BUILDING SCIENCE SERIES 19

A Study of the Variables Involved in The Saturating of Roofing Felts

U.S. DEPARTMENT OF COMMERCE
National Bureau of Standards

Announcing—The Building Science Series

The "Building Science Series" disseminates technical information developed at the Bureau on building materials, components, systems, and whole structures. The series presents research results, test methods, and performance criteria related to the structural and environmental functions and the durability and safety characteristics of building elements and systems.

These publications, similar in style and content to the NBS Building Materials and Structure Reports (1938–59), are directed toward the manufacturing, design, and construction segments of the building industry, standards organizations, officials responsible for building codes, and scientists and engineers concerned with the properties of building materials.

The material for this series originates principally in the Building Research Division of the NBS Institute for Applied Technology. Published or in preparation are:

BSS1. Building Research at the National Bureau of Standards. (In preparation.)
BSS2. Interrelations Between Cement and Concrete Properties: Part 1, Materials and Techniques, Water Requirements and Trace Elements. 35 cents
BSS3. Doors as Barriers to Fire and Smoke. 15 cents
BSS4. Weather Resistance of Porcelain Enamels: Effect of Exposure Site and other Variables After Seven Years. 20 cents
BSS5. Interrelations Between Cement and Concrete Properties: Part 2, Sulfate Expansion, Heat of Hydration, and Autoclave Expansion. 35 cents
BSS6. Some Properties of the Calcium Aluminoferrite Hydrates. 20 cents
BSS7. Organic Coatings. Properties, Selection, and Use. $2.50
BSS8. Interrelations Between Cement and Concrete Properties: Part 3, Compressive Strengths of Portland Cement Test Mortars and Steam-Cured Mortars. 55 cents
BSS9. Thermal-Shock Resistance for Built-Up Membranes. 20 cents
BSS10. Field Burnout Tests of Apartment Dwelling Units. 25 cents
BSS11. Fire Resistance of Steel Deck Floor Assemblies. 25 cents
BSS12. Performance of Square-Edged Orifices and Orifice-Target Combinations as Air Mixers. 15 cents
BSS13. Shrinkage and Creep in Prestressed Concrete. 15 cents
BSS14. Experimental Determination of Eccentricity of Floor Loads Applied to a Bearing Wall. 15 cents
BSS15. Interrelations Between Cement and Concrete Properties: Part 4, Shrinkage of Hardened Portland Cement Pastes. 75 cents
BSS16. Techniques for the Survey and Evaluation of Live Floor Loads and Fire Loads in Modern Office Buildings. 40 cents
BSS17. Causes of the Variation in Chemical Analyses and Physical Tests of Portland Cement. 40 cents
BSS18. Smoke and Gasses Produced by Burning Aircraft Interior Materials. 35 cents.

Send orders with remittance to: Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402. Remittances from foreign countries should include an additional one-fourth of the purchase price for postage.

[See mailing list announcement on last page.]

UNITED STATES DEPARTMENT OF COMMERCE • Maurice H. Stans, *Secretary*

NATIONAL BUREAU OF STANDARDS • A. V. Astin, *Director*

A Study of the Variables Involved in the Saturating of Roofing Felts

Sidney H. Greenfeld

Research Associate
Asphalt Roofing Manufacturers Association*
*(Formerly Asphalt Roofing Industry Bureau)

Building Research Division
Institute for Applied Technology
National Bureau of Standards
Washington, D.C. 20234

Building Science Series 19

Nat. Bur. Stand. (U.S.), Bldg. Sci. Ser. 19, 18 pages (June 1969)
CODEN: BSSNB

Issued June 1969

For sale by the Superintendent of Documents U.S. Government Printing Office
Washington, D.C. 20402 - Price 30 cents

Contents

	Page
1. Introduction	1
2. Materials	2
2.1. Felts	2
2.2. Saturants	2
3. Apparatus	3
4. Procedures	4
5. Results and discussion	4
5.1. Contact times	4
5.2. Moisture and temperature	5
5.3. Spacers on press rolls	7
5.4. Pressure	9
5.5. Moisture absorption	11
5.6. Air permeability	15
6. Conclusions	15
7. References	16
8. Glossary	16

A Study of the Variables Involved in the Saturating of Roofing Felts

Sidney H. Greenfeld

The degree of saturation of a #27 [1] felt with a typical roll saturant and a #55 felt with roll, mixed, and shingle saturants varied with saturation time and pressure, saturant temperature and viscosity, felt conditions, and press roll pressure and clearance. Optimum temperature and viscosity ranges were determined for each asphalt-felt combination. Both pressure and vacuum increased the completeness of saturation under optimum conditions, but frequently shortened the working temperature range in which optimum saturation could be produced.

Rate and degree of moisture and liquid water absorption decreased with increasing saturation. Air permeability decreased with increasing saturation. The consequences of some of these findings are discussed.

Key words: Asphalts, felts, moisture, absorption, roofing, saturation.

1. Introduction

The function of a roofing felt is to supply a strong backing for a weather-resistant asphalt coating. When used in the manufacture of prepared roofing, the felt permits the product to be cut into appropriate designs, packaged, handled, and applied without distortion. When used in built-up roofing, it serves to isolate the several layers of waterproofing and provides the strength necessary for large areas of roofing to cope with the environmental stresses to which the roof membrane is subjected.

In order for the felts to function properly over a period of time, they must be protected both externally and internally, for the felts themselves are vulnerable to the weather.

The internal protection is provided by a light bituminous saturant applied through a series of dips, or sprays and dips, as described by Abraham [1] [2] and Krchma [2]. The external protection is provided by the coating applied to both the weather side and back of the roofing. This coating will not be discussed.

Complete saturation is very difficult to achieve commercially, for modern roofing machines operate at 250 to 500 lineal feet [3] per minute and frequently allow times of less than 1 min for saturation to occur. During this time, the felt, usually at room temperature with 5 to 7 percent moisture, must be heated to the saturant temperature, dried, and saturated. The final stages of saturation actually occur beyond the saturant baths, where the liquid saturant on the felt surfaces is drawn into the felt as the felt cools.

The saturant in the vicinity of the felt is cooled as the felt is heated and the moisture evaporated. Thus, its increased viscosity at this lower temperature tends to slow the penetration of the saturant into the felt. This cooling effect also makes it possible for the felt to carry more saturant with it from the saturator. (A typical saturator running at 400 ft per min would saturate 12 squares of felt per minute. At 6 percent moisture content, about 15,000 Btu [4] per minute would be required to heat the felt and evaporate the moisture. This quantity of heat, if supplied entirely by the saturant used in saturating those 12 squares of felt, would lower the saturant temperature about 135 °F (57 °C). In practice, there is agitation in the saturator and heat is supplied by saturant other than that which actually enters the felt; however, all of this heat must be furnished by heating the saturant to temperatures in excess of that desired.) Thus, optimum conditions must be found for particular felt-saturant systems.

While, in principle, it is desirable to protect the felt by saturating it as completely as possible, poor adhesion of coating to felt in shingles and roll roofing may result if a large excess of saturant is permitted to remain on the felt surface. Incompatibility and coating slippage problems (through thinning of the coating by the excess saturant) are aggravated by this condition. In the case of saturated felts, sticking in storage under over-saturated conditions is possible. Thus, when specifications are written, compromise saturations are required.

In asphalt shingles 170 percent saturation (saturant weighing 1.70 times as much as dry felt) is the minimum permitted. For roll roofing this minimum is dropped to 160 percent, and for saturated felt it is dropped further to 140 percent. These figures are the compromises made to accommodate production, storage, and application requirements. Theoretically, completely impregnated felt can hold more than 235 percent [5] of its weight in satu-

[1] Please see the glossary for definitions of unfamiliar terms or words used in this publication.
[2] Figures in brackets indicate the literature references on page 16.
[3] One foot equals approximately 0.3 meter.
[4] One Btu equals approximately 1.05×10^3 joules.
[5] Calculated on the assumption that the felt is cellulose with a specific gravity of 1.53 [3], the ratio of space to cellulose in felt is 2.35. If felt is assumed to be similar to cotton linters, true density values of 1.55–1.61 would have to be used [4] and a somewhat higher theoretical porosity obtained.

rant. Asphalt capacities of about 210 percent by the vacuum method [6] and 195 percent by the buret method [6] may be more realistic values to try to attain commercially.

Contemporary commercial saturating techniques produce felts meeting the specifications and exceeding them only by small margins. Improved techniques could lead to tighter specifications and better internally protected felts.

Based on these considerations, a study was undertaken to investigate the felt-saturating process and determine the effects of temperature, pressure, moisture, time, and saturant on the saturation of organic felts.

2. Materials

2.1. Felts

Two grades of commercial felt were used. These were taken from the normal production of a major felt manufacturer and slit into 12-in [7] rolls for this project. These felts had the characteristics reported in table 1.

TABLE 1. *Felt characteristics* [a]

Grade number	27	55
Dry weight, lb/480 ft²	27	53
Caliper, mils (mm)	33 (0.84)	64 (1.63)
Tensile strength, machine direction (Scott) [d], lb/in [e]	31	40
Tensile strength, cross direction (Scott) [d], lb/in	15 [b]	21 [b]
Densometer, seconds/400 cm³	18 (16.2) [b]	18 (18.3) [b]
Asphalt capacity	183 [c] (177) [b]	197 [c] (187) [b]
Moisture (as received), percent	4.1	4.1

[a] Manufacturer's data.
[b] Determined at NBS.
[c] These numbers are based on a specific gravity of 1.035 for the saturant. When converted for a saturant of specific gravity of unity, as used in this program, these figures become 177 (#27 felt) and 190 (#55 felt).
[d] Scott Tester—speed 12 in/min.
[e] One pound=approx 0.45 kg.

The furnish of the felt was not supplied; the ratios of wood fibers, rags, and papers were continually being adjusted during production to keep the felt properties uniform. The furnish contained oak and pine fibers, along with No. 1 waste paper and rags.

