Phase II of coal tar study finds mechanical application EVT

This article is the full text of the report "Program to Study the Relationship Between Temperature-Viscosity and Interply Weight During Mechanical Application of Roofing Membranes Using Hot-Applied Coal Tar Products," Phase II. The report was prepared by The Koppers Co. and the National Roofing Contractors Association (NRCA), who have completed a two-phase joint program to determine the relationship between heating and application temperatures, application viscosity, and the interply quantity of hot-applied coal tar products used in the construction of built-up roofing membranes. Phase I dealt with hand-mopping application techniques and the results were reported in the April 1985 issue of Roofing Spec, pp. 35-42. Phase II, which addressed mechanical-spreader application procedures, has been completed and the results are presented in this report.

Forty-two test-roof sections, 3 feet wide by 50 feet long, were constructed under controlled conditions to study the effect of three major variables on applied interply weights: (1) temperature at point of application; (2) materials—coal tar pitch and coal tar bitumen' were used; and (3) mechanical equipment and application procedures.

Three types of mechanical application units were used: (1) a hot bitumen dispenser without a felt layer attachment; (2) a forward-rolling unit with integral hot bitumen dispenser and felt layer; and (3) a reverse-rolling unit with integral bitumen dispenser and felt layer.

Eight 1-foot-square coupons were cut from each test-roof section for a total of 336 coupons. Eighty-four coupons were forwarded to NRCA and 252 coupons were retained by Koppers. The examination of these coupons included calculating the interply quantity of the coal tar materials, and measuring the coupons' tensile strength and elongation at 0F. The physical properties of the coal tar products were determined by the methods described in the American Society for Testing and Materials' (ASTM) D-450-78. Viscosity measurements of the bitumens used were determined over a temperature range of from 300F to 450F.

The Task Group consisted of Koppers representatives George Adomshick, Donald Waltz Jr. and James Weideman, and NRCA representatives William Cullen, Robert First and Robert LaCosse.

Spreaders put down product uniformly, says study

Report prepared jointly by representatives of The Koppers Co. and NRCA's Task Group

Objective

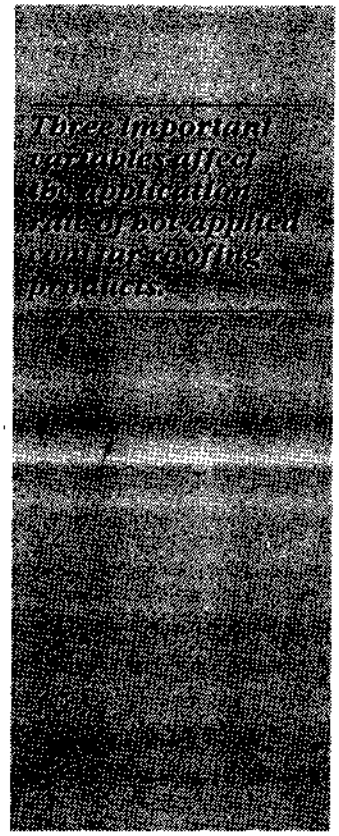
The objective of Phase II was to determine the relationship between the application temperature, the application viscosity and the interply mopping weights of coal tar products using mechanical equipment spreading procedures.

Study parameters

Three important variables affect the interply mopping weights of hot-applied coal tar roofing products. They are:

- physical and rheological properties of the material;
- point-of-application temperature; and
- method of application.

It is recognized that there are several factors that occur at the jobsite that influence the amount of coal tar actually used in addition to the variables that affect the amount used for interply moppings. However, a study of these factors and their contribution to the total amount of coal tar used was not a part of this study.



Variables studied under controlled conditions

Materials: two coal tar products were included in the study: coal tar roofing pitch as described in ASTM D-450 Type I and coal tar bitumen as described in ASTM D-450 Type III. Type I is the traditional coal tar pitch in use for decades, while Type III's formulation is modified for low fume evolution to improve environmental and working conditions during application. The materials used were taken from stock inventory and are representative of those available in the market.

Temperature: tests were conducted at six application temperatures: 300F, 325F, 350F, 375F, 400F, and 425F.

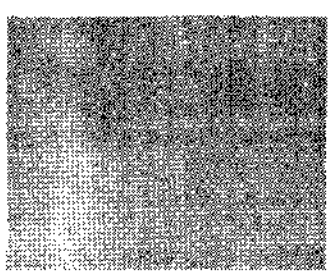
Application methods: built-up roof membranes were constructed using three mechanical spreaders. The hot dispenser without felt layer applied only the coal tar product. The felt was rolled in manually behind the spreader and not broomed. The other two spreaders applied the hot coal tar product and felt concurrently. In some cases, the felts were broomed in and in others they were not. Table 1 lists and identifies the variables.

TABLE 1: Test Runs

Bitumen				Pitch			
Test #	Temp.	Unit*	B or NB	Test#	Temp.	Unit*	B or NB
B-1	300	A	NB	P-1	300	A	NB
B-2	325	A	NB	P-2	325	A	NB
B-3	325	B	NB	P-3	325	B	NB
B-4	325	C	NB	P-4	325	C	NB
B-5	350	A	NB	P-5	350	A	NB
B-6	350	B	NB	P-6	350	B	NB
B-7	350	B	B	P-7	350	B	B
B-8	350	C	NB	P-8	350	C	NB
B-9	350	C	B	P-9	350	C	B
B-10	375	A	NB	P-10	375	A	NB
B-11	375	B	NB	P-11	375	B	NB
B-12	375	B	B	P-12	375	B	B
B-13	375	C	NB	P-13	375	C	NB
B-14	375	C	B	P-14	375	C	B
B-15	400	A	NB	P-15	400	A	NB
B-16	400	B	NB	P-16	400	B	NB
B-17	400	B	B	P-17	400	B	B
B-18	400	C	NB	P-18	400	C	NB
B-19	400	C	B	P-19	400	C	B
B-20	425	C	NB	P-20	425	C	NB
B-21	425	A	NB	P-21	425	A	NB

NB–Not Broomed
B–Broomed

*See Section "Mechanical Spreaders" for description of spreaders.



