FIELD TEST RESULTS OF EXPERIMENTAL EPDM AND PUF ROOFING

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For several years, the Department of Defense has been spending more than $100 million a year for maintenance, repair and replacement of its inventory of built-up roofing (BUR). Roofs expected to last for 20 or more years have had an average life of eight to 12 years and many have failed in two years or less. Because of this record, the U.S. Army Corps of Engineers began investigating alternatives to BUR during the mid 1970s.

The first materials selected for field testing under controlled conditions were EPDM synthetic rubber and sprayed polyurethane foam (PUF) with suitable elastomeric coatings. To determine climatic effects on the materials, sites were selected in different areas of the country: Fort Benning, Ga, Fort Knox, Ky., and Fort Lewis, Wash. Both PUF and EPDM roofs were constructed at Fort Lewis and Fort Benning. At Fort Knox, only a PUF roof was installed. The EPDM was installed at Fort Benning and Fort Lewis as a fully adhered system. Data from Fort Knox are incomplete and are not shown in this report.

DESCRIPTION OF TEST PROGRAM

The test program was undertaken to determine the effect of weathering on the mechanical and physical properties of the materials and, to some extent, of the systems. The specific properties selected for study were those deemed essential for successful performance as roofing materials. ASTM test methods were used for the most part, but in a few cases, it was necessary to use tests developed by the United States Bureau of Reclamation (USBR) or the Navy Civil Engineering Laboratory (NCEL).

We also wanted to determine the immediate effect of ambient conditions on the roofing materials. We installed thermocouples below and above the roofing systems and strain gauges on the membrane surfaces. Weather recording stations also were installed.

It was not possible to obtain long-term, meaningful data from the instrumentation, as the strain gauges began to deteriorate after about a year and were completely useless after 18 months. This instrumentation is mentioned only to show that it was considered, and that an attempt was made to measure the movement. Results of these tests are reported in CERL Report M-357.

This discussion is limited to the results of the first two years of testing. Samples taken after the initial two-year period have not yet been tested, so further results are not yet available. The entire program is scheduled to last 10 years. During this time, our roofs will have been subjected to extreme abuse. When you take five samples every six months for two years, plus five samples every year for eight more years, plus about 10 initial samples, you have a total of 70 samples cut out of each test roof. If it should develop that a roof can no longer be repaired before the 10 years will have elapsed, the test will be terminated and the roof membrane removed and replaced with one that will not be disturbed.

EPDM TEST RESULTS

Graphs of the EPDM properties were plotted using the average values from each set of five samples. For simplicity, only the tests in the longitudinal direction are used for tensile and elongation properties. As may be expected, the membranes at Forts Benning and Lewis have aged differently. Tests indicated that the material was not fully cured when installed. The near-tropical climate at Fort Benning caused the membrane to age more rapidly than it did at Fort Lewis. This difference in aging is evident in all the graphs except that the elongation values were the same at both places. The peel strength of the seams was too widely scattered at Fort Benning to be significant and is not shown.

A change in the EPDM surface has been evident at Fort Benning, but so far it has not been possible to quantify it. Apparently because of the effects of the intense solar radiation, the surface degradation of the EPDM membrane has made it more difficult each time to repair the hole where the sample specimen has been removed. We have been in close contact with the manufacturer about this and he has been recommending procedures for us to follow. A large amount of buffing and abrasion is necessary before a surface is obtained to which the adhesive will bond. If the membrane ever deteriorates to the point where it cannot be repaired, then it can be considered to have failed and the roof will have to be replaced. The surface at Fort Lewis has not degraded at all.

