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DOE/CS/40166-T1
(DE82011115)

ASPHALT SATURATION OF ROOFING FELT ON THE FELT MACHINE

Final Report and Progress Report for the Period
January 1980—July 1981

By
William J. Woodring
Duane A. Davis
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DOE/CS/40166--T1

DE82 011115

Work Performed Under Contract No. AC01-78CS40166

GAF Corporation
South Bound Brook, New Jersey

DEPARTMENT OF ENERGY · UNITED STATES OF AMERICA

U. S. DEPARTMENT OF ENERGY

Division of Industrial Energy Conservation

Available from the National Technical Information Service, U. S. Department of Commerce, Springfield, Virginia 22161.

Price: Printed Copy A03
Microfiche A01

Codes are used for pricing all publications. The code is determined by the number of pages in the publication. Information pertaining to the pricing codes can be found in the current issues of the following publications, which are generally available in most libraries: *Energy Research Abstracts, (ERA); Government Reports Announcements* and Index (*GRA* and I); *Scientific and Technical Abstract Reports (STAR);* and publication, NTIS-PR-360 available from (NTIS) at the above address.

DOE/CS/40166-T1
(DE82011115)
Distribution Categories UC-95e and UC-95f

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OFFICE OF INDUSTRIAL PROGRAMS

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I. ABSTRACT

The asphalt roofing industry manufactures approximately 10 million tons of product annually. This requires an estimated 40 trillion BTU's in process heat and 4 million tons of asphalt having a fuel value of 140 trillion BTU's.

Pilot equipment was installed on a commercial felt machine to determine whether saturation on the felt machine was feasible and whether energy savings would result. A process was demonstrated by which adequate saturation levels can be achieved. Energy savings are estimated at 6.3 trillion BTU's per year on an industry-wide basis.

An economic study with consideration of the rapid industry conversion from organic felt to the less energy-intensive glass mat based roofing precluded further process scale-up and plans for commercialization.

II. SUMMARY

The objective of this investigation was to determine the feasibility, energy savings, and cost effectiveness of asphalt saturating roofing felt in the paper mill instead of the roofing plant. This report details accomplishments on this program from January 1980 through July 1981 and summarizes the entire program from its start in October 1978. Phase I report, issued February 1980, details the work from October 1978 through December 1979.

The specific hypothesis being investigated is that the asphalt saturation process, which normally takes place at a roofing mill where finished products are produced, can be better performed at the paper mill where an intermediate, the roofing felt, is manufactured.

Paper mill saturation is expected to reduce energy consumption by utilizing the BTU's in the hot saturant to assist in moisture removal during felt manufacture. In addition, the roofing plant saturation utilizes large volumes of recirculating asphalt, which results in energy losses and the generation of pollutants. It is expected that paper mill saturation will improve on these energy and pollution aspects. Theoretical energy savings for felt mill saturation are estimated at 6.3 trillion BTU per year on an industry-wide basis. This energy savings potential, however, will be reduced proportionately with the increased usage of glass mat in roofing.

Pilot asphalt application equipment was designed and installed on a commercial 12 ft. wide felt machine. Eighteen trial runs were made applying asphalt to sections of the felt up to 42" wide. Both shingle felt and built-up roofing felt were produced, which exceed industry asphalt saturation level minimums.

Two trial runs of felt mill saturated felt were made into shingles on a commercial roofing machine. The physical properties of these shingles are satisfactory, and samples have been put on outdoor exposure in New Jersey, Florida, and Puerto Rico to evaluate long-term durability.

The economics of converting a typical felt mill to asphalt spray saturation appears favorable provided the roofing plants being supplied by the felt mill are within a 125 mile radius of the felt mill and provided the felt mill is scheduled to continue to operate for more than 5 years. The long-term operation of felt mills producing organic felt for roofing may be limited in most cases because of the rapid increase in the usage of glass mat in roofing.