Site: the tests were conducted in I ing 37 at Verona, Pa., an auxiliary u Koppers Science & Technology C Monroeville, Pa., near Pittsburgh. Th site is an enclosed area capable of mai ing inside air temperature between and 80F.

Test equipment

Kettle: a 125-gallon kettle was sel because it was large enough to supply quate quantities of bitumen for each t was capable of raising and mainta bitumen to preselected temperatures it was convenient to maneuver and e when changing from one type of ma to the other.

Mechanical spreaders: three typ mechanical spreaders were used. U was a hot dispenser without felt lay was 36 inches wide, of steel constru with a hand-controlled flow and a 36 brass chain mop. It weighed 120 poun

Unit B was a forward-rolling spr with integral bitumen dispenser an layer. It had a 40-gallon capacity, eigh inch-diameter jets and a 5-inch-by-36 chain mop. It weighed 257 pounds.

Unit C was a reverse-rolling spre with integral bitumen dispenser and layer. It had an insulated aluminum bo 40-gallon capacity, a hand-controlled safety lids with latches and a safety pa brake. It weighed 98 pounds.

The broom used was a spring-t type, measuring 35 inches wide. It used for brooming in felts.

Template for cutting coupon obtain the coupons a 12-inch-by-12 flat steel template with a handle was tioned flat on the membrane and the pons were carefully cut to template s with utility knives.

Scale: a Metler 15,000-gram balance with 2-decimal accuracy was used to weigh the coal tar material, felt and membrane samples.

Test surface: the deck was 22-gauge steel with a 2½-inch-wide flute placed on wood framing. Flake board, 15/32 inch thick, was laid over the steel decking and nailed to the wood framing through the steel ribs. No. 15 coal tar saturated felt was rolled out and stapled at each end to serve as a separator sheet. Each test section was approximately 36 inches wide and 50 feet long in overall dimensions.

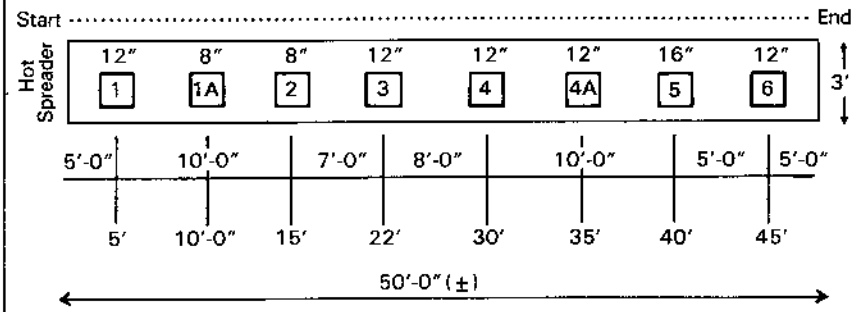
Roofing personnel: the roofing crew, which consisted of a spreader operator, roll man and kettle operator, was employed by Pennsylvania Roofing Systems, Inc., a contractor member of NRCA. Crew members were experienced in the mechanical spreader application of felts and coal tar products used for built-up roof systems. They were members of the United Union of Roofers, Waterproofers and Allied Workers Association, Local No. 37 (AFL/CIO).

Test procedures

Eighty-four rolls of felt were prepared by discarding the first 10 feet of each roll. Ten 12-inch-by-12-inch specimens were removed from the next 15 feet of each roll. The specimens were then weighed, labeled, packaged and retained. The actual felt weights were used in calculating interply mopping quantities.

The test applications were started at the low temperature and progressed to the high temperature in 25-degree increments. Table 1 lists the program sequence. The kettle temperature was raised to approximately 25 degrees above the selected

FIGURE 1: Coupon Locations



Coupons #1 and #6 at ends, to check potential extremes due to starting and stopping.
Coupons #2, 3, 4 & 5 for calculating average interply quantities.
Coupons #1A, 4A procured for NRCA Evaluations.

Note: Dimensions shown represent dimensions from start end of test membrane to center of coupons.

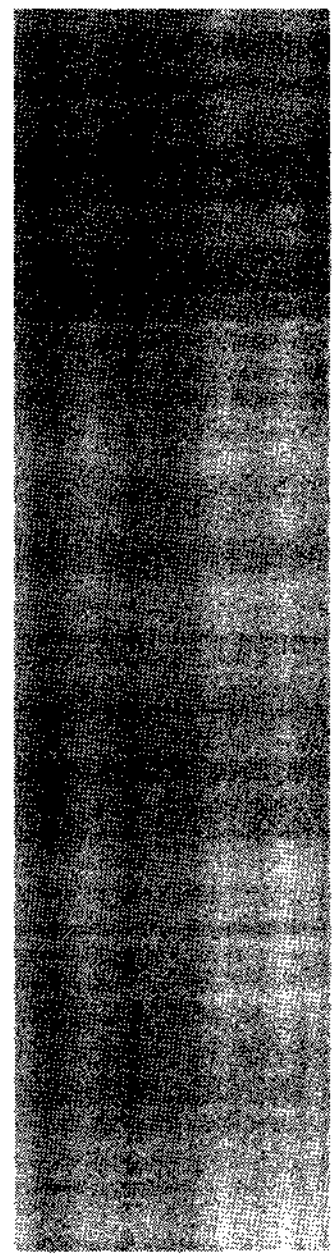
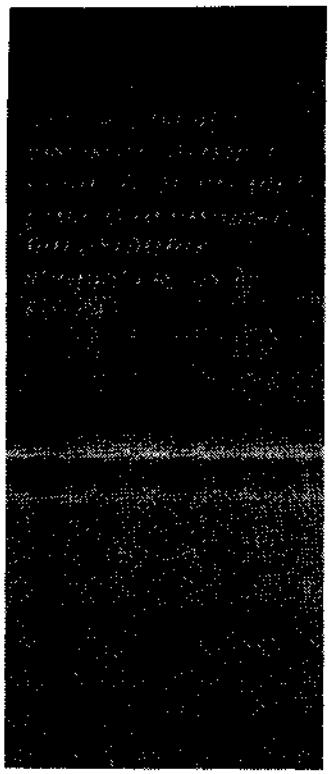