The effect of climate is most evident in the changes which have occurred in tensile strength (*Figure 1*) and hardness (*Figure 4*). Tensile strength increased until it peaked. However, it took almost twice as long to reach this peak at Fort Lewis as it did at Fort Benning. Tensile strength is the only mechanical property that exhibited this behavior. A somewhat similar behavior was noted for the water vapor transmission at Fort Lewis, which is a physical property (*Figure 3*), peaking at approximately the same time as the tensile strength. However, there is no known relationship between tensile strength and water vapor transmission. Elongation values essentially were the same at both locations (*Figure 2*), showing a decrease at a decreasing rate. The seam strengths exhibited inconsistent behavior. Shear strength increased at Fort Benning but decreased at Fort Lewis (*Figure 5*). It was not possible to make comparisons of peel strength between the two locations because of sample conditions. Observations of the seam area from the Fort

Benning samples after separation indicated that the sheet was not completely cleaned of talc coating before the seam cement was applied. The values at Fort Lewis are shown in Figure 6.

The effect of climate on physical properties is most consistent for hardness (*Figure 4*), abrasion resistance (*Figure 7*), water absorption (*Figure 8*), and glass transition temperature (*Figure 9*), where, in each case, the more severe climate at Fort Benning has a greater effect on the changes in the particular property than does the milder climate at Fort Lewis.

PUF TEST RESULTS

The PUF roofing also demonstrated changes in mechanical and physical properties. Changes were evident not only in the foam and the coating but also in the bond between them. In most cases, the changes at Forts Benning and Lewis were similar. The exceptions were for density (*Figure 10*), tensile strength (*Figure 12*), and impact strength (*Figure 14*), where the curves indicate opposite changes with times. Since the foams used were the products of two different manufacturers, it is possible that these different aging histories are the result of different formulations. It should be noted here that the tensile test in reality measures the bond between lifts of foam, the value at break being that at the weakest interface. In all of the tensile tests, the failure was always at the lift interface.

Because PUF, as used in spray-applied roofing insulation, is essentially "manufactured" at the site with various ambient conditions rather than under controlled conditions, trends can be more important than the value of the properties which may result from a variance in any one of many ambient conditions. In other words, the way the material behaves as time passes can be more important than the numerical value of any given property at any specific time.

Although the density at Fort Benning demonstrates an increase of 22 percent in 18 months, this change is not reflected in the changes in compressive strength, which remained essentially constant. Today's industry standard as published by the Urethane Foam Contractors Association in their *Design Considerations and Guide Specifications* for both New Roofing and Remedial Roofing requires the foam to have a minimum compressive strength of 40 pounds per square inch and it is readily seen from Figure 11 that both installations meet this requirement. Annual inspections at Fort Lewis and Fort Benning have not indicated any evidence of delamination of the foam so the changes in tensile strength (*Figure 12*) may be of academic interest only. Changes in indentation strength (*Figure 13*) roughly parallel the changes in compressive strength (*Figure 11*), which should be anticipated. Impact strength changes as seen in Figure 14 are not consistent, but, as hail is extremely rare in the Tacoma, Wash., area, this decrease is not at present considered a cause for concern. The decreasing water absorption (*Figure 15*), along with the increasing compressive and indentation strengths, all indicate an age-hardening of the foam structure, accompanied by an increasing resistance to water penetration, all of which are desirable. As the material becomes harder, it is more resistant to hail or other impact damage.

The decrease in coating adhesion at Fort Lewis (*Figure 16*) is not considered serious as it has been very slight. The decrease at Fort Benning, however, may be of great concern if it continues. It should be mentioned that the Fort Lewis coating consists of a catalyzed urethane base coat with a hypalon top coat, while the Fort Benning coating consists of two layers of silicone. The continued annual inspections will indicate whether either coating is coming loose from the foam.

The vapor transmission properties and glass transition temperatures have remained, for all practical purposes, essentially constant.

The sampling and testing of these roofing systems will continue until a total of 10 years has elapsed since construction. This will occur in 1990. At the end of this period, we will have learned much about the effects of different climates on these materials, and on the ability to make repairs in case of damage.