2.2. Saturants

Two saturants were obtained from a Kansas refinery. These consisted of a soft, roll saturant and a hard, shingle saturant. These two were blended to produce a third saturant, termed a "mixed" saturant. The properties of these three materials are listed in table 2. The viscosity-temperature relations (determined with a Brookfield Viscometer) are presented in figure 1. The selection of ordinates has been found useful in characterizing the saturants since a straight-line relationship is thus obtained. No theoretical significance can be attached, for the fahrenheit scale of temperature is completely arbitrary in nature.

TABLE 2. *Properties of saturants*

Saturant	Roll	Shingle	Mixed
Softening point, °F (°C)	111 (44)	141 (61)	125 (52)
Penetration at 77 °F, 1/10 mm	139	48	81
Penetration at 32 °F, 1/10 mm	—	18	23
Specific gravity, 77/77 °F	0.9954	1.0002	—
Flash point (C.O.C.), °F (°C)	630 (332)	625 (329)	625 (329)
Loss on heating, 5 hr at 325 °F, percent	0	0	0
Solubility in CCl_4, percent	99.4	99.4	99.4

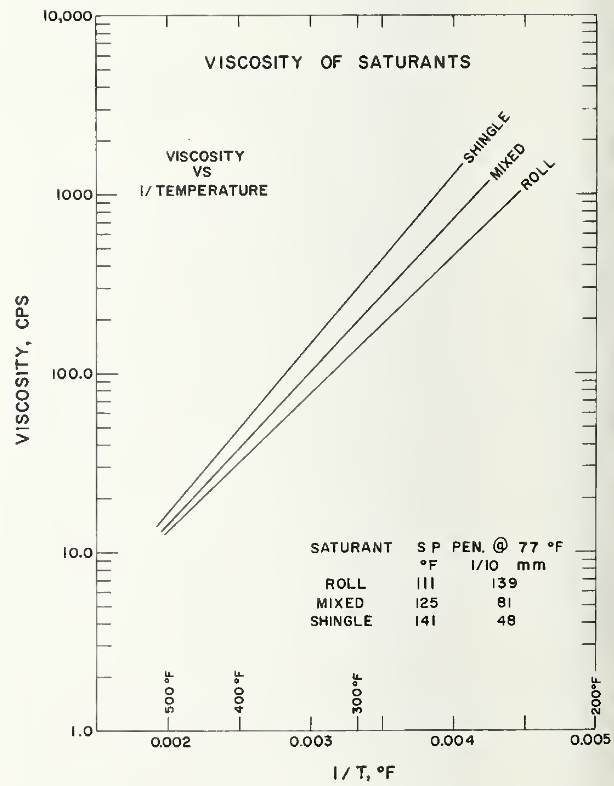

FIGURE 1. *Viscosity of saturants.*

The mixed saturant was obtained by blending the shingle and roll saturants to produce a saturant with properties approximately mid-way between the two.

[6] Vacuum Method ASTM D 727
Buret Method ARIB No. 2.125
[7] One inch=2.54 cm.

3. Apparatus

Three apparatuses were used in this study. For all specimens saturated at atmospheric pressure, the apparatus shown in figure 2 was used. For those saturated under vacuum or pressure, the apparatuses in figures 3 and 4, respectively, were used.

The apparatus used for saturating at atmospheric pressure consisted of a stainless-steel saturant pan 7 in × 9 in × 2 in and press rolls. The pan was heated on a thermostatically controlled hot plate capable of temperatures up to 600 °F (316 °C). Once the specimens were saturated, they were passed through the heated, manually operated rolls shown to the left in figure 2. These rolls were provided with pressure adjustments to permit pressures resulting from the weight of the roll and higher. For most of the saturations, the weight of the upper roll was the sole source of pressure. However, in one series of saturations, spacers consisting of multiple layers of 5-mil thick aluminum tape were used to permit controlled excesses of saturant to be carried on the felt. A thermostatically controlled air oven was used to maintain the saturated specimens at elevated temperatures (250° or 350 °F) (121° or 177 °C) for a period of time to simulate the soaking-in period between saturation and coating in commercial operation. A similar oven, maintained at 225 °F (107 °C), was used to dry the felt prior to saturation (when desired).

Whereas 6- × 8-in felt specimens were saturated at atmospheric pressure, under both vacuum and elevated pressures, smaller specimens, 1- × 2.5-in, were used. The saturator (fig. 3) in the vacuum studies was a 32- × 200-mm test tube heated in an aluminum block furnace. Vacuum was applied by a water aspirator and measured with a mercury manometer. The same furnace was used to heat a brass pressure vessel for the above-atmospheric pressure saturations, as shown in figure 4. Dry nitrogen was used to produce the pressure.

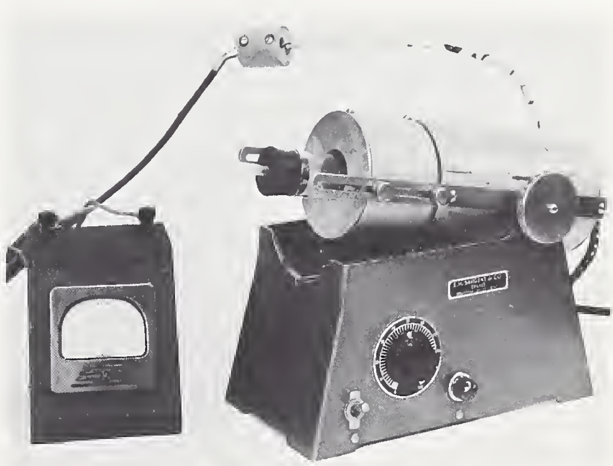

FIGURE 3. *Saturator used for saturations at pressures below atmospheric pressure.*

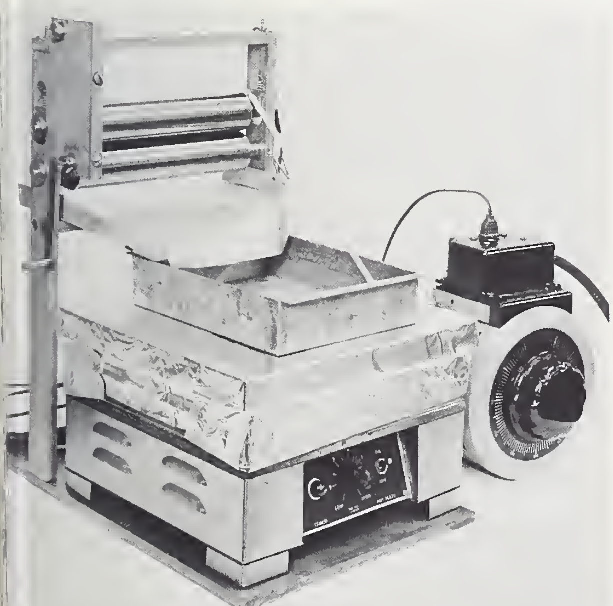

FIGURE 2. *Saturator used for all atmospheric pressure saturations.*

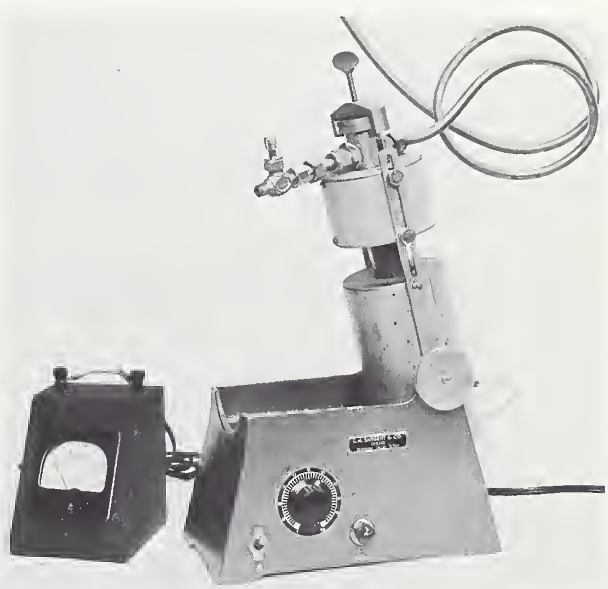

FIGURE 4. *Saturator used for saturations at pressures above atmospheric pressure.*

4. Procedures

The procedures followed while saturating felts at ambient pressure, under vacuum and at above-atmospheric pressure were different and, therefore, will be described separately. Every day, while the saturant was being heated, moisture determinations were made on two representative samples of felt. It was found that both the #27 and #55 felts required at least 45 min in an oven at 225 °F (107 °C) to be dried to constant weight. Therefore, the felts were heated in the oven for 1 hr and weighed immediately, for even in a desiccator the felts were found to absorb moisture. The average of two moisture determinations was used in calculating the percent saturation of the felts.

When the saturant in the pan had reached the desired temperature and the pressure rolls were at 240±10 °F (116±6 °C), a 6- × 8-in piece of felt was floated on the saturant for 1½ min, submerged for 2 min, passed once through the rolls, hung in the "soaking-in" oven at 250 °F (121 °C) for 5 min, and then weighed. This procedure was arbitrarily adopted because it required about 1½ min for the saturant to penetrate through the floating felt at 400 °F (204 °C) and it required about 2 min of complete submergence for the bubbling of gases and vapors from the felt to stop. Later in the work it was found that, with the 2-min-submergence time, saturation was independent of float time and, therefore, the float time was eliminated. It was also found that the "soaking-in" period for the commercial processes was more nearly 350 °F (177 °C) than the 250 °F (121 °C) being used in these saturations. The higher temperature seemed to reduce the number of felts rejected for "wetness" of their surfaces, but had no effect on the quantity of saturant remaining in the acceptable felts. Thus the saturation figures reported were not influenced appreciably when this temperature change was made.

In the vacuum series of saturations, the saturant was heated in the test tube as shown in figure 3. The felt was placed in the test tube above the saturant with the furnace inclined about 30°. The tube was evacuated. The furnace was rotated to a vertical position to permit the felt to submerge in the saturant. After the periods of time of submergence reported, the vacuum was broken, the specimen passed once through the rolls in the atmospheric-pressure apparatus, and soaked in the oven for 5 min at 250 °F (121 °C). Any excess saturant on the edges of these specimens was wiped off prior to final weighing, for this material was not part of the true saturation of the felt.