TABLE 2: Physical Properties of Bitumens

	Requirements/ASTM D 450-78		Test Date		
	Type I	Type III	Type I	Type III	ASTM Test Method
Water, max., %	0	0	0	0	D-95
Specific gravity, 25/25°C (77°F)	1.22–1.34	1.22–1.34	1.25	1.27	D-70
Softening Point (R&B), °C	52-60	56-64	58.1	56.1	D-36
Softening Point (R&B), °F	126-140	133-147	137	133	D-36
Flash Point (COC), min., °F	248	248	420	415	D-92
Total Bitumen Soluble in Carbon Disulfide, %	72–85	72–85	86.16	78.30	D-4
Ash, max., %	0.5	0.5	0.14	.14	D-2415
Distillation:					
0–300°C, (32–572°F), max., %	10	0	.79	0	
0–315°F, (32–599°F), max., %	N.A.	0	N.A.	0	
0–360°F, (32–680°F), max., %	N.A.	5	N.A.	2.2	
Specific Gravity of Distillate from 0–300°C, min, (32–572°F min.) 38/15.5°C	1.03	N.A.	*	N.A.	
Softening Point (R&B) of Residue from Distillation to 300°C max.,	80°C	N.A.	67.0	N.A.	D-36
to 572°F max.	176°F	N.A.	152.6	N.A.	D-36

N.A.–Not applicable * –Insufficient sample for test from distillation



point-of-application temperature. The hot material was then transferred to the appropriate mechanical spreader and allowed to cool to about 5 degrees above the preselected point-of-application temperature.

Meanwhile, the first layer of felt was rolled on the deck and stapled into place. When the bitumen in the mechanical spreader reached the desired temperature, application continued with the application of three additional plies of felt with interply moppings of bitumen or pitch.

When the membrane cooled, 1-foot-square coupons were cut from the membrane at preselected locations, labeled and weighed. Figure 1 identifies the location of the various coupons taken. These coupons were packaged and retained for laboratory evaluation. The average interply quantity in pounds per square feet per ply was calculated by subtracting the actual felt weight in the coupon from the total coupon weight.

Test results

Physical properties: the two types of coal tar materials were tested for conformance with ASTM Standard D450-78. Tal shows that the materials essentially me requirements of the standard, except Type I material exceeded the ASTM m mum for total percentage of bitumen s ble in carbon disulfide by 1.2 percent.

The results of viscosity measurem over the temperature range from 300 450F are plotted in Figure 2, indicating pitch and bitumen have similar shaped cosity curves in this range. It is also in esting to note the similarity in visc curves between Phase I and Phase II both coal tar materials in spite of the sl differences in property values. The sha area shown in Figure 2 approximates ap cation temperature ranges and indic that the application viscosity should maintained somewhere between 15 an centipoise (12 to 32 centistokes) for h men and pitch.

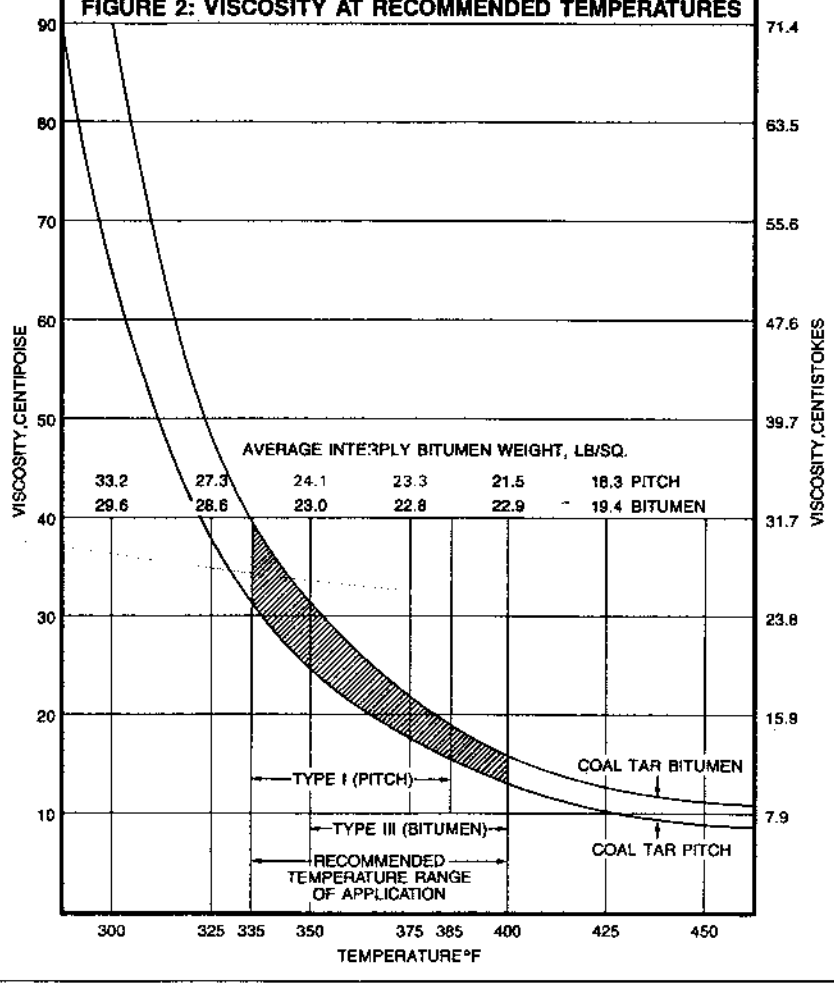
The scale superimposed along abscissa in the center of Figure 2 appr mates the average interply mopp weights achieved at the respective appl tion temperatures. The results indicate the mechanical spreader techniques g applied interply mopping weights of to 28.6 pounds per square for both pi and bitumen with application temp tures ranging from 325F to 400F. higher viscosities at temperatures lo than 325F resulted in heavier inte weights for both pitch and bitumen. C versely, lower viscosities at temperatu higher than 400F resulted in ligh weights.