In the meantime, certain conclusions can be drawn from this work:

EPDM single-ply membrane roofing, when properly applied and maintained, is a good material for use, having demonstrated its ability to retain its properties for a long period of time. The effect of climate on the surface characteristics does not seem to influence the property changes, at least within the time frame of this report. Surface change will bear careful watching, however, as the membrane will be considered as having failed if it can no longer be repaired.

It is to be noted from the curves that in most cases, the initial properties of the EPDM vary between the two sites. However, the values always exceed the minimums specified by the manufacturer, and it is to be expected that actual numerical values will vary from batch to batch. Also, all of the properties are still within the values as stated by the manufacturer, (except for the seam strengths for which no values are published) and all of the properties seem to be levelling off with time.

No direct comparison can be made between the two PUF roofs as regards the initial properties. Since they are the products of two different manufacturers, the chemical compositions are assumed to be different, in which case the properties also are bound to be somewhat different. These chemical compositions are proprietary and so are not known. As with the EPDM, the PUF properties also seem to level off with time. The exception here is the density, which will require additional time to make this determination.

For the present, we are satisfied with the results of the tests to date. Both systems probably will provide us with roofs that will perform satisfactorily for the 10-year test period. Five years from now, I may be able to give you a final report.

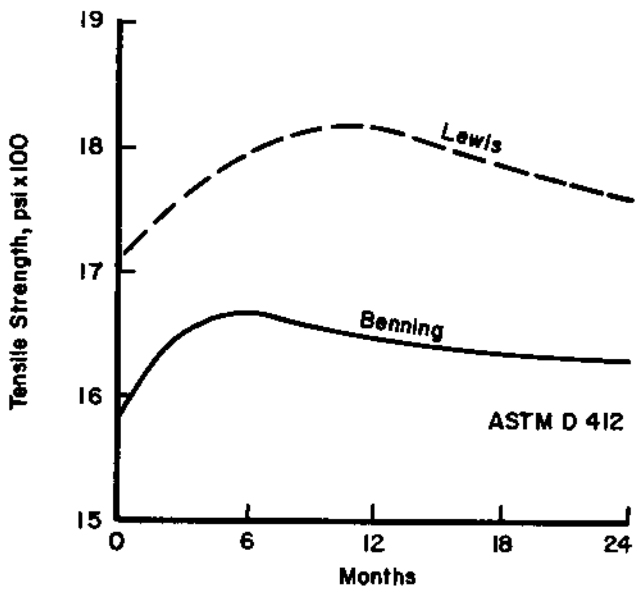


Figure 1 EPDM tensile strength

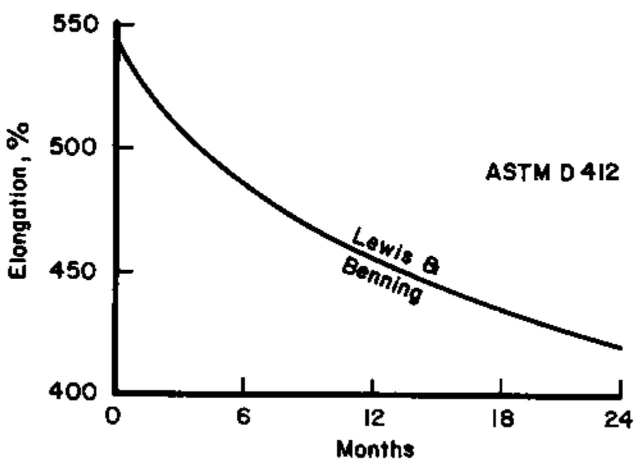


Figure 2 EPDM elongation

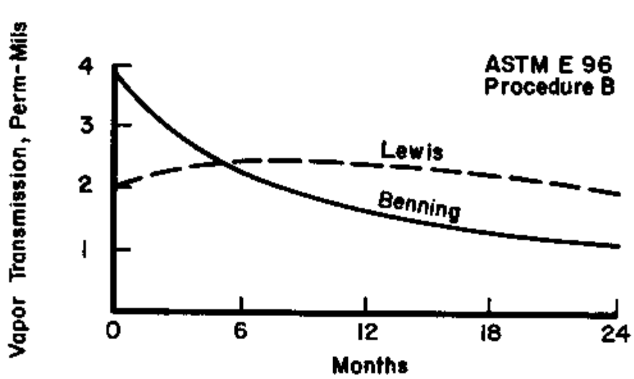


Figure 3 EPDM water vapor transmission

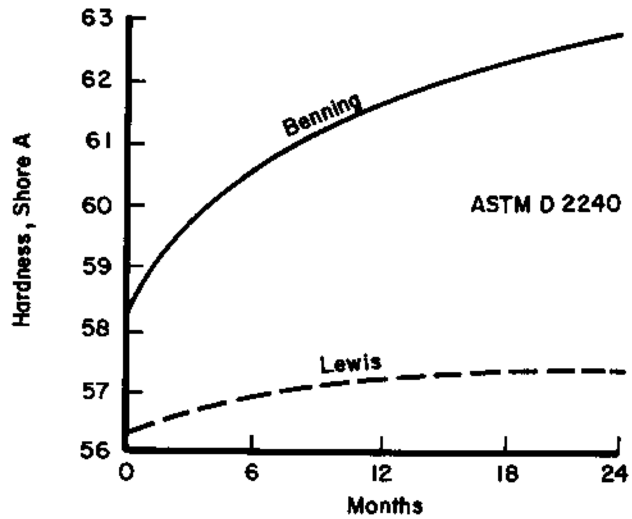


Figure 4 EPDM hardness

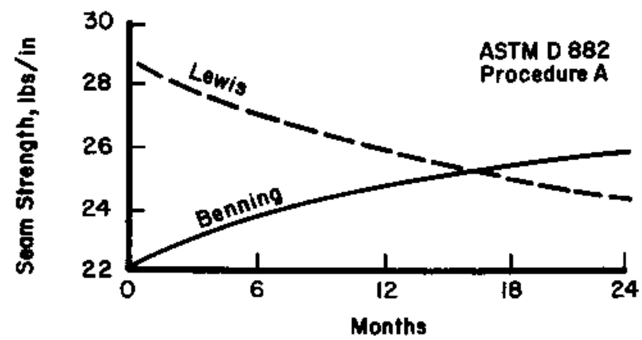


Figure 5 EPDM seam shear strength

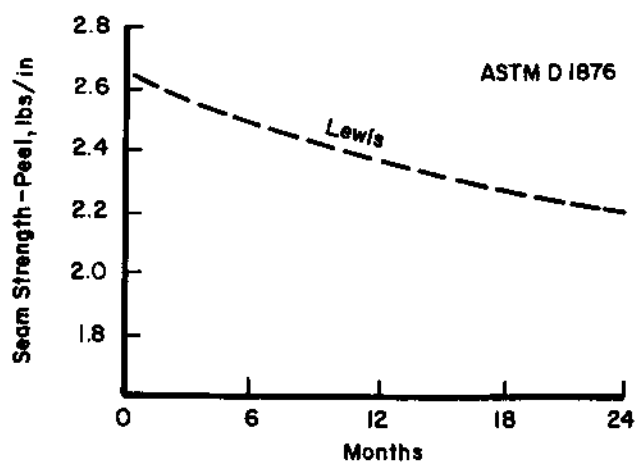


Figure 6 EPDM seam peel strength

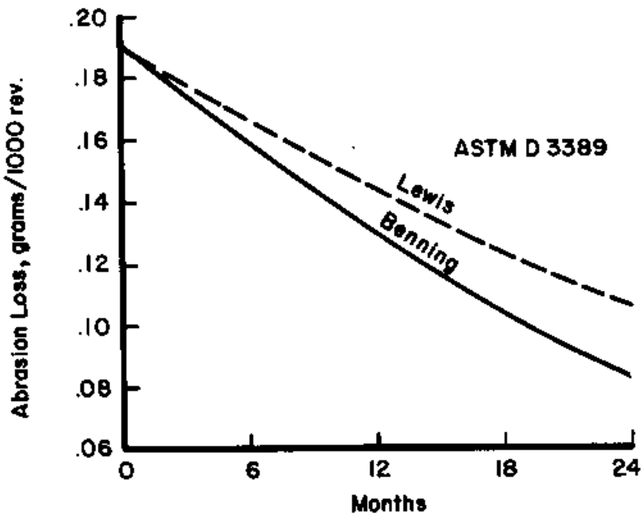


Figure 7 EPDM abrasion resistance

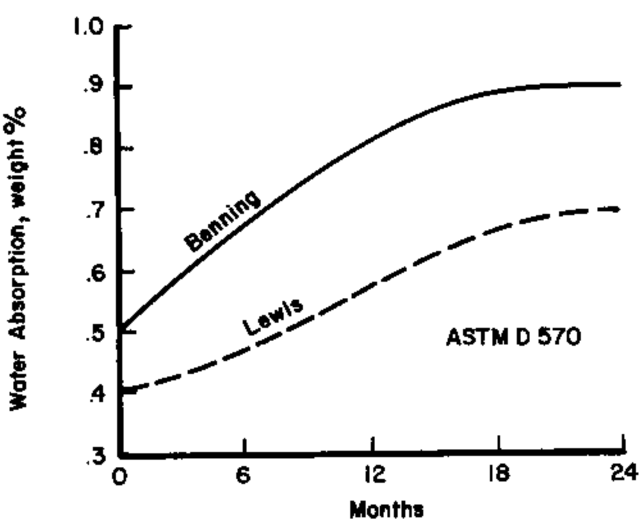


Figure 8 EPDM water absorption

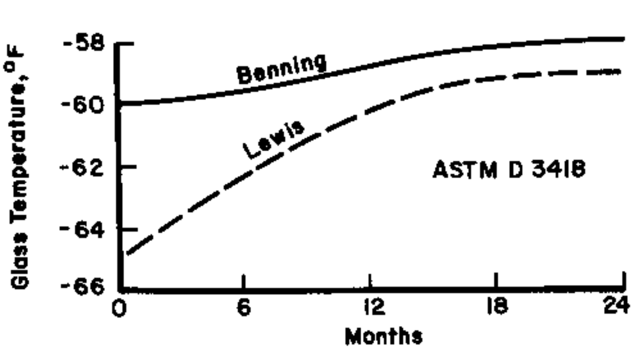


Figure 9 EPDM glass temperature

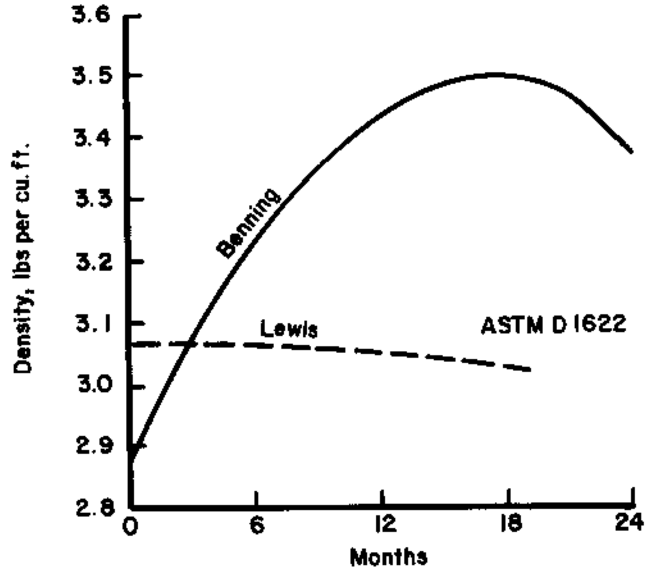
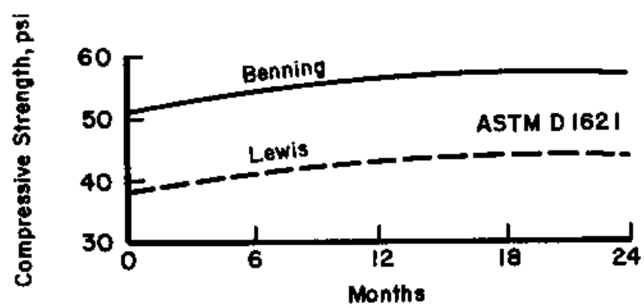