In view of the last factor, work on this program was halted prior to expanding the pilot equipment to saturate the full 12 ft. width of the felt machine. Several areas of risk in this process, which would require additional work to fully evaluate prior to commercialization, are listed later in this report.

III. INTRODUCTION

Asphalt roofing products protect the vast majority of homes and buildings in the United States. These products, for the most part, provide satisfactory in-service performance for 20 years, thus providing low life-cycle cost.

In 1978, U.S. production of roofing materials was 8 million tons of roofing shingles, 1 million tons of saturated felt products, and 1 million tons of roll roofing products. In common with most materials, rapidly increasing energy costs are increasing the cost of these widely used materials. In addition to substantial quantities of process heat used in their manufacture, asphalt roofing products utilize 4 million tons of asphalt (equivalent to 24 million barrels of oil) as a component in their manufacture. As a starting point in the reduction of process heat, it was decided to investigate a change in the asphalt saturation process.

The production of organic based asphalt roofing products starts with the dry felt, which is manufactured in a felt mill from cellulose fibers such as those from waste papers and wood. The dry felt is then taken to a roofing mill in jumbo rolls, where it is saturated and coated with asphalt and surfaced with selected mineral aggregates appropriate to the finished product. This may be smooth roll roofing surfaced with mica or talc, or it may be mineral surfaced rolls or shingles, surfaced with slate, stone, or ceramic granules. A detailed description of the process is given in the Phase I* report.

* "Asphalt Saturation of Roofing Felt on the Felt Machine"; Phase I - Progress Report Oct. 1978-Dec. 1979; Davis, Walker, & Smith; Feb. 1980.

The energy-saving process which was investigated includes the same basic operation as the current process, except the energy intensive dip saturation step at the roofing plant would be replaced by spray saturation on the felt machine. The energy savings result from the use of the BTU's in the hot asphalt saturant to assist in moisture removal from the damp felt, thereby reducing the steam requirements in the drum dryers at the felt plant. Energy savings also result from the elimination of the heat loss from the large volume of excess hot asphalt needed for the dip tanks in the current process.

IV. ENERGY SAVINGS

The energy savings for the process under evaluation result from the elimination of all energies associated with felt saturation on the roofing machine; the elimination of all energies associated with the saturator only machine; and the reduction of energy required to dry the felt minus the energy required for the saturation process in the felt mill. Calculations of the energy savings are based on actual plant energy usage data developed during conventional operation. These were adjusted to average or typical industry plant energy values based on 50 felt mills, 100 roofing machines, 50 saturator only machines, and the 1976 total U.S. production of asphalt roofing products.

Based on the data developed, the annual production and annual operating hours of typical industry machines are:

	Annual Production Tons	Annual Operating Hours
Felt Machine	28,100 (Dry Felt)	8,000
Roofing Machine	86,900 (Roofing Products)	5,000
Saturator	20,100 (Saturated Felt)	5,000

A typical roofing line requires 36,265 million BTU/year to operate the saturator section of the machine. This includes the energy for the saturant reheater, steam requirements, and the electrostatic precipitator for pollution control. Also taken into consideration was the energy requirement for non-operating hours.

A typical saturator machine where only saturated roofing felt is produced was found to require 30,635 million BTU/year.

Since equilibrium energy use measurements at the felt mill were beyond the scope of the trial runs undertaken during this study, the potential energy savings at the felt mill had to be calculated based on known energy usage during conventional operation and the theoretical heat balance on the proposed process. This indicates 15.4% of the normal energy required to dry the felt could be shut down. This energy savings is offset by the need for an asphalt heater, but results in a net energy savings of 23,200 million BTU/Year for a typical industry felt mill.