The viscosity/temperature curve for h men shows that an applied viscosity o ±10 centipoise (20 ±8 centistokes) sh result in interply mopping weights of so where in the vicinity of 22 to 24 pounds ply per square. Therefore, the conclus may be made that the equiviscous temp ture (EVT) range for both coal tar prod used in this study appears to be 335F to 4

Figure 2 shows that pitch has a so what lower viscosity than bitumen at given temperature. Nonetheless, applied weights of pitch and bitumen virtually equal within the application t peratures of 350F and 400F. Based on th data, the assignment of the same EVT both bitumen and pitch in the range 350F to 400F appears to be valid. More cisely, due to the variation of viscositie these two materials at any given temp ture, the EVT is 375F ±25 degrees for tar bitumen, and 360F ±25 degrees for

Application temperatures of 300F 425F resulted in average interply wei ranging from 15.3 to 37.2 pounds square feet per ply. The quantities va

PHASE II
FIGURE 2: VISCOSITY AT RECOMMENDED TEMPERATURES



Some helpful hints for proper hot material use

The point-of-application temperature of the hot material is important to achieve the proper material application. It can influence the quantity of material used at the jobsite, especially for interply and top pours. Some variables in achieving the proper point-of-application temperature are as follows:

- atmospheric conditions, including ambient temperature, wind velocity, etc.;
- the distance from the kettle to the point of application (bitumen temperature drop);
- the use of insulated equipment and piping in cold weather;
- the kettle temperature;
- the nature and temperature of substrate;
- the method and speed of application, and the experience and teamwork of the crew; and
- the efficiency and type of equipment.

In addition, The Koppers Co. suggests the following parameters that may influence the quantity of hot material used at the jobsite:

- the glaze coating (the frequency and area covered);
- the start-up operations and day-end cut-offs;
- the bitumen run-out at felt edges;
- the flashing at parapet walls, gravel stops and roof penetrations;
- the peak and valley tie-ins.
- tear-off and replacement jobs, especially areas of daily cut-offs and tie-ins; and
- kettle operations and dumping bitumen from equipment at breaks and end of day.

Additionally, maintaining daily records of materials used and number of squares applied will provide a record of the actual amount of material used.

tar pitch. These values are similar to those suggested in Phase I of this study.

Application rates of interply material: Tables 3a and 3b give the interply weights of bitumen and pitch for each of the 252 coupons. The weights are expressed in pounds per 100 square feet per ply. A general correlation exists between the interply application weight and the point-of-application temperature, with larger quantities of both coal tar products being applied as the temperature decreased. However, there was not a straight line relationship between the average interply quantity and the point-of-application temperature.

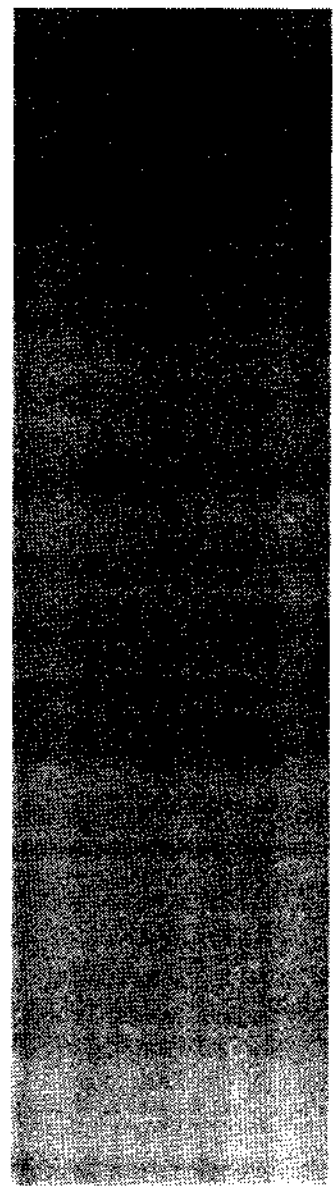
TABLE 3A: Coal Tar Bitumen/Coal Tar Organic Felt Interply Weights 4 Plies – 3 Interply Applications