When saturating under pressure, the 1- × 2.5-in specimen was dropped directly into the saturant when the latter was at the desired temperature. The cover was fastened in place and the pressure raised rapidly to the desired level. After the desired time had elapsed, the pressure was released, the specimen passed through the heated rolls of the apparatus in figure 2, and hung in the oven for 5 min at 350 °F (177 °C). Excess saturant was wiped from the edges immediately prior to weighing.

In all instances, the reported value for each condition is the average of five specimens.

5. Results and Discussion

The saturating of organic felts is affected by many variables. Those involved in the furnish and production of the felt, or in the production of saturants, will not be considered; those relating to the saturating process, that is the conditions of the felt and saturant at the time of contact and their interactions during contact, will be discussed.

5.1. Contact Times

Large volumes of inert gases and vapors are released from organic felts when contacted with hot saturants. These expand and escape from the felt as the saturant penetrates and saturates it. There is obviously a conflict between these processes during saturation. A number of methods have been devised to cope with this problem. The most common procedure has been wetting the felt from one side, either by spraying hot saturant on it or by bringing the saturant into contact with one side only, and permitting the gases and volatiles to escape from the other side. This approach was simulated by floating the felt on the asphalt saturant surface prior to complete immersion. In figure 5 are the results of various times of floating prior to complete submersion for 1 or 2 minutes and various times of submersion with no float time for both the #27 and #55 felts. For the #27 felt, which is only about 30 mils thick, the method of processing had only a very limited effect on the degree of saturation; the percent saturation was essentially independent of the procedure. There is, however, a small, but consistent decrease in saturation with longer periods of exposure of the felts to the high temperature of the saturants. It is quite apparent that contact times between the #27 felt and saturants of more than a quarter-minute are adequate to produce saturations in excess of that required by current specifications (140 percent minimum).

Saturation of the #55 felt, on the other hand, was sensitive to the means by which the felt was saturated. When the felts were submerged without previous floating, the saturation increased progressively with time of submersion up to about 2 min; however, beyond about 1½ min, saturation was essentially independent of submersion time. When float time was followed by 2 min of submersion, the shorter float times produced the highest saturations. However, the results were essentially constant after 1 min of float time. Long submersion times were detrimental to the percent saturation. Based on these results, floating was eliminated and 2 min of submersion became the standard practice. This practice produced saturations of about 170 percent for the #55 felt and 150 percent for the #27 felt at 400 °F (204 °C) ; both would meet current specifications.

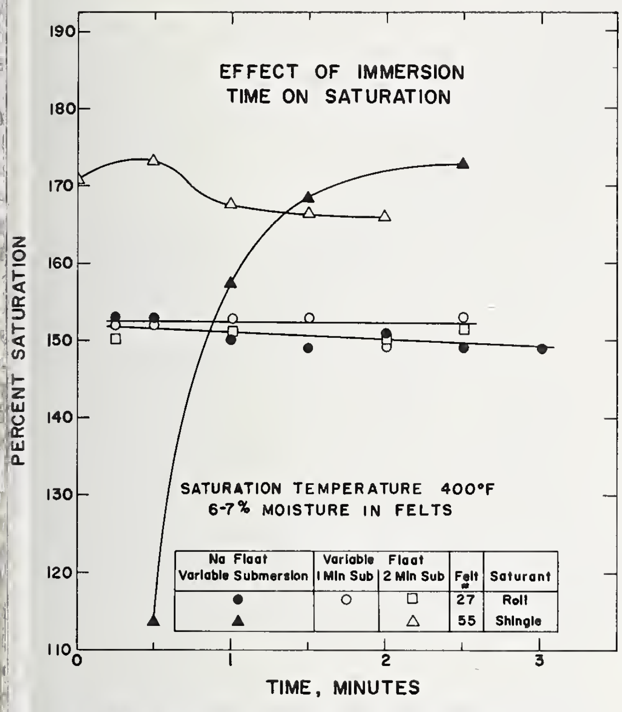

Figure 5. *Effect of immersion time on saturation.*

Because of its greater thickness, the #55 felt had saturating characteristics different from the #27 felt.

5.2. Moisture and Temperature

The roofing manufacturer usually has little control over the moisture content of the dry felt, for it varies widely with the relative humidity of the atmosphere in which the felt is stored. The data presented in figure 6 show how rapidly the felts absorb moisture from the atmosphere when exposed to relative humidities in the range of 30 to 75 percent. At higher relative humidities, the moisture content of the felts increases rapidly. At room temperature and 78 percent relative humidity (saturated sodium hyposulfite solution), the equilibrium moisture content of these felts was about 12 percent [8] and in a saturated atmosphere it was between 32 and 33 percent.

During the saturating process the moisture in the felt must be eliminated. In the process of being volatized, it absorbs large quantities of heat. As this moisture escapes, it slows the penetration of the saturant into the felt. However, moisture in the felt serves two beneficial purposes. Felts with moisture contents below about 3 percent are very brittle. They frequently tear in the commercial

[8] Moisture content is expressed on an "oven dry" basis rather than an "as received" basis.

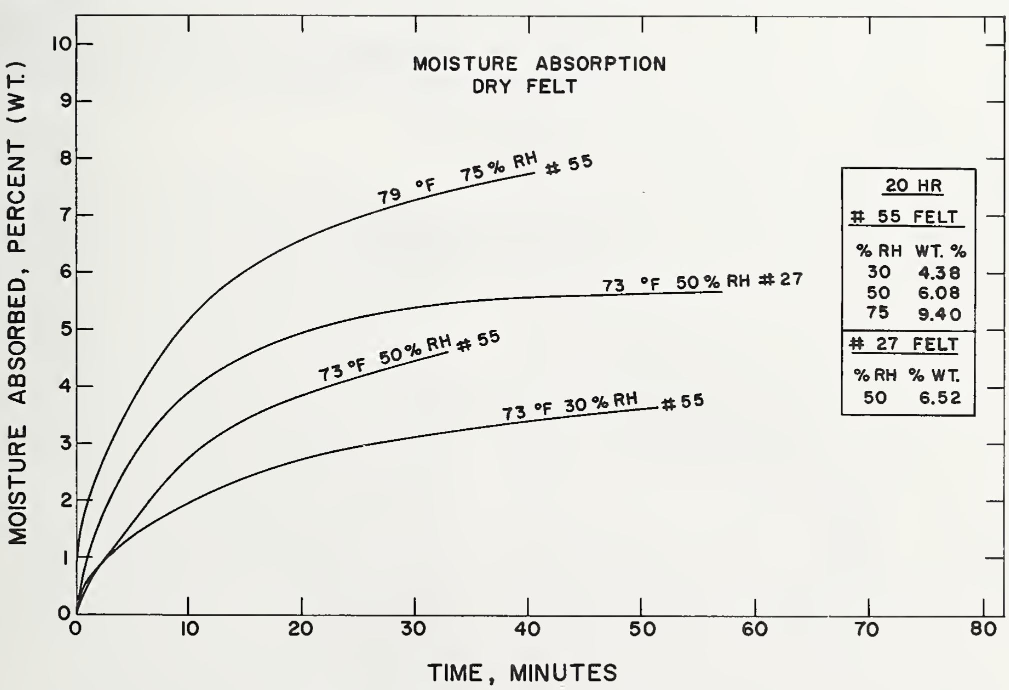

Figure 6. *Moisture absorption of dry felt.*

Dry felt, unprotected by saturant or coating, absorbs moisture very rapidly.

saturating process and require patching or rethreading of the machine. Thus, for continuous operation a minimum of 3 percent moisture is desirable. Moisture tends to lubricate the fibers or fiber bundles to permit their movement over each other and swells the fibers to permit the saturant to penetrate more easily. However, when the moisture content is too high, the felts again become weak and breaks occur.

In order for relative humidity changes to affect felts rapidly, there must be intimate contact between the atmosphere and the felts. Because felts are stored in large rolls, only their edges are affected by short-term changes in relative humidity. (Some edge curling might be attributed to this effect). The interior of the rolls of felt remains essentially as they were when rolled, except after long-term storage under extreme humidity conditions.

The temperature of the saturant is more readily controllable than is the moisture content of the felts. Through heating the saturant and agitating it in the saturators, fairly good temperature control can be attained. The data presented in figure 7 are of the variation in the saturant content of the #27 felt with the viscosity of the saturant for three conditions of the dry felt. There was little difference between felt that was oven dry and cooled to room temperature in a desiccator and that which was saturated as it was removed from the drying oven. However, the felt with 7 percent moisture absorbed 3 to 7 percent more saturant in the normal saturating range. At the lowest temperatures at which saturation was successful with these materials, the moisture content was relatively unimportant, for a heavy film of saturant remained on the surface of the felt and soaked in during the period in the oven. At the higher temperatures, the saturant was very fluid and had a larger specific volume than at room temperature; the felt could not carry enough saturant to meet specifications at temperatures above 400 °F (205 °C) with 7 percent moisture or above 350–375 °F (177–190 °C) when initially dry.

For the #55 felt (fig. 8), some moisture was necessary to permit sufficient saturation with the shingle saturant to meet the ASTM specification of 170 percent (ASTM D 225–65). Both dry felts, cold or warm, could not be saturated beyond 165 percent. In addition, the saturant did not penetrate well at temperatures below 325 °F (163 °C) (viscosity of about 180 cps) when dry felt was used. With 7 percent moisture, good penetration was found down to 300 °F (149 °C). At the higher temperatures, again, saturation was reduced rapidly with increasing temperature. In the range above 400 °F (204 °C) the felt with 4 percent moisture saturated like the dry felt; as the temperature was reduced below 400 °F (204 °C), at the point tested, it behaved more like the felt with 7 percent moisture.