The energy consumptions and savings are summarized in Table 1.* The energy savings for the typical machines are extrapolated for the industry as a whole. Based on complete conversion (50 felt machines, 100 roofing machines, and 50 saturator only machines), industry savings are 6.3 trillion BTU/year, which is equivalent to 43.5 million gallons of #6 fuel oil. This energy savings, however, is based on the asphalt roofing industry using 100% organic felt base products. The rapid conversion to fiber glass mat based asphalt roofing over the last few years reduces this industry potential energy savings proportionately to the percentage of glass mat based products produced. It is estimated that at least 50% of the asphalt roofing in the U.S. will be made on fiber glass mat by 1985.

* Note values in this table differ from the information given in the Phase I report due to adjustments in the energy flow sheets, which were made in view of actual plant energy data.

One of the advantages of converting to fiber glass mat for asphalt roofing is a reduction of energy usage. An energy balance was done for organic vs. fiber glass shingles starting with the incoming raw materials at the organic felt mill and the glass fiber plants. This indicated that it requires 59.3% less energy to make fiber glass mat based shingles than organic based. In addition to this, fiber glass shingles contain 31.5% less asphalt than do organic shingles.

TABLE 1

ENERGY CONSUMPTION AND SAVINGS
(MM BTU/Year)*

Type of Machine	Energy Consumption		Energy Savings		
	Conventional Operation	Saturated Felt From Felt Machine	Savings Per Typical Machine	No. of U.S. Machines	Total Energy Savings Potential
Felt Machine	392,065	368,865	23,200	50	1,160,000
Roofing Machine	67,030	30,765	36,265	100	3,626,500
Saturator	30,635	0	30,635	50	1,531,750
					6,318,250

* MM BTU = 1,000,000 BTU

NOTE: Individual plants use more or less energy depending on production volume, product mix, hours of operation, types of equipment, condition of equipment, climate, etc. Data given is for average or typical industry machines.

V. ECONOMIC EVALUATION

The overall economics of this project were developed taking the following costs and savings into consideration.

1. Energy Savings resulting from the asphalt saturation of roofing felt on the felt machine in comparison to the production of dry felt with subsequent asphalt saturation on the roofing machine for shingles and other coated products and on the saturator only machine for saturated felt sales.

2. Additional costs of operations (These costs are based on depreciation and insurance and taxes for additional capital requirements only. The additional repairs and maintenance costs for the felt mill saturation are considered to be equivalent to the reduction in repair and maintenance costs on the saturation section of the roofing machine and the saturator only machine in this analysis.)

3. Additional freight costs for shipping of the saturated felt to the roofing machine which is not located at the felt mill site as compared to the transport of dry felt. (Saturated felt at 175% saturation will increase the shipping charges by 1.75 as compared to the equivalent square footage of dry felt.)

The average industry-wide capacity and projected energy savings per unit* for felt machines, roofing machines and saturator only machines as developed for this study are:

* Based on 50 felt mills, 100 roofing machines, 50 saturator only machines, and the 1976 total U.S. production of asphalt roofing products.

	Tons/Year Final Products	Tons/Year Equivalent Dry Felt	Tons/Year Equivalent Saturated Felt	Annual Energy Savings Million BTU's
Felt Machine	--	28,100	77,275	23,300
Roofing Machine	86,900	10,750	29,563	36,300
Saturator Only	20,300	6,600	18,150	30,700

The typical industry-wide model for roofing products manufacture is projected on the basis of one felt machine producing the felt requirements for two roofing machines producing shingles and other coated products, and for one saturator only machine producing saturated felt for sales.

For this evaluation, the felt requirement for shingle production would be produced as saturated felt on the felt machine, thus eliminating the saturation step on the roofing machine. The remaining capacity of the felt machine (approximately 25%) would be used to produce saturated felt for direct sales as saturated felt or uncoated roll roofing products, thus completely eliminating the operation of the saturation only machine.

During the experimental runs, felt saturated in the felt mill contained 1-2% moisture, which may cause foaming if applied in hot asphalt on a built-up roof. However, for this evaluation it was assumed further development work would allow the use of felt mill saturated felt in this application.