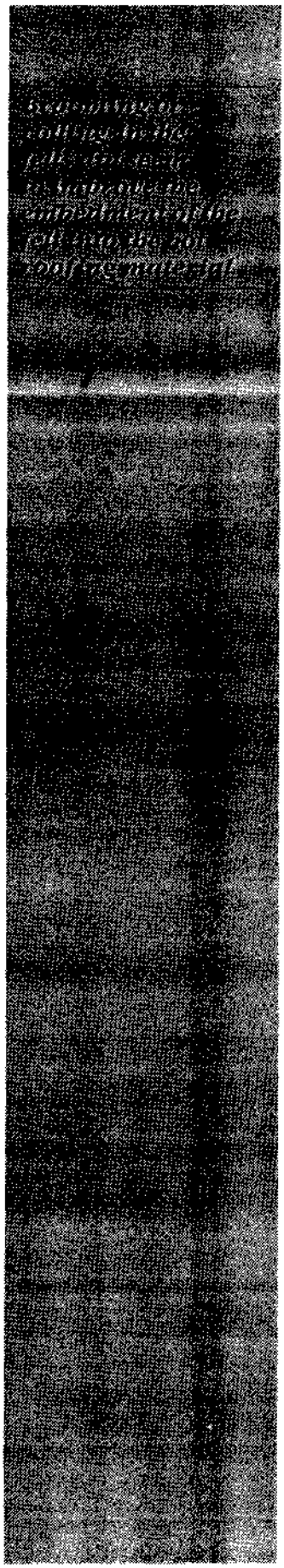
Test No.	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11
Temp. at Point of Application (°F)	300	325	325	325	350	350	350	350	350	375	375
Application Unit[1]	A	A	B	C	A	B	B	C	C	A	B
Broomed	No	No	No	No	No	No	Yes	No	Yes	No	No
Interply, lbs./100 ft.²											
Coupon #1	32.8	21.4	28.2	–	23.2	26.1	25.7	26.1	30.1	20.6	38.3
2	27.1	28.8	26.8	31.5	25.0	22.1	18.8	21.6	23.6	19.2	28.9
3	32.3	34.8	28.3	29.6	27.3	23.5	20.1	22.6	23.8	21.1	25.1
4	25.3	24.1	27.6	27.5	28.9	24.1	18.5	21.8	25.7	19.3	22.3
5	33.8	28.0	27.2	29.5	25.0	23.0	19.4	21.8	22.8	24.7	24.5
6	27.8	27.1	28.3	40.5	22.2	23.9	20.4	24.7	25.7	17.5	28.2
Average (6 coupons)	29.9	27.4	27.7	31.7	25.3	23.8	20.5	23.1	25.3	20.4	27.9
Average (4 coupons)	29.6	28.9	27.5	29.5	26.6	23.2	19.2	22.0	24.0	21.1	25.2
Standard Deviation	4.1	4.4	0.6	1.6	1.9	0.8	0.7	0.4	1.2	2.6	2.7
Variance	16.6	19.6	0.4	2.7	3.6	0.7	0.5	0.2	1.5	6.6	7.5

Test No.	B12	B13	B14	B15	B16	B17	B18	B19	B20	B21
Temp. at Point of Application	375	375	375	400	400	400	400	400	425	425
Application Unit[1]	B	C	C	A	B	B	C	C	C	B
Broomed	Yes	No	Yes	No	No	Yes	No	Yes	No	No
Interply, lbs./100 ft.²										
Coupon #1	27.2	26.7	28.5	20.2	30.9	28.1	26.4	24.7	23.1	18.7
2	20.9	23.2	24.3	19.4	24.6	22.6	23.0	23.5	19.6	18.0
3	20.3	23.1	22.8	21.8	26.0	22.6	23.6	24.1	19.8	20.7
4	19.2	21.5	23.5	19.6	22.5	21.2	22.1	26.9	21.7	15.3
5	20.3	24.9	26.1	17.2	23.0	25.8	22.0	27.1	21.9	18.1
6	24.8	26.0	24.0	17.5	24.1	30.1	23.9	23.7	24.8	17.3
Average (6 coupons)	22.1	24.2	24.9	19.3	25.2	25.1	23.5	25.0	21.8	18.0
Average (4 coupons)	20.2	23.2	24.2	19.5	24.0	23.1	22.7	25.4	20.8	18.0
Standard Deviation	0.7	1.4	1.4	1.9	1.6	1.9	0.8	1.9	1.2	2.2
Variance	0.5	1.9	2.0	3.5	2.5	3.8	0.6	3.5	1.5	4.9

Note: Coupons No.1 and No. 6 were taken approximately 5'0" from the beginning and end of each test roof section. Test coupons Nos. 2 through 5 were used to calculate the average of the (4 coupons) in this table, Figure 2, and other tables in this report.

(1) See Section "Mechanical Spreaders" for description of spreader units.





with material, temperature, the mechanical spreader used, and whether or not it was broomed. The viscosity of coal tar roofing products ranged from about 10 to 100 centipoise (8.0 to 80.0 centistokes) over the temperature range of 300F to 450F.

A study of the standard deviation and variance among the interply mopping weights from the four inner coupons of each test section indicates that with few exceptions (specimens from Test Nos. B1, B2, P2, P4 and P10 in Tables 3a and 3b) the uniformity was quite good. This is in contrast to the evaluation of the hand-mopping application techniques reported in Phase I.

Further, Tables 3a and 3b show the average interply mopping weight for each test section as the average of all six coupons and the inner four coupons. Initially, it was erroneously anticipated that variations in the amount of the coal tar applied would occur at the beginning and end of the spreader run compared to the center of the run. Although in cases some variation was found, it is not especially significant for all practical purposes. For uniformity, the average of the four inner coupons has be used in all figures and tables.

As shown in Table 4, there was no app ent correlation between interply mopp weight and whether the sample w broomed during application. Howev from visual observations, brooming rolling-in the felts did seem to improve t embedment of the felt into the hot roofi material. Table 5 summarizes the avera interply weights of bitumen and pitch the test application temperatures for all t roof sections, broomed and unbroomed.

Load/strain properties of me brane specimens: load/strain propert were measured on selected test coupo These coupons were selected from amo those having weights closest to the gro average interply weight. The specime were tested in accordance with AST method D-2523 in the across-machi direction at a temperature of 0F. Stress a modulus at break values were calculat using the actual cross-sectional dimensio of the specimens tested.