A few specimens of felt were exposed to high humidities, and moisture contents of 12 and 32 percent were achieved. At 12 percent moisture, the

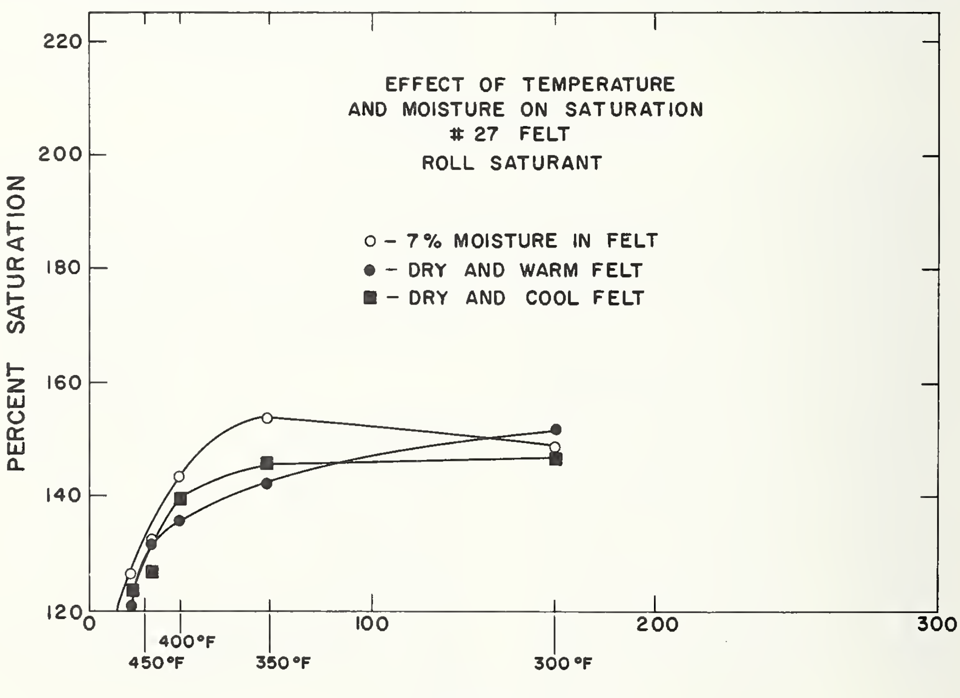

Figure 7. *Effect of temperature and moisture on saturation—#27 felt with roll saturant.*
A small amount of moisture in the felt seems to improve the felt s saturating characteristics.

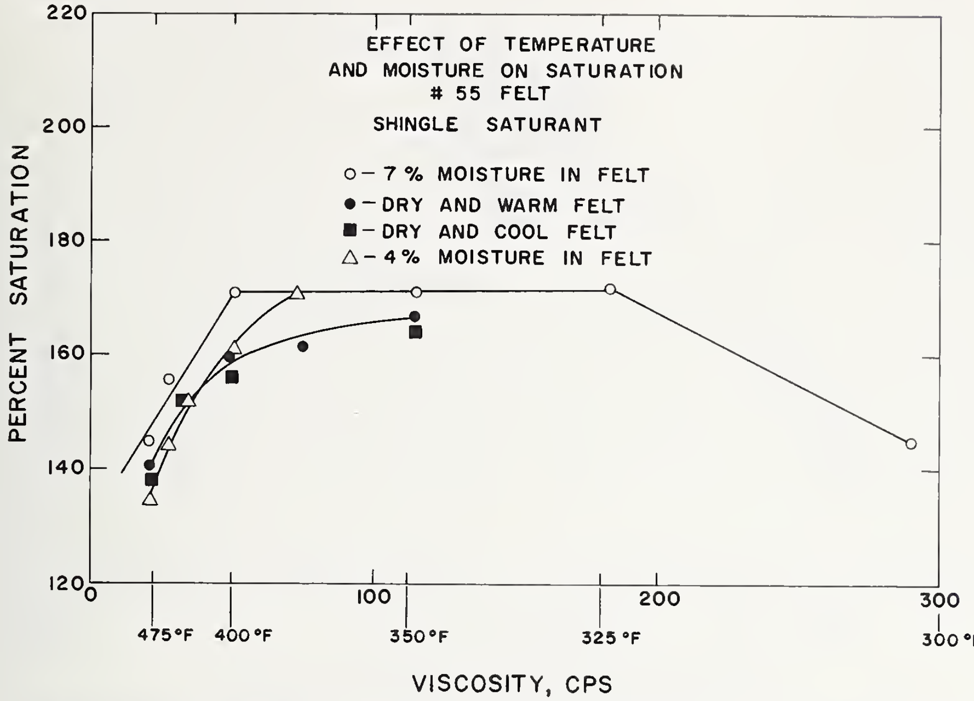

Figure 8. *Effect of temperature and moisture on saturation—#55 felt with shingle saturant.*

saturation of the #27 felt was the same as with 7 percent of saturant. However, the #27 felt with 32 percent moisture absorbed 204 percent of saturant. This swelling of the felt structure by moisture permitted improved saturation but was accompanied by a serious lowering of the tensile strength of the moist felt and the production of a tremendous amount of foaming during the saturation process.

5.3. Spacers on Press Rolls

One way of regulating the amount of free saturant carried on the sheet is to regulate the pressure applied on the press rolls. All of the results already discussed were obtained with the upper roll "floating." Attempts to increase the pressure resulted in decreased saturations. Attempts to decrease the pressure by elevating the bearings upon which the upper rolls rotated produced a condition that prevented the rolls from pulling the felt through themselves as they rotated; there was not sufficient "bite" to move the felt. A compromise was sought in the use of spacers directly on the upper roll, consisting of aluminum tape 5 mils thick in multiple thicknesses. The edges of the felt were gripped between the bottom roll and the spacers on the top roll, leaving a free area over the felt to carry excess saturant. While this idea seemed good theoretically, in practice the results were very erratic. Wet areas frequently remained after the soak-in period and the results could not be used. All the results reported in figures 9, 10, and 11 are based on only the specimens that were in a "surface-dry" condition when removed from the soaking-in oven. The low temperature cutoffs in these figures represent the saturation temperatures below which "surface-wet specimens" only were obtained.

From the results shown in figure 9, it is obvious that the use of spacers did not improve the saturation with shingle saturant under any conditions. The operating range was narrowed and only under the best conditions could satisfactory saturation be obtained with 30- or 50-mil spacers.

When the mixed saturant was used, as seen in figure 10, the saturation was improved at the higher temperatures with both 30- and 50-mil spacers. However, again the spacers raised the lowest temperature at which surface-dry specimens could be produced.

Spacers thicker than 30 mils were not investigated with the #55 felt-roll saturant system. However, when 30-mil spacers were used, viscosities at which satisfactory saturation could be obtained were reduced further than with either the mixed or shingle saturants. These data are shown in figure 11. The apparent anomaly of more low softening point saturant remaining in the felt at the lower viscosities may be explained on the basis that this viscosity is attained at lower temperatures, and a greater weight of asphalt occupies the same volume. Another factor that undoubtedly helped the saturation was that the saturated felts were all exposed to a 350 °F (177 °C) oven during the soak-in period. The

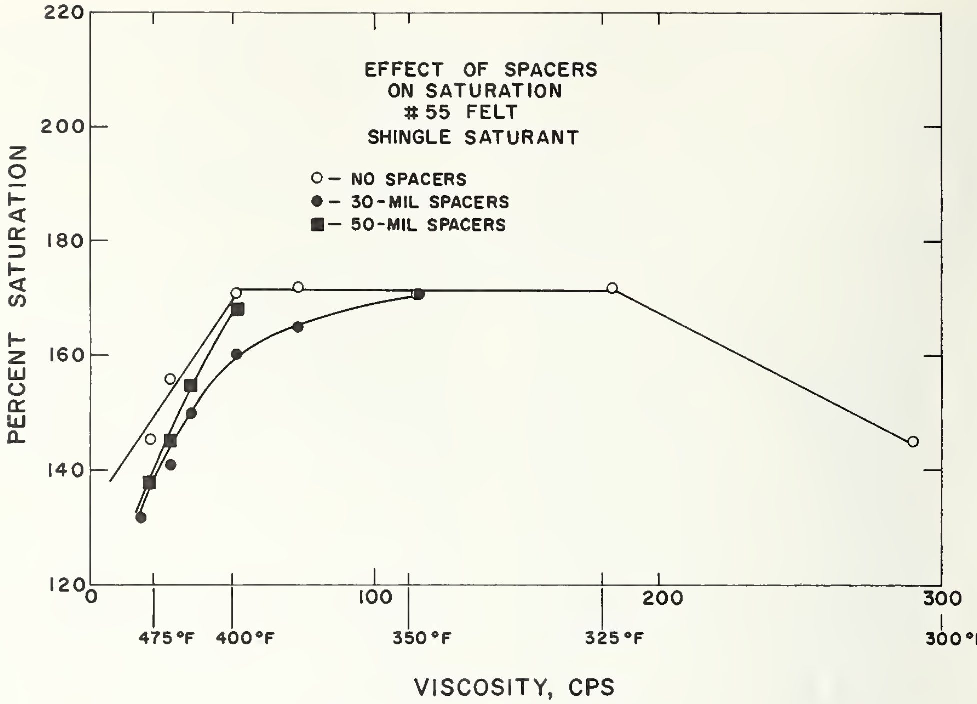

FIGURE 9. *Effect of spacers on saturation—#55 felt with shingle saturant.*

The use of spacers on the press rolls did not improve the level of saturation attainable with this system, but did shorten the working range in which satisfactory specimens could be made.