Projected Energy Savings:

Based on the industry-wide model as developed, the typical usage of felt machine production and energy savings are:

	Annual Dry Felt Tons	Annual Saturated Felt Tons	Annual Energy Savings Million BTU's
Felt Production			
Felt Machine	28,100	77,275	23,200
Felt Usage			
Roofing Machine #1	10,750	29,563	36,300
Roofing Machine #2	10,750	29,562	36,300
Subtotal	21,500	59,125	72,600
Saturator Only Machine	6,600	18,150	30,700
Total Felt Usage	28,100	77,275	103,300
Total Energy Savings			126,500

The total energy savings based on the projected model as shown are 126,500 million BTU per year.

Further, based on the use of fuel oil #6 at $1.00/gallon with 145,000 BTU per gallon heat content ($6.90 per million BTU's), the projected energy savings is $872,800 per year.

Projected Additional Cost of Operations:

The estimated capital cost required for the installation of asphalt spray saturation facilities at a felt machine is $1,250,000 (± 20%). The estimate is based on a felt mill located at facilities which have a roofing mill and associated asphalt storage and asphalt heating facilities.

For this study, depreciation life is based on five years or 20% with annual depreciation of $250,000. Taxes and insurance are estimated at 2.0% of the capital cost or $25,000. On this basis, the total additional cost of operation is $275,000 per year.

Projected Additional Freight Costs:

The additional freight cost for the shipment of saturated felt, as compared to the shipment of dry felt, is a function of the location of the felt machine to the location of the roofing machines which use the saturated felt. Without any consideration for possible load weight advantages of saturated felt, the additional shipping costs would be 1.75 times the current costs of dry felt due to the 175% weight saturation of the dry felt with saturant asphalt.

For this study, a freight rate of $10.00/ton for shipments within 125 miles and $18.00/ton for shipments up to 250 miles have been projected. The additional freight charges are based on the typical industry-wide model roofing machine which uses 29,563 tons per year of saturated felt as compared to 10,750 tons of dry felt or an added shipment of 18,813 tons.

For this study, the data were developed for four cases based on location of the felt machine in relationship to the roofing machine.

For Case I: Felt machine and 2 roofing machines at the same location - no additional freight cost would be required.

For Case II: Felt machine and 1 roofing machine at same location and 1 roofing machine within 125 miles - the additional freight costs would be:

18,813 tons x $10.00/ton or $188,100

For Case III: Felt machine with 2 roofing machines within 125 miles - the additional freight costs would be:

Roofing Machine #1	18,813 tons x $10.00/ton or	$188,100
Roofing Machine #2	18,813 tons x $10.00/ton or	188,100
	Total	$376,200

For Case IV: Felt machine with 1 roofing machine within 125 miles and 1 roofing machine within 250 miles - the additional freight costs would be:

Roofing Machine #1	18,813 tons x $10.00/ton or	$188,100
Roofing Machine #2	18,813 tons x $18.00/ton or	338,600
	Total	$526,700

A summary of the overall economics is shown in Table 2.

For Case I (Felt machine and the two roofing machines at the same location) the energy savings are projected at $872,800 with $275,000 for added operating costs. No added freight costs are incurred in Case I. The net savings before taxes are $597,800. With the current federal corporated income tax rate at 46.0% the net earnings after taxes are $322,800.

A tax credit of 20% of the capital investment of $1,250,000 or $250,000 is allowed from this energy saving installation. Based on the inclusion of $322,800 savings after taxes annually, $250,000 for depreciation and $250,000 tax credit in the first year, the profitability index (discounted cash basis) is calculated to be 30.2%.

For Case II (Felt machine and one roofing machine at the same location with the other roofing machine within 125 miles) an added freight cost of $188,100 is incurred. Case II net savings before taxes are $409,700 and after tax savings is $221,200. Based on the inclusion of $221,200 savings after taxes annually, $250,000 for depreciation and $250,000 tax credit in the first year, the profitability index is calculated to be 24.1%.