Figure 10 PUF density



Figue 11 PUF compressive strength

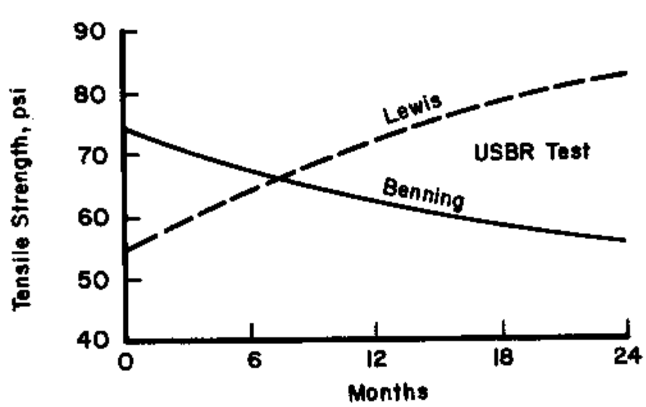


Figure 12 PUF tensile strength

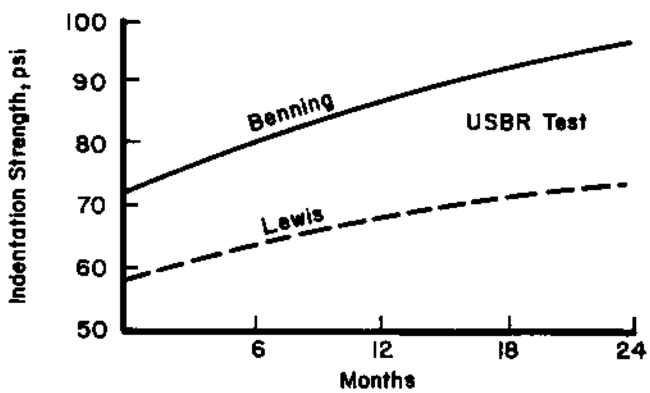


Figure 13 *PUF & coating indentation strength*

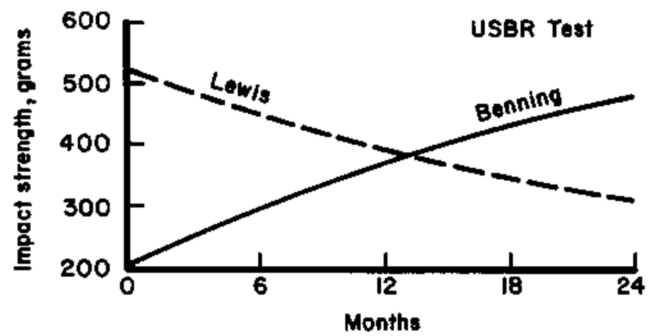


Figure 14 *PUF & coating impact strength*