TABLE 3B: Coal Tar Pitch/Coal Tar Organic Felt Interply Weights 4 Plies—3 Interply Applications

Test No.	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P1
Temp. at Point of Application	300	325	325	325	350	350	350	350	350	375	37
Application Unit[1]	A	A	B	C	A	B	B	C	C	A	B
Broomed	No	No	No	No	No	No	Yes	No	Yes	No	N
Interply, lbs./100 ft.²											
Coupon #1	23.1	19.5	27.5	31.2	20.3	31.0	37.0	24.4	26.5	14.8	30.
2	32.8	27.2	25.3	24.4	21.3	26.4	29.4	21.2	22.1	18.5	22.
3	37.2	36.7	23.7	35.0	23.4	23.9	30.5	21.9	21.4	30.2	26.
4	32.0	24.3	23.0	27.6	20.7	25.7	31.7	20.1	21.8	19.0	22.
5	30.8	26.0	23.1	30.5	20.6	25.2	30.2	21.7	22.2	19.2	20.
6	28.0	24.4	26.3	35.9	19.9	28.2	30.2	24.2	25.1	24.7	23.
Average (6 coupons)	30.7	26.4	24.8	30.8	21.0	26.7	31.5	22.3	23.2	21.1	24.
Average (4 coupons)	33.2	28.6	23.8	29.4	21.5	25.3	30.5	21.2	21.9	21.7	22.
Standard Deviation	2.8	5.6	1.1	4.5	1.3	1.1	1.0	0.8	0.4	5.7	2.
Variance	7.8	30.9	1.1	20.3	1.7	1.1	0.9	0.6	0.1	32.0	7.

Test No.	P12	P13	P14	P15	P16	P17	P18	P19	P20	P21
Temp. at Point of Application	375	375	375	400	400	400	400	400	425	425
Application Unit[1]	B	C	C	A	B	B	C	C	C	B
Broomed	Yes	No	Yes	No	No	Yes	No	Yes	No	No
Interply, lbs./100 ft.²										
Coupon #1	31.3	29.7	28.2	18.8	23.4	26.5	26.9	20.2	18.4	13.8
2	22.6	26.1	24.4	22.3	22.1	21.7	24.7	20.4	19.0	16.7
3	24.3	24.4	24.3	25.2	24.8	21.8	19.9	19.0	16.8	16.9
4	26.0	22.6	23.4	22.6	22.1	22.3	20.5	19.3	17.0	19.8
5	22.1	25.4	22.7	19.8	21.5	20.3	19.6	19.3	20.1	19.8
6	28.6	24.9	24.6	17.9	22.9	23.2	21.3	22.2	20.3	18.9
Average (6 coupons)	25.8	25.5	24.6	21.1	22.8	22.6	22.2	20.1	18.6	17.7
Average (4 coupons)	23.8	24.6	23.7	22.5	22.6	21.5	21.2	19.5	18.2	18.3
Standard Deviation	1.8	1.5	0.8	2.2	1.5	0.9	2.4	0.6	1,6	1.7
Variance	3.1	2.3	0.6	4.9	2.2	0.7	5.7	0.4	2.5	3.0

Note: Coupons No.1 and No. 6 were taken approximately 5'0" from the beginning and end of each test roof section. Te coupons Nos. 2 through 5 were used to calculate the average of the (4 coupons) in this table, Figure 2, and other tables in this report.

(1) See Section "Mechanical Spreaders" for description of spreader units.

TABLE 4: Consolidated Interply Applied Weight/Square Averages

	Broomed		Not Broomed	
Temp., °F	Bitumen Type III	Pitch Type I	Bitumen Type III	Pitch Type I
300	—	—	29.6	33.2
325	—	—	28.6	27.3
350	21.6	26.2	23.9	22.7
375	22.2	23.8	23.2	23.0
400	24.3	20.5	22.1	22.1
425	—	—	19.4	18.3

TABLE 5: Consolidated Interply Applied Weight/Square Averages Per Application Test Temperatures

	Broomed and Unbroomed	
Temp., °F	Bitumen Type III	Pitch Type I
300	29.6	33.2
325	28.6	27.3
350	23.0	24.1
375	22.8	23.3
400	22.9	21.5
425	19.4	18.3

Tables 6 and 7 report the results of the load/strain tests. The data indicate there are no apparent correlations between the load/strain properties and the application temperature, interply mopping weights, or whether or not the test sections were broomed. The specimens obtained from the sections prepared with the ASTM D450 Type I (pitch) product gave average tensile strength and elongation values of 181 pounds per inch and 3.8 percent respectively with all 21 specimens falling somewhat below the suggested 200-pounds-per-inch criterion for tensile strength described in the National Bureau of Standards' Preliminary Performance Criteria for Bituminous Membrane Roofing (BSS #55, 1974).

On the other hand, the ASTM D450, Type III (bitumen) material gave average values of 201 pounds per inch and 4.2 percent respectively for tensile and elongation characteristics. Although the average value was above the 200-pounds-per-inch crite-

