is lost, the friable surface can make bonding difficult. For this reason, EPS insulation should be covered if it is to be stored in the open for extended periods. Discolored boards can often be swept clean to expose sound material for a satisfactory bond.

• **Storage and Handling**

Like all other roofing materials, EPS insulation should not be installed when its surface is wet. Make sure boards of EPS are completely dry. If possible, store under roof or cover with a light-colored opaque material.

Boards of EPS stored or stacked awaiting installation should be weighted down to prevent them from being blown away.

Similarly, installed boards should be secured to the deck or covered by the membrane as soon as practical. EPS insulation is best fabricated with simple hand tools to fit corners, edge stops, and parapet walls and around pipes, vents, chimneys, air-conditioning units or other projections. Knives and hand saws work best.

NOTE: Field experience has shown that any given roof system installation may present unique problems for which the foregoing may provide assistance but not a total solution. Accordingly, when proceeding with actual application of a roofing system it will be necessary to obtain expert design advice and complete specifications for that application.

REFERENCES:

1. Wayne Tobiasson and John Ricard, U.S. Army Cold Regions Research and Engineering Laboratory, Hanover, New Hampshire, **Moisture Gain and Its Thermal Consequence for Common Roof Insulations**, reprinted from Proceedings 5th Conference of Roofing Technology, April 19-20, 1979.

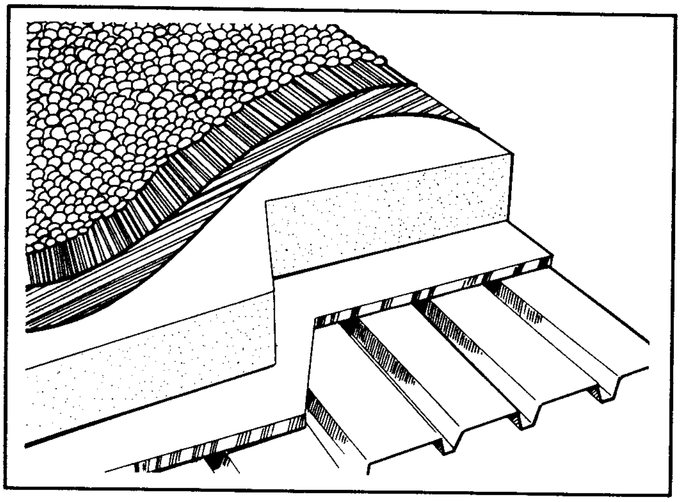

FIGURE 1
A typical ballasted single-ply system showing (top to bottom) stone ballast, membrane, optional plasticizer barrier sheet, EPS insulation, and thermal barrier over a steel deck.

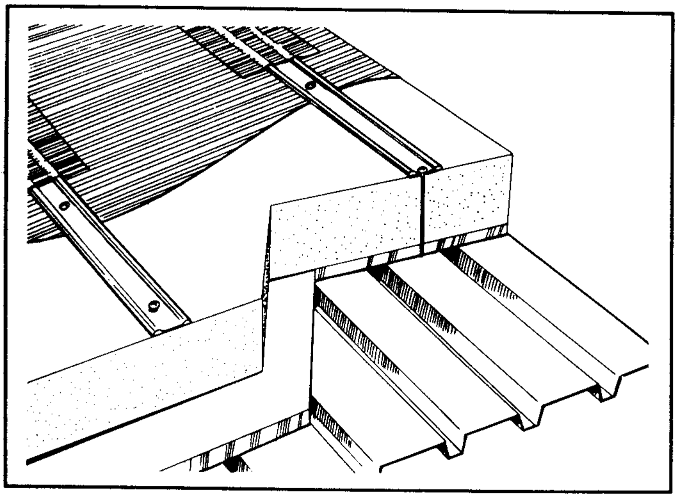

FIGURE 2
A mechanically attached single-ply system using batten strips covered with lengths of membrane material and solvent welded to the membrane. EPS insulation and a thermal barrier over a steel deck form the rest of the system.