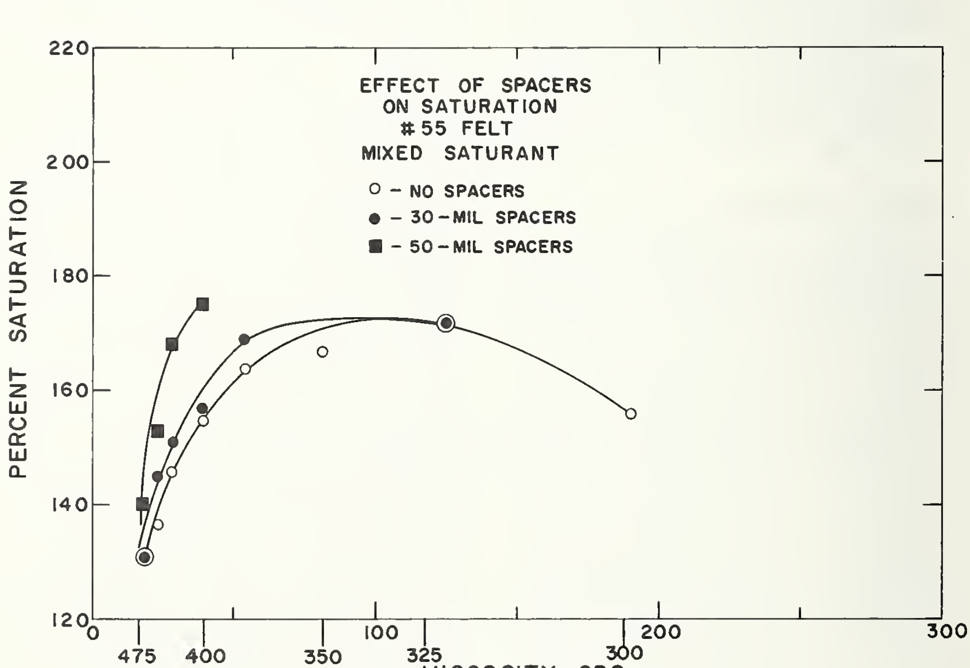

FIGURE 10. *Effect of spacers on saturation—#55 felt with mixed saturant.*

Spacers on the press rolls improved the saturation of the #55 felt with the mixed saturant at temperature around 400 °F. (204 °C).

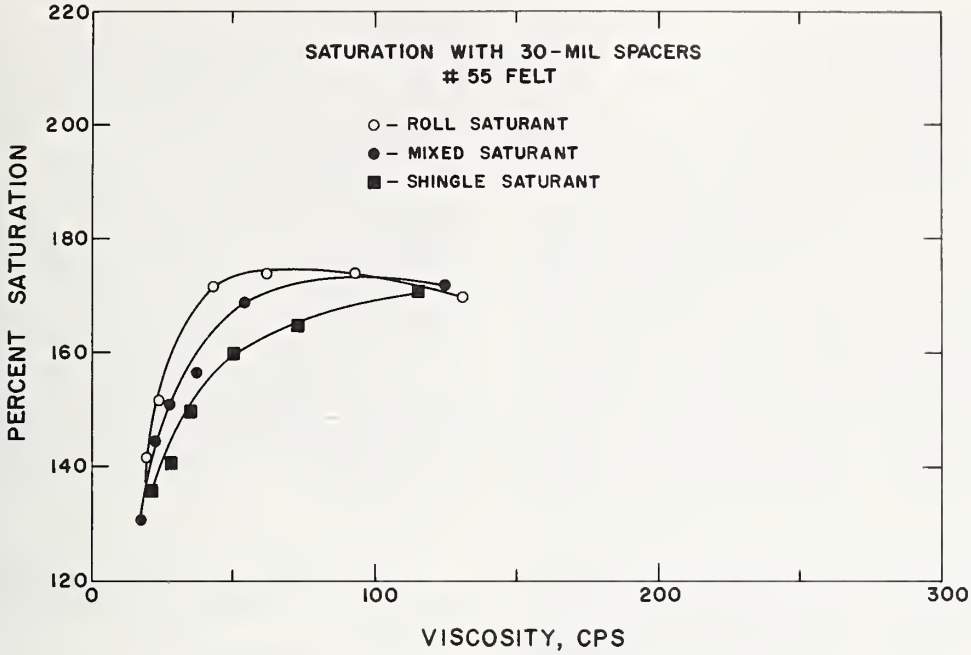

FIGURE 11. *Saturation with 3-mil spacers—#55 felt.*

Under equiviscous conditions, the saturant at the lowest temperature results in the highest saturation over most of the working range.

softer saturant was the most fluid under these conditions and excess saturant could soak in better than the more viscous, higher-softening-point materials. Thus, surface conditions that provided "wet" saturated felts with the saturants normally employed with #55 felt resulted in surface-dry felts when the roll saturant was used. Undoubtedly, the "soaking-in" temperature could be modified in practice to accommodate the higher viscosity saturants.

5.4. Pressure

Another way of increasing the saturation of felts is through increasing or decreasing the pressure in the saturator. The results of both pressure variations are presented in figures 12 through 15.

For the combination #55 felt-shingle saturants in figure 12, a small increase in pressure produced a significant increase in saturation. Progressively higher pressures improved the saturation further to 180 percent at 30 psig.[9] The operating ranges of temperature remained essentially the same at all pressures; uniformly high saturations were produced between 325 F (163 C) and 400 F (204 C) at viscosities of 190 to 50 cps, respectively. Pressures higher than 30 psig were not investigated.

Reduction of the pressure in the saturator below atmospheric pressure permitted further increase in the saturation of the felts. At a vacuum of 74 cm Hg (below atmospheric pressure) the percent saturation was approximately 190, with a top figure of 195.

The saturations under vacuum were extremely slow; whereas those under pressure were accom-

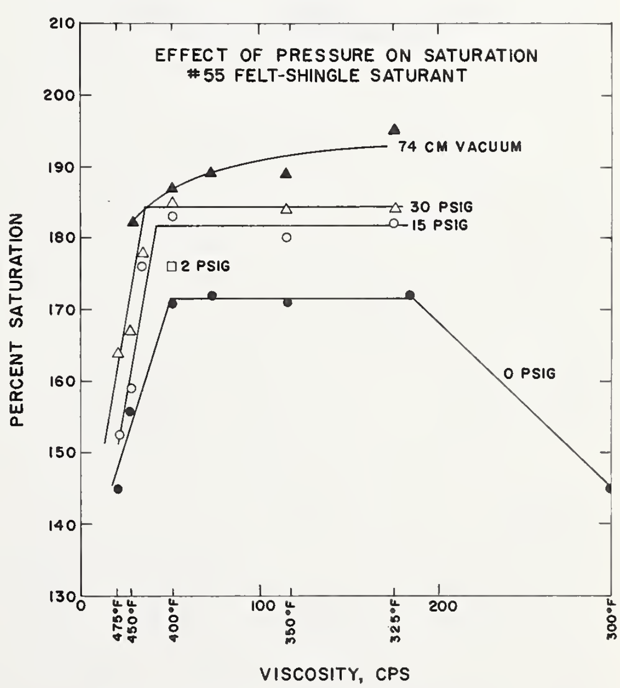

FIGURE 12. *Effect of pressure on saturation—#55 felt with shingle saturant.*

Pressures both above and below atmospheric pressure resulted in improved saturation levels.

[9] One pound force equals approximately 4.45 newtons.

plished rapidly. Periods of 30 min were used for the specimens saturated under vacuum because bubbles continued to be released from the felt for 30 minutes. However, after the series was completed, it was found that times from 5 to 30 min produced essentially the same results. Periods below 5 min produced erratic results. The pressure results were all accomplished with 1-min submergence, followed by a rapid decrease to atmospheric pressure while the specimen was submerged.

An interesting consideration involving the use of pressure is the appreciable increase in saturation with small increases in pressure. In practice, pressure can be increased by merely making the saturant tank deeper and running the sheet close to the bottom of the tank. Pressure is attained at the average rate of 0.44 psi per foot depth. Thus, the results obtained in figure 12 at 2 psig could, presumably, be accomplished with saturant just over 4 ft deep.

The beneficial effects produced by saturating with shingle saturant under pressure were also evident when the mixed saturant was used. As seen in figure 13, a pressure of 2 psig was sufficient to take a combination of saturant, felt, and temperature that produced saturated felts failing to meet specifications under normal conditions and produce results comfortably above 170 percent. It is in this borderline type of situation that these small modifications in procedure can be most beneficial. Further increases in pressure to 15 psig produced additional improvement in saturation. However, beyond 15 psig, no further improvement was noted. As a matter of fact, 30 psig produced saturations essentially the same as 15 psig.

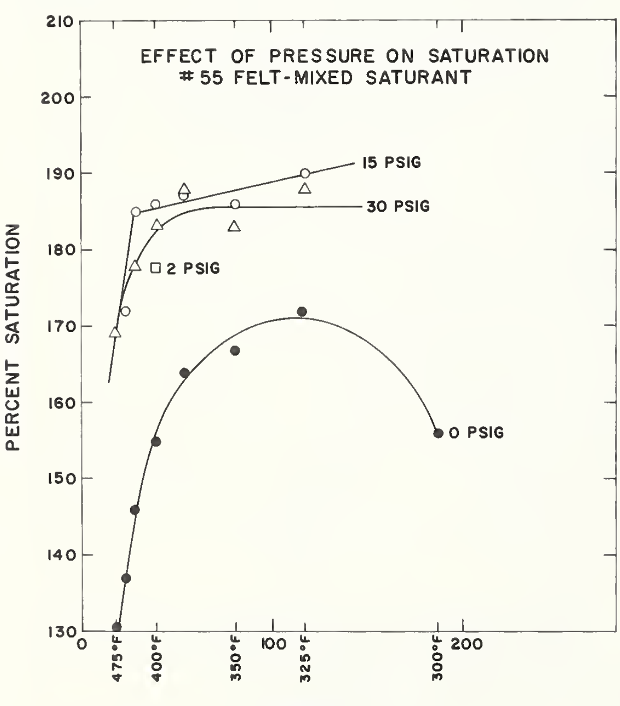

FIGURE 13. *Effect of pressure on saturation—#55 felt with mixed saturant.*

For this system pressure increases beyond 15 psig did not result in further improvement of the level of saturation.

As might be expected, saturation with the most fluid saturant used, the roll saturant, was not greatly influenced by pressure. The data in figure 14 reveal that all elevated pressures produced essentially the same degree of saturation between 325 °F (163 °C) and 400 °F (204 °C), as did atmospheric-pressure saturation. However, the range over which the saturation of about 174 percent was attained was extended about 50 °F (28 °C) to 425 °F (218 °C) at above-atmospheric pressures. Thus, even when roll saturant was used, some improvement could be obtained by the use of pressure.