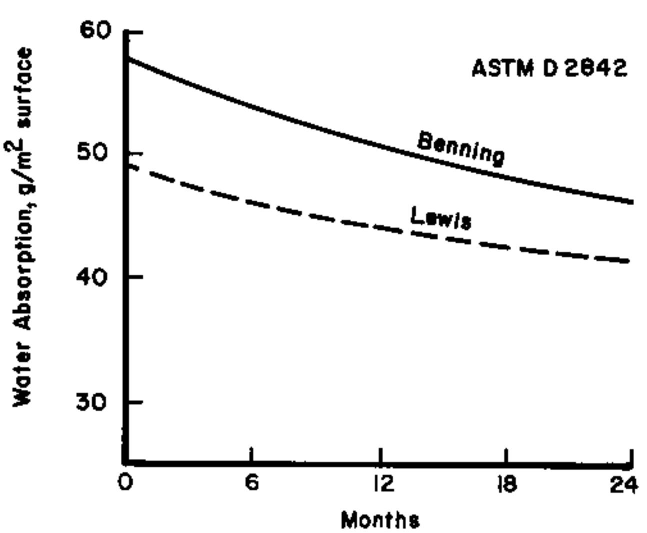


Figure 15 *PUF water absorption*

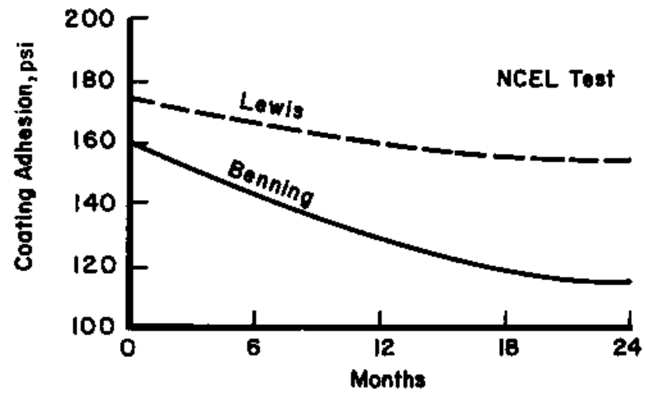


Figure 16 *Coating adhesion*

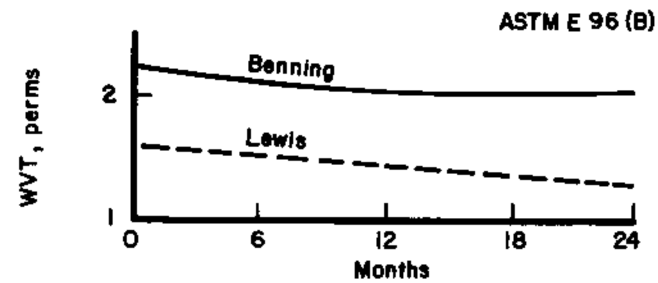


Figure 17 *Coating vapor transmission*

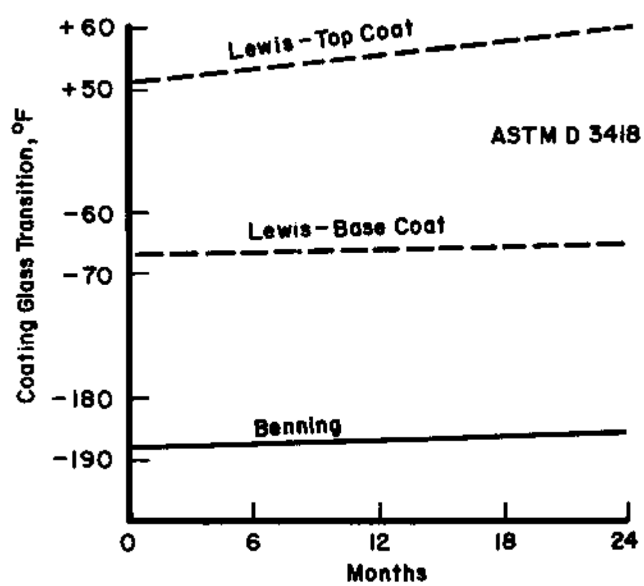


Figure 18 *Coating glass transition*