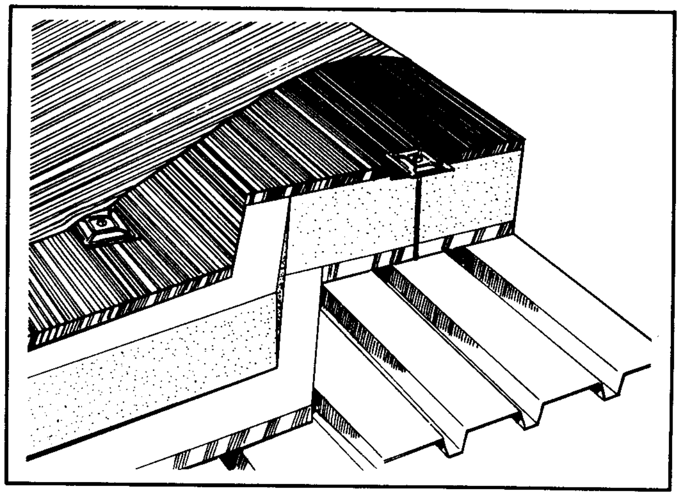

FIGURE 3
Fully adhered, mechanically attached single-ply system. EPS insulation—with a thermal barrier below and 1/2" of wood fiber board above—is mechanically anchored to the deck. The single-ply membrane is applied with a full coating of adhesive.

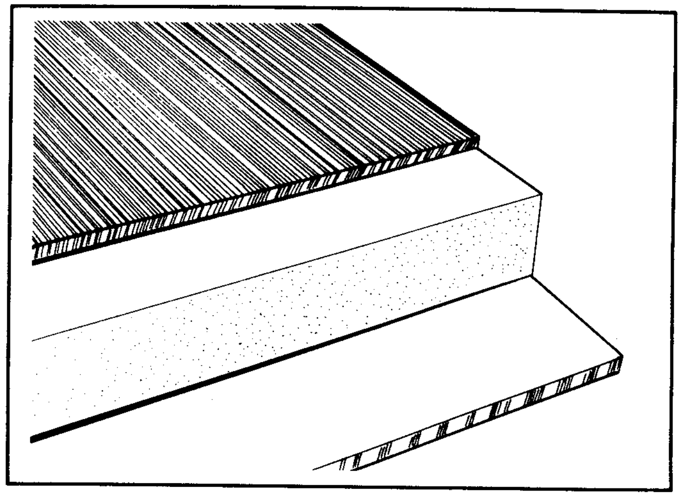

FIGURE 4
Sandwich panels of EPS insulation with a thermal barrier below and protective top surface are available from many manufacturers of EPS. Panels may be applied with asphalt or mechanical fasteners.

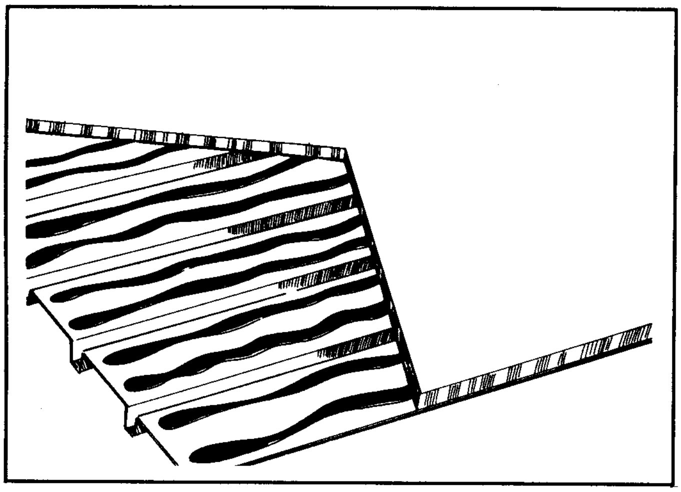

FIGURE 5
First layer of a BUR system over a steel deck is a thermal barrier (gypsum board, perlite, or fiber board) applied in ribbons of asphalt.

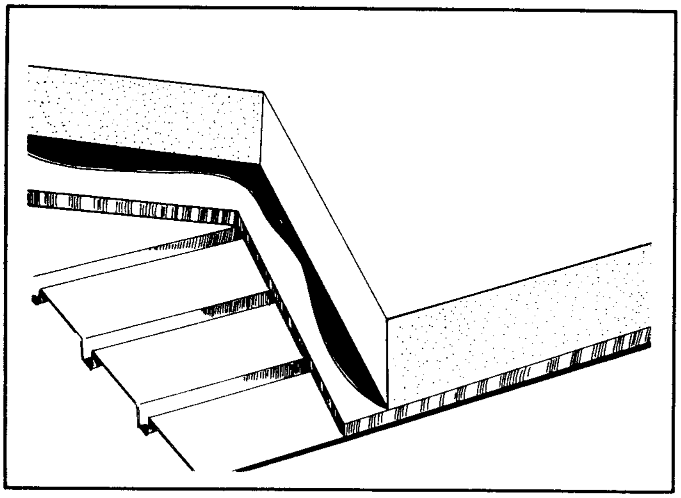

FIGURE 6
Second layer is EPS insulation applied in a full mopping of asphalt, cooled to 225-250°F.