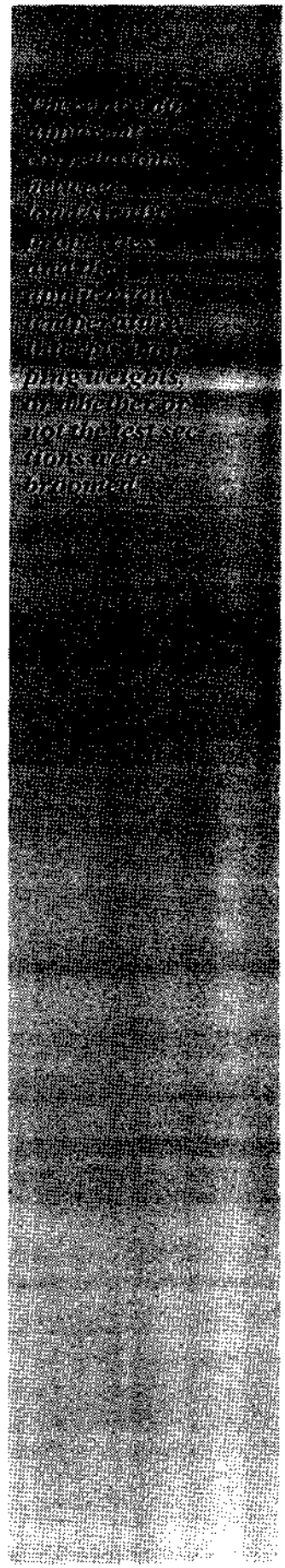
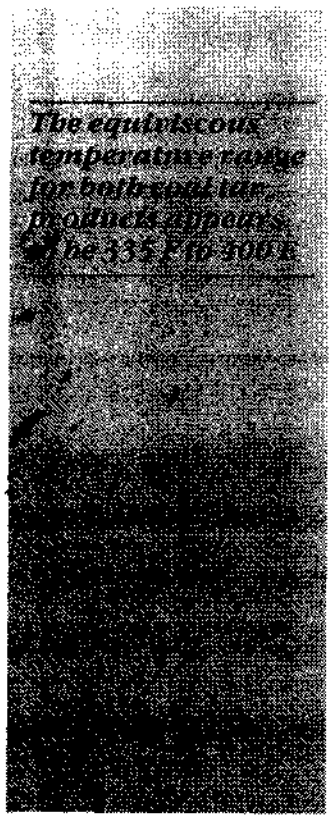


TABLE 6: Coal Tar Pitch—ASTM D-450 Type I BUR Load/Strain Properties

	Tens. Prop. @ Peak Load			Modulus	Interply		Membrane
Membrane ID[1][2]	Peak Load (lbs./in.)	Stress (lbs./in.²)	Strain %	Break lbs./in.²	@ Test Coupon (lbs./sq.)	Test Avg. (lbs./sq.)	Application Test Temp., °F
P1-NB-2	171.4	1071.4	4.4	84,532	32.8	33.2	300
P2-NB-2	183.4	1146.4	5.3	81,899	27.2	28.6	325
P3-NB-3	182.5	1140.6	3.9	73,301	23.7	23.8	325
P4-NB-5	174.7	1091.7	3.4	88,650	30.5	29.6	325
P5-NB-2	191.6	1197.4	3.6	61,982	21.3	21.5	350
P6-NB-5	172.3	1076.6	4.3	77,587	25.2	25.2	350
P7-B-3	175.8	1099.0	3.6	83,735	30.5	30.5	350
P8-NB-2	162.4	1015.1	3.6	68,533	21.2	21.2	350
P9-B-4	169.2	1057.3	4.1	71,903	21.8	21.7	350
P10-NB-5	184.6	1153.4	3.9	85,271	19.2	21.7	375
P11-NB-4	179.0	1118.8	4.0	73,277	22.4	22.8	375
P12-B-3	185.1	1156.8	4.0	61,569	24.3	23.7	375
P13-NB-3	173.4	1083.9	3.8	65,393	24.4	24.6	375
P14-B-4	183.4	1146.4	3.8	64,231	23.4	23.7	375
P15-NB-4	192.2	1207.4	3.7	87,982	22.6	22.5	400
P16-NB-2	185.3	1158.4	3.7	70,011	22.1	22.6	400
P17-B-2	197.5	1234.5	3.4	81,221	21.7	21.5	400
P18-NB-4	180.8	1129.7	3.4	77,530	20.5	21.2	400
P19-B-5	192.1	1200.6	3.7	79,885	19.3	19.5	400
P20-NB-2	179.6	1122.4	3.4	69,921	19.0	18.2	425
P21-NB-5	188.7	1179.2	3.6	80,585	19.8	18.3	425
Total	3805.0	23787.0	80.6	1,588,998	492.9	495.6	
Average	181.2	1132.7	3.8	75,667	23.5	23.6	

Notes: 1. BUR membrane test specimens were preconditioned at 0°F for two hours prior to testing in cold chamber
2. Sequence in membrane ID represents test number—Brooming/Not Brooming—Sample No. ("B" = Broomed); ("NB" = Not Broomed).



The equiviscous temperature range for both coal tar products appears to be 335 F to 400 F.

rion, 10 of the 21 specimens tested fell below the 200 pounds per inch value.

The intent of this report is not to compare the results of the Phase I and Phase II tests. However, there appears to be such an unexplained and significant difference between the load/strain property values of samples prepared by the hand-mopping technique and those prepared using mechanical equipment that further investigation is warranted.

Summary and conclusions

The application of coal tar pitches and bitumens in a viscosity range of 15 to 40 centipoise (12.0 to 32.0 centistokes) resulted in approximate interply application rates of 21.5 to 28.6 pounds per square.

The suggested EVT for both the Type I and Type III coal tar products is that temperature at which the viscosity of the material is 25 centipoise (approximately 20 centistokes). For the specific products used in this study, the EVT for coal tar bitumen is 375F ±25 degrees for the coal tar bitumen (Type III) and 360F ±25 degrees for the coal tar pitch (Type I). Point-of-application temperatures from 335F to 400F appear to be an appropriate range for mechanical spreader application depending on bitumen type, environmental conditions and the like. In general, the lower the point-of-application temperature, the greater the quantity of interply material applied.

The uniformity of the interply mopping weights among the individual specimens from each test run was generally good with some exceptions noted. There appeared to be no significant differences in interply application weights between broomed test sections and those not broomed, when applied at the same temperature.