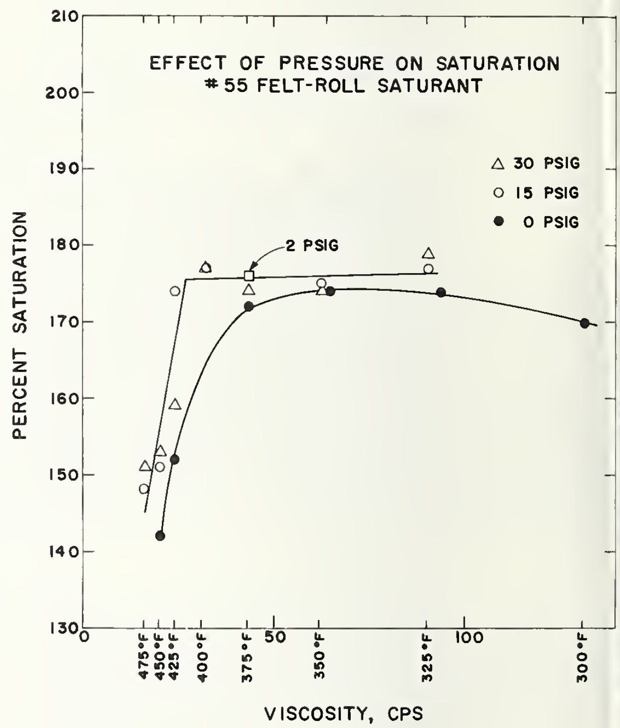

FIGURE 14. *Effect of pressure on saturation—#55 felt with roll saturant.*

Saturation under pressure did not materially improve the level of saturation attainable with this system.

Commercially no difficulty is encountered in saturating #27 felt. A very soft saturant is used to keep the saturated felt pliable in cool weather and compatible with mopping-grade asphalts. The saturation is kept low, 140 percent minimum, to prevent the adjacent layers in the rolls from adhering to each other. However, it is known that greater saturations improve the protection of the fibers. Therefore, the effect of vacuum and pressure on the saturation of #27 felt with roll saturant was studied. The results are reported in figure 15.

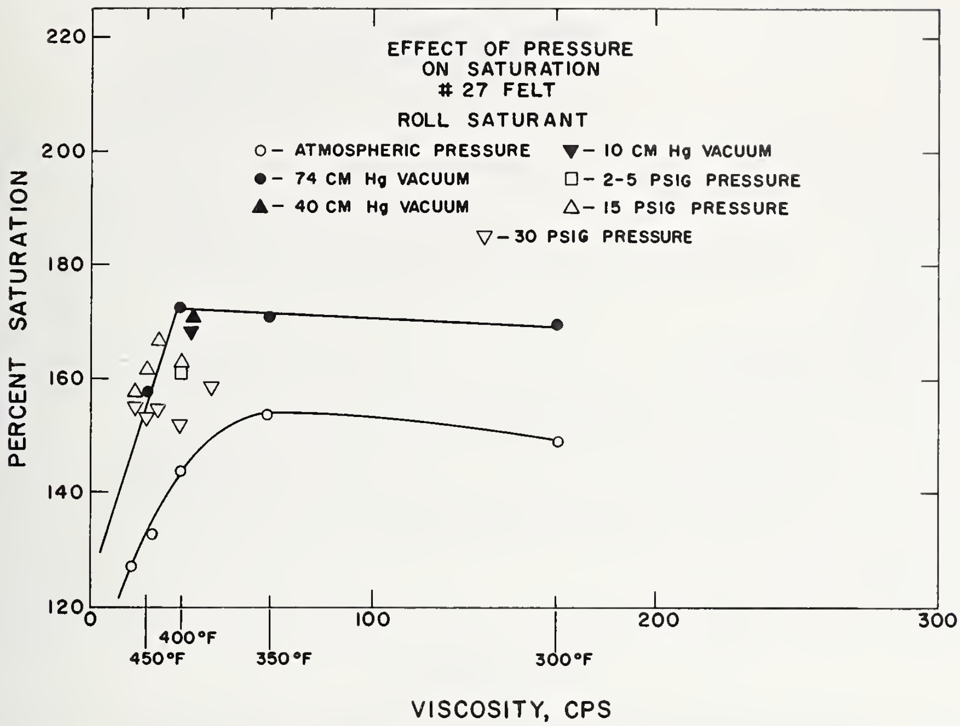

Figure 15. *Effect of pressure on saturation—#27 felt with roll saturant.*

Both pressure and vaccum increased the level of saturation attainable with this system.

Both elevated pressures and vacuums down to about one-half atmosphere greatly restricted the temperature range in which surface-dry, saturated felts could be obtained to 390 °F (199 °C) or higher. In this range, improved saturation was always obtained. When 74 cm Hg of vacuum was used, satisfactory and maximum saturation could be obtained over the complete temperature range from 300 °F (149 °C) to 400 °F (204 °C). The percent saturation began to decrease, however, as the saturant temperature was raised above 400 °F (204 °C). The #27 felt, thus, could be saturated to 170 percent saturation and still be surface dry with the use of vacuum. Elevated pressures could be used to produce saturations up to 165 percent if the saturant temperature was closely controlled in the higher temperature range.

5.5. Moisture Absorption

The purpose of saturating felts with asphalt is to protect the felts and make them more resistant to attack by the elements of weather. Dry felts are particularly vulnerable to moisture in both liquid and vapor form. The results in figure 6 show that dry felts absorb up to 9 percent moisture when exposed to relative humidities of 75 percent for less than a day. The equilibrium moisture will be higher if the storage temperature is lower and lower if it is higher than 79 °F (26 °C). It has been reported that large dimensional changes occur in felts with moisture changes and progressively larger shrinkages result [5].

To determine how well saturation protects felts, a series of exposures was made of #55 felt saturated with the mixed saturant in the range of 64 to 185 percent to relative humidities of 30, 50, and 75 percent. It had been planned to contine determinations at all three relative humidities for 500 hr, but the exposure conditions drifted out of the control ranges after 200 hr at 30 percent relative humidity and 150 hr at 75 percent relative humidity. The figures in the inserts represent the last set of readings under controlled conditions.

The specific data for the #55 felt saturated with the mixed saturant are presented in figures 16, 17, and 18 for relative humidities of 30, 50, and 75 percent, respectively. Similarly, data for the moisture absorption of the #27 felt saturated with roll saturant and exposed at 73 °F (23 °C) and 50 percent relative humidity are in figure 19.

At all relative humidities moisture absorption proceeded rapidly at first and then at progressively lower rates until some constant moisture content was attained. The rate of absorption, rate of attaining "equilibrium," and "equilibrium" moisture content decreased as the saturation of the felt was increased. The final moisture content decreased approximately linearly with the log of the percent saturation. Similarly, for any particular saturation, the "equilibrium" moisture content increased with the relative humidity to which the felts were exposed.

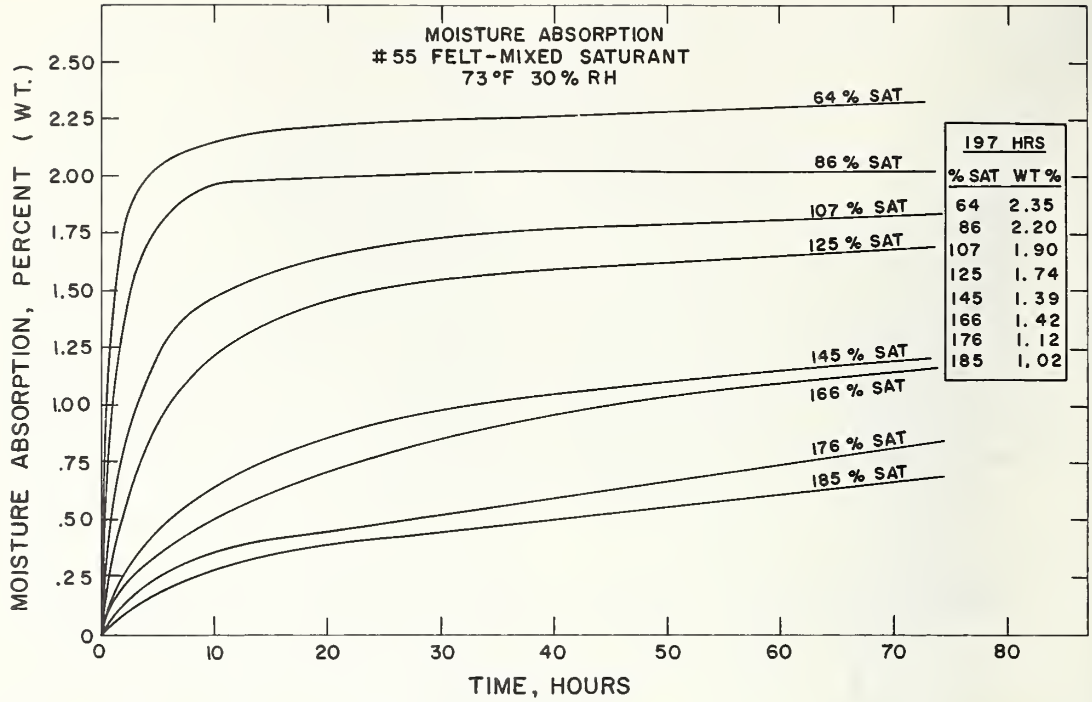

FIGURE 16. *Moisture absorption—#55 felt with mixed saturant at 73 °F (23 °C) and 30 percent relative humidity.*

Both the rate of absorption and the amount of absorption decreased rapidly as the level of saturation of the felt was increased.