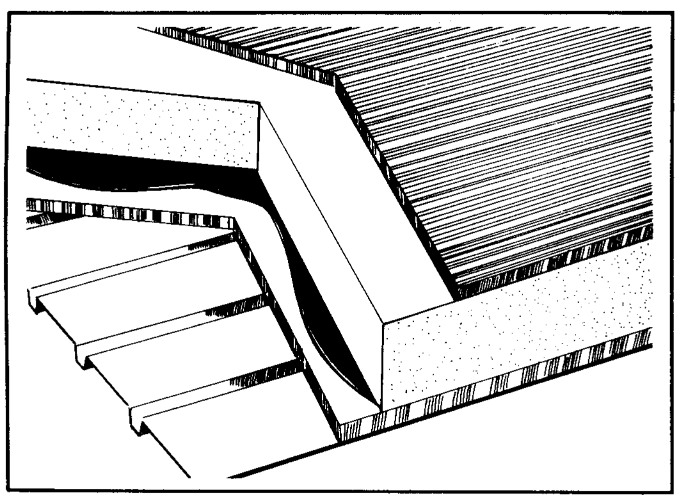

FIGURE 7
Third layer of BUR system is an overlayment, usually wood fiber board, applied with mop-and-flop method.

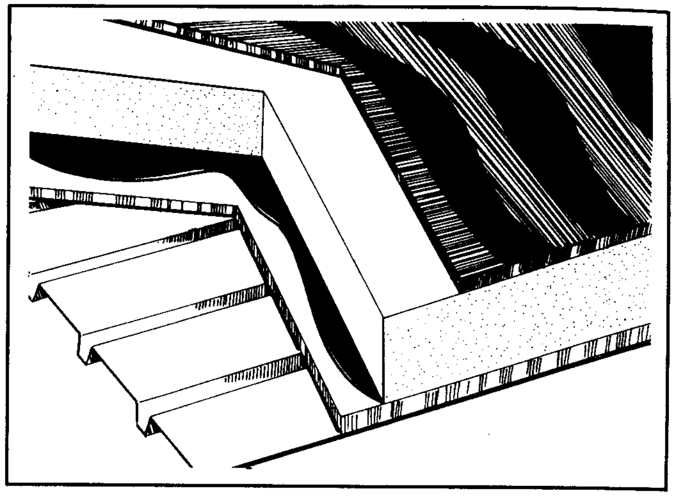

FIGURE 8
The BUR membrane is then applied to the overlayment according to manufacturer's specifications.

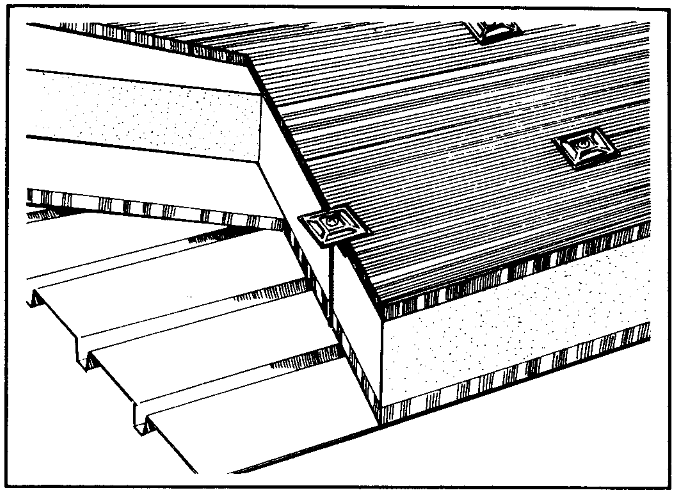

FIGURE 9
An alternative method for BUR systems: the first three layers (thermal barrier, EPS insulation, overlayment) are loose-laid and mechanically attached.