The average ultimate breaking load for the 21 bitumen specimens was approximately 201 pounds per inch, while the 21 pitch specimens averaged approximately 181 pounds per inch when tested at 0F. The average elongation was 3.8 percent for pitch specimens and 4.2 percent for bitumen specimens. The amount of interply material did not appear to have any significant effect on the value of the breaking load.

TABLE 7: Coal Tar Bitumen—ASTM D-450 Type III BUR Membrane Load/Strain Properties

Membrane ID[2]	Tens. Prop. @ Peak Load: Peak Load (lbs./in.)	Tens. Prop. @ Peak Load: Stress (lbs./in.²)	Strain %	Modulus Break (lbs./in.²)	Interply @ Test Coupon (lbs./sq.)	Test Avg. (lbs./sq.)	Membrane Application Test Temp., °F
B1-NB-2	188.8	1179.7	5.1	89,049	27.1	29.6	300
B2-NB-2	199.1	1244.3	4.2	78,614	28.8	28.9	325
B3-NB-4	210.0	1312.5	4.2	109,720	27.6	27.5	325
B4-NB-5	184.3	1152.1	3.9	93,443	29.5	2959	325
B5-NB-3	203.8	1274.0	4.6	68,464	27.3	26.6	350
B6-NB-5	186.5	1165.6	5.1	81,068	23.0	23.2	350
B7-B-5	196.8	1229.7	4.3	85,324	19.4	19.2	350
B8-NB-4	203.2	1269.8	4.3	82,243	21.8	21.9	350
B9-B-3	209.3	1308.3	4.5	65,220	23.8	24.0	350
B10-NB-3	213.1	1331.8	4.9	73,985	21.1	21.1	375
B11-NB-3	196.4	1227.6	4.0	82,681	25.1	25.2	375
B12-B-3	195.0	1218.8	4.0	74,242	20.3	20.2	375
B13-NB-3	208.0	1300.0	4.0	90,522	23.1	23.2	375
B14-B-2	211.1	1319.3	3.8	89,520	24.3	24.2	375
B15-NB-4	212.2	1326.0	3.8	89,797	19.6	19.5	400
B16-NB-2	196.4	1227.6	4.0	93,054	24.6	24.0	400
B17-B-2	205.2	1282.3	4.1	110,940	22.6	23.0	400
B18-NB-2	205.3	1282.8	3.7	90,786	23.0	22.7	400
B19-B-3	196.4	1227.1	3.7	74,656	24.1	25.4	400
B20-NB-3	196.3	1277.1	3.7	74,656	19.8	20.7	425
B21-NB-2	211.1	1319.3	4.1	91,960	18.0	18.0	425
Total	4228.3	26475.7	88.0	1,789,941	493.9	497.6	
Average	201.3	1260.7	4.2	85,235	23.5	23.7	

Notes: 1. BUR membrane test specimens were preconditioned at 0°F for two hours prior to testing in cold chamber.
2. Sequence in membrane ID represents test number—brooming/not brooming—Sample No. ("B" = Broomed); ("NB" = Not Broomed).

TABLE 8: Consolidated BUR Membrane Load/Strain Properties

Membrane ID	Peak Load (lbs./in.)	Tensile Prop. @ Peak Load Stress (lbs./in.²)	Tensile Prop. @ Peak Load Strain %	Modulus Break (lbs./in.²)	Application Test Temperature Membrane Application Test Temp. °F	Application Test Temperature Average Interply (lbs./sq.)
P1	177.4	1071.4	4.4	84,532	300	32.8
B1	188.8	1179.7	5.1	89,049		27.1
P2-P4	180.2	1126.2	4.2	81,283	325	27.1
B2-B4	197.8	1236.3	4.1	93,926		28.6
P5-P9	174.3	1089.1	3.8	72,748	350	26.0
B5-B9	199.9	1249.5	4.6	76,464		23.1
P10-P14	181.1	1131.9	3.9	69,948	375	22.7
B10-B14	204.7	1279.5	4.1	82,190		23.5
P15-P19	189.6	1186.1	3.6	79,326	400	21.2
B15-B19	203.1	1269.2	3.9	91,846		23.6
P20-P21	184.2	1150.8	3.5	75,253	425	19.4
B20-B21	203.7	1298.2	3.9	83,308		18.9

ıe data presented in this Phase II report ies to the use of mechanical spreader niques to determine the relationship veen heating and application tempera-s, application viscosity, and the interply ıtities of hot-applied coal tar products l in the construction of built-up roofing ıbranes. Phase I of the study dealt with l-mopping application techniques.

ıgestions for future research

ertain objections have been raised as to validity of the "phase construction" l in the preparation of test samples in ı Phase I and Phase II of this study as ıpared to the usual field construction :tice of applying felts in shingle-ion. Therefore, an additional series of s (Phase III) have been made using the gle-fashion methods for both hand ›ping and mechanical application tech-ıes. The results will be reported in a equent document.

is suggested that a summary report be ›ared comparing the results of the se I, Phase II and Phase III portions of project along with recommendations implementing the findings of the pro-ı into realistic construction practices.

is also suggested that, because similar ication testing has not been done with er glass felts or polyester felts and ıalts or coal tars, an additional series of s be conducted by the roofing industry udy the relationship between applica-temperature, viscosity, and interply ghts using the glass- and polyester-d felts now being used in practice and ıajor hot-applied asphalt and coal tar lucts.

It is further suggested that a study be made to determine reasons for differences in load/strain properties between products and Phase I and Phase II specimens.

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(All are members of Local No. 37 [AFL/CIO] of the United Union of Roofers, Waterproofers, and Allied Workers Association.)

Notes

[1] Coal tar pitch refers to ASTM D-450 Type I and coal tar bitumen refers to ASTM D-450 Type III.