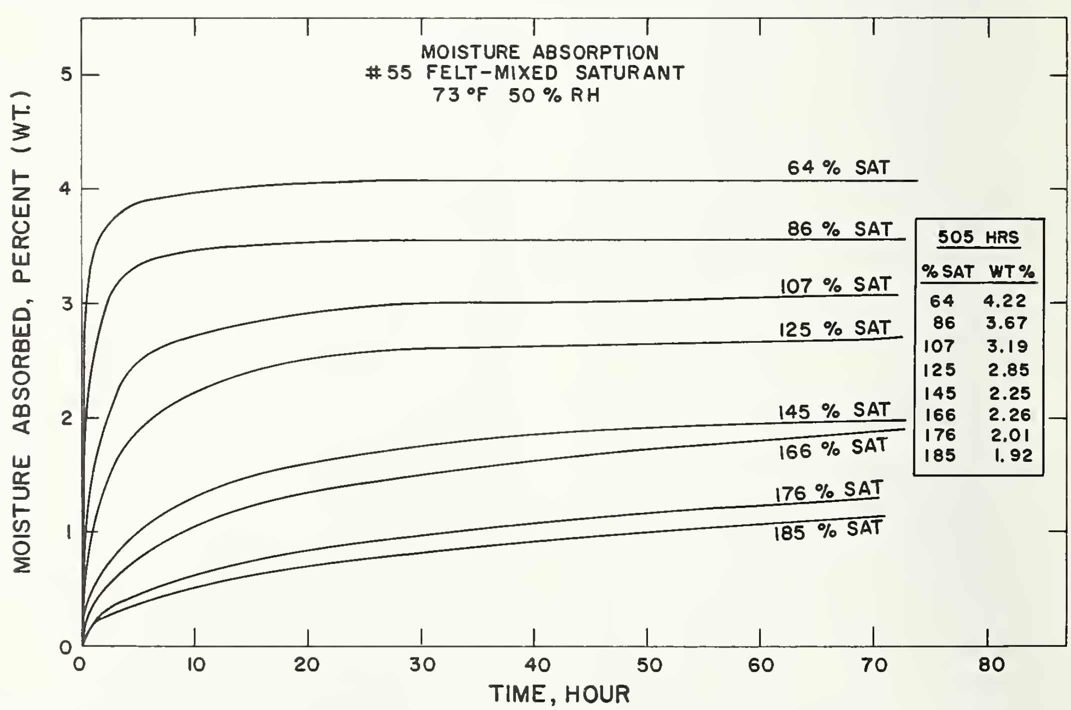

FIGURE 17. *Moisture absorption—#55 felt with mixed saturant at 73 °F (23 °C) and 50 percent relative humidity.*

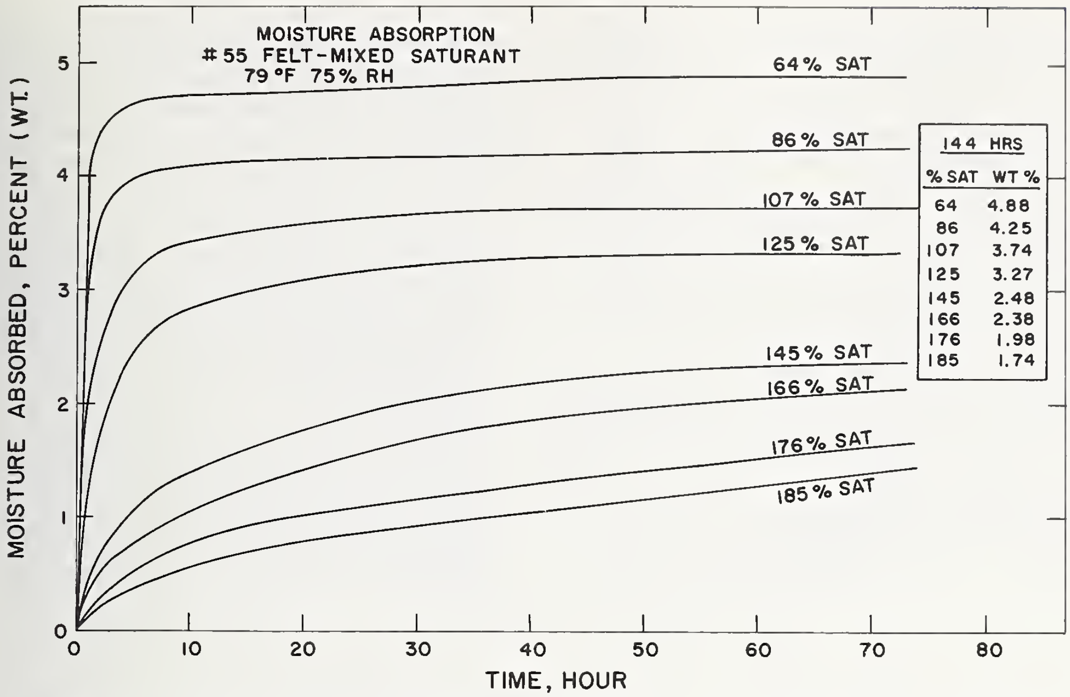

FIGURE 18. *Moisture absorption—#55 felt with mixed saturant at 79 °F (26 °C) and 75 percent relative humidity.*

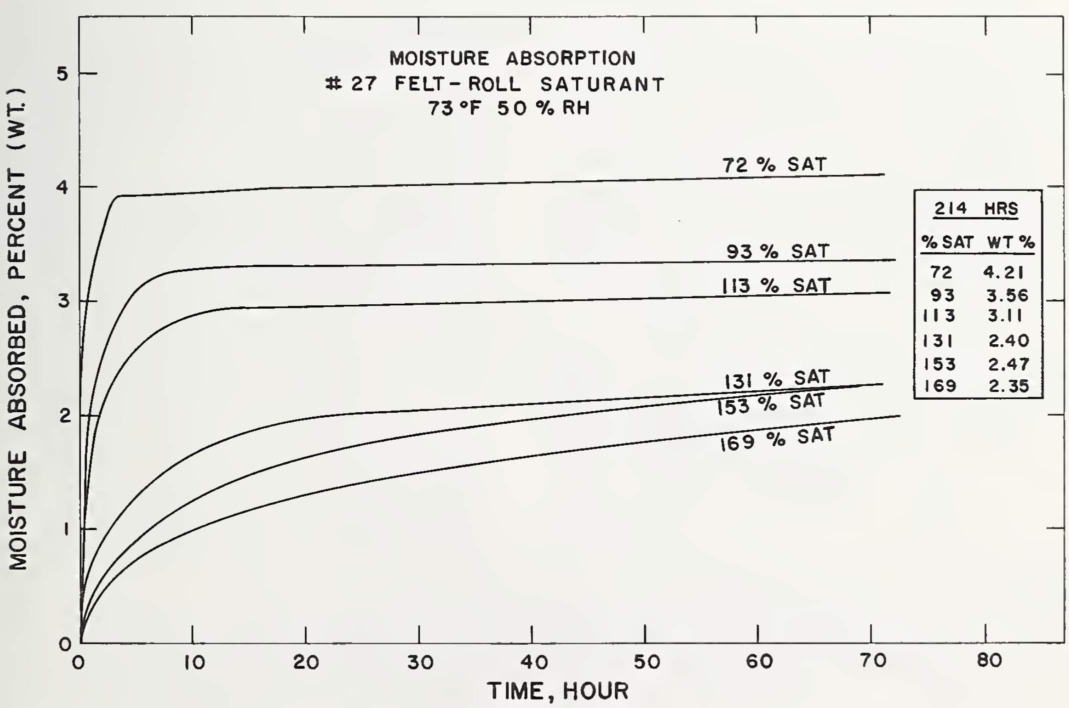

FIGURE 19. *Moisture absorption—#27 felt with roll saturant at 73 °F (23 °C) and 50 percent relative humidity.*

The initial absorption of moisture is more rapid for the #27 felt than for the #55 felt with the same saturation. However, the final moisture concentrations are essentially the same.

Even a small degree of saturation, such as about 60 percent, reduced both the rate of moisture absorption and final moisture content of the felts appreciably. Data from figures 6 and 16 show that at 30 percent relative humidity the final moisture content is reduced by 50 percent at this low saturation, and the time to attain it is increased appreciably. At specification saturations and higher, the final moisture content is reduced by 75 percent and the time to attain it increased. The beneficial effects of greater saturation are more evident at higher relative humidities.

However, even the most highly saturated felts in this study absorbed moisture to some extent. It is, therefore, necessary to front- and back-coat roofing products to isolate and protect the felts from moist environments.

When considering the #27 saturated felts, this vulnerability to moisture absorption is very significant. They are normally saturated to above 140 percent and, thus, may absorb up to 2.5 pe[rcent] moisture at 50 percent relative humidity ar[d] 73 °F (23 °C). Absorption can occur in storage [or] on the roof, if the roof is not completed in o[ne] session. The exposure of an unsurfaced roof ov[er]night, when the temperature drops and the rel[a]tive humidity increases, could lead to much high[er] moisture absorption. As the roof is finished, t[he] hot asphalt application must vaporize this moi[s]ture. Asphalt cooling and some frothing an[d] foaming often result. Moisture absorption, [if] accomplished nonuniformly throughout a roll o[f] felt, can also lead to temporary or permanent di[s]tortions of the felt.

If conditions are made more severe, and th[e] felt is submerged in liquid water for periods i[n] excess of 1 hr, the quantity of water absorbe[d] increases rapidly. Felts meeting ASTM specifica[-]tions will absorb about 10 percent water in a week. The data in figure 20 are for the #55 saturate[d]

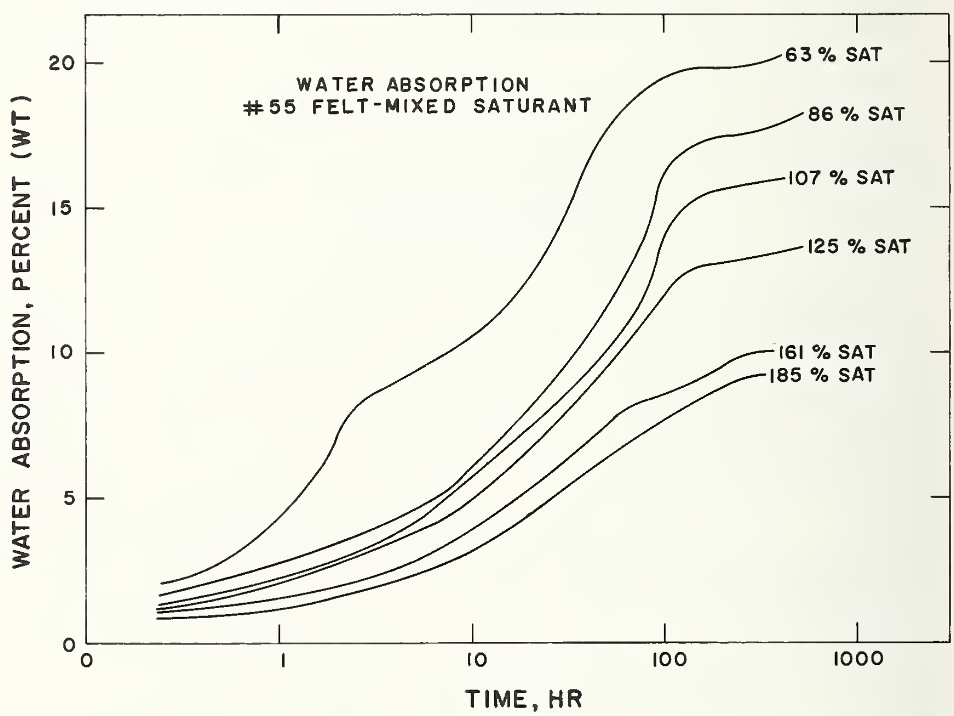

FIGURE 20. *Water absorption—#55 felt with mixed saturant.*

The amount of water absorbed on immersion is greater for felts at any level of saturation than that resulting from exposure to humid air. The final water content decreases as the level of saturation is increased.

felts. While the #27 felts were not evaluated, it is anticipated that comparable results would be obtained in shorter periods of time. These data further emphasize the necessity for protecting saturated felts by impermeable surface coatings as rapidly as possible.

5.6. Air Permeability

Air permeability of saturated felts decreases rapidly as the saturation is increased. With the densometer normally used for dry felts the results become rather erratic and the times become long for saturations higher than 125 percent. It is interesting to note that both the #27 and #55 felts fell on the same curve in figure 21. (In order to obtain the data for this correlation, the entire felt from the actual areas through which the air permeated was extracted with chlorothene to obtain the saturations. Therefore, each point represents an individual determination. The local variations in any piece of saturated felt were too large to permit the use of average values.)

For applications in which felt is used as a wind barrier, but not as a vapor barrier, highly saturated, but uncoated, felts should be recommended. If a vapor barrier is desirable, saturated and coated felt should be used.

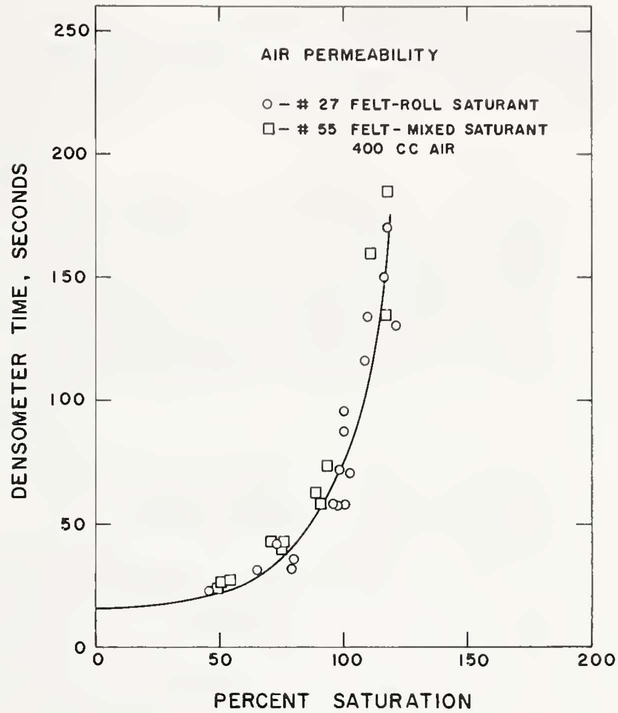

FIGURE 21. *Air permeability.*

The air permeability of saturated felts decreases rapidly as the level of saturation is increased.

6. Conclusions

Saturating organic felts under controlled conditions in the laboratory has demonstrated that the efficiency of saturation varies with a large number of parameters, including time of immersion, temperature and viscosity of the saturant, pressure on the press rolls, and pressure in the saturator. However, even under the most favorable conditions, only 82 percent of the theoretically possible saturation was attained. This figure, 25 percent over the specification minimum, was equal to the asphalt capacity as determined by the buret method; thus, an efficiency of 100 percent of the buret asphalt capacity was attained.

The technical conclusions obtained from this study may be summarized as follows:

(1) At 400°F (205°C) with the saturants normally used, it was immaterial whether the #27 felt was saturated from either one or both sides if more than 15 sec of submersion time was used. The #55 felt required a minimum of 1½ min of complete submersion to meet minimum specification requirements.

(2) Felts containing about 4 percent moisture were saturated more easily and more completely than dry felts. As the moisture content increased, the level of saturation attainable also increased, but beyond 7 percent moisture excessive foaming and cooling of the saturant were observed. The moisture seemed to "open up" the felt.

(3) Under normal conditions felts saturated best in the viscosity range of 50 to 150 Hz. At higher viscosities the penetration was hindered; at lower viscosities, the sheet could not "carry" sufficient saturation to meet specifications.

(4) Spacers on the press rolls increased the quantity of saturant carried on the sheet, but the viscosity range in which surface-dry saturated felts could be produced was greatly shortened. The beneficial effects were more noticeable with the softer saturants.

(5) Small increments of pressure in the saturator produced marked increases in saturation, especially with the harder saturants. Higher pressures produced further improvements in saturation with the shingle saturant, but not with the softer saturant.

(6) Vacuum saturation produced the highest saturations.

(7) Rate of moisture and liquid water sorption of saturated felt decreased with increasing saturation. A large fraction of the total sorption occurred in the first few hours of exposure.

(8) Air permeability decreased rapidly with increasing saturation.

The author wishes to thank Messrs. J. C. Weeks and T. R. Davis for their assistance in the experimental work. The felts were supplied by Mr. J. J. Klimas, of the Building and Industrial Products Division, GAF Corp. (Formerly Ruberoid Co.). The saturants were furnished by Mr. L. C. Krchma, of the Mobil Oil Co. This work was spon sored by the Asphalt Roofing Manufacturers As sociation (formerly the Asphalt Roofing Industr Bureau).

7. References

[1] Abraham, H., Asphalts and Allied Substances, Fifth Edition, I, 743–747, D. Van Nostrand & Co., Inc., New York (1945).

[2] Krchma, L. C., Asphalts for Process Industries, Chapter in Bituminous Materials, II, 593, Interscience Publishers, Inc. (1965).

[3] Casey, J. P., Pulp and Paper Chemistry and Technology I, 81, Interscience Publishers, Inc. (1960).

[4] Ott, E., H. M. Spurlin and M. W. Grifflin, Cellulos and Cellulose Derivatives, 5, Part 1, Interscienc Publishers, Inc., New York (1955).

[5] Martin, K. G., Changes in Bituminous Roofing Felt Associated with Changes in Moisture Content, Div of Bldg. Res. Tech. Paper No. 8, C.S.I.R.O., Australia (1959).

8. Glossary

This glossary contains definitions of terms retricted to their use in this study. Many of these terms are more broadly defined for other uses.

Asphalt—The residue from the distillation of some types of petroleum processed further to products with specific properties.

Asphalt capacity—The kerosene number multiplied by the ratio of the specific gravity of the asphalt saturant to that of the kerosene used. When no specific saturant is being considered, 1.035 is used as the specific gravity of the saturant.

Built-up roofing—Roofing fabricated in place from alternate layers of saturated felt and asphalt.

Densometer—An air-permeability apparatus used in the paper industry to measure the openness, or density, of paper and felts.

Dry felt—Unsaturated felt in an oven-dry condition.

Felt—A paper-like material made by a felting process, rather than a weaving process. While felts may be made of asbestos, paper, wood, rags, glass, etc., those in this study were made from a mixture of paper, rags, and wood fibers.

Felt number—The weight of 480 square feet of dry felt, i.e., #27, #55.

Furnish—The composition of the felt in terms of fiber types.

Kerosene number—The weight of kerosene th felt can hold divided by the weight of the dr felt, expressed as a percentage. The kerosen number varies with the procedure by which i has been determined.

Mixed saturant—Saturant made by the blendin of the roll and shingle saturants.

Moisture—Water vapor in the air and water con tent of felts.

Percent saturation—The ratio of the weight of th saturant to that of the dry felt, expressed as a percentage.

Prepared roofing—Roofing completely manufac tured in a roofing mill, as distinguished from built-up roofing, which is fabricated in place

Roll saturant—Saturant normally used for mak ing roll roofing.

Roof membrane—The built-up roof, exclusive of surfacing.

Roofing felt—A felt used in the manufacture of asphalt roofing.

Saturant—A relatively soft asphalt used to impregnate felts.

Saturated felt—Felt containing some asphalt saturant, not necessarily as much as it can hold.

Saturation—The impregnation of a felt with a saturant.

Square—One hundred square feet of material.

Water or moisture absorption—The penetration of water (vapor or liquid) into the felt, including both adsorption and absorption.

U.S. GOVERNMENT PRINTING OFFICE: 1969 O—336-259

(cut here)

Announcement of New Publications in Building Science Series

Superintendent of Documents,
Government Printing Office,
Washington, D.C. 20402

Dear Sir:

Please add my name to the announcement list of new publications to be issued in the series: National Bureau of Standards Building Science Series.

Name____

Company____

Address____

City________________ State________________ Zip Code__________

(Notification key N-339)

U.S. DEPARTMENT OF COMMERCE
WASHINGTON, D.C. 20230

OFFICIAL BUSINESS

POSTAGE AND FEES PAID
U.S. DEPARTMENT OF COMMERCE