Based on a similar analysis, for Case III (Felt machine with two roofing machines within 125 miles) the profitability index is calculated to be 16.8%.

Case IV (Felt machine with one roofing machine within 125 miles and other roofing machine within 250 miles), the net savings after taxes is only $38,400 and the profitability index is calculated to be 9.8%.

The economic feasibility for the production of saturated felt on a felt machine for an individual plant will require a detailed analysis of the various cost factors pertinent to the specific situation.

* Profitability index reflects the interest rate which equates the present value of the proposed receipts from the project to the present value of the proposed outlays for the project over the life of the project.

Profitability Index and Cost of Energy:

The data developed in this study for energy cost are based on #6 fuel oil as the energy source at $1.00/gallon or $6.90 per million BTU's.

The current average industrial cost of natural gas is $3.00/thousand cubic feet or $3.00 per million BTU's. Based on production facilities which use natural gas rather than fuel oil, the overall economics would be much less favorable.

Separate calculations developed in this study indicate that at the following minimum purchased prices of energy ($/million BTU) a profitability index of 15.0% is obtained for the cases studied (net saving after taxes of $97,000).

	$/MM BTU	Oil $/Gallon	Natural Gas $/Thousand Cubic Feet
Case I	$3.60	$0.52	$3.60
Case II	4.30	0.62	4.30
Case III	6.55	0.95	6.55
Case IV	7.75	1.12	7.75
Current Cost		1.00	3.00

At energy costs higher than the above minimum purchase prices of energy, the profitability index is higher.

As may be noted from the above table, the current cost of fuel oil #6 at $1.00/gallon would provide a profitability index exceeding 15.0% for Cases I, II and III, as previously discussed. However, at the current cost of natural gas at $3.00/thousand cubic feet, none of the cases would provide a profitability index of 15.0%. Case I requires natural gas cost of $3.60/MCF to provide a profitability index of 15.0%, and Case II requires natural gas cost of $4.30/MCF.

TABLE 2

ASPHALT SATURATION OF ROOFING FELT AT THE FELT MILL
SUMMARY OF ECONOMICS

Case I: Felt machine and 2 roofing machines at same location.

Case II: Felt machine and 1 roofing machine at same location and 1 roofing machine within 125 miles.

Case III: Felt machine with 2 roofing machines within 125 miles.

Case IV: Felt machine with 1 roofing machine within 125 miles and 1 roofing machine within 250 miles.

The projected results of this study are:

Overall Economics:	Case I Thousand Dollars	Case II Thousand Dollars	Case III Thousand Dollars	Case IV Thousand Dollars
Estimated Capital Investment (± 20%)	$1,250	$1,250	$1,250	$1,250
Energy Savings	$872.8	$872.8	$872.8	$872.8
Added Operating Costs	$275.0	$275.0	$275.0	$275.0
Added Freight Costs	---	188.1	376.2	526.7
Subtotal Added Costs	$275.0	$463.1	$651.2	$801.7
Net Savings Before Taxes	$597.8	$409.7	$221.6	$ 71.1
Net Savings After Taxes	322.8	221.2	119.7	38.4
Tax Credit (1st Year)	$250.0	$250.0	$250.0	$250.0
Profitability Index*	30.2%	24.1%	16.8%	9.8%

* Profitability index reflects the interest rate which equates the present value of the proposed receipts from the project to the present value of the proposed outlays for the project over the life of the project.

VI. EXPERIMENTAL PROGRAM

Pilot Plant Description:

The asphalt saturation pilot plant equipment was mounted on an existing commercial felt machine and was operated experimentally while the commercial machine is producing standard product.

The sections of concern of the existing commercial felt machine are the typical dryer drums, calender stack and winder. These are shown schematically in Figure 1. The machine used for this study produces various calipers of 12 foot wide felt.

The felt is losing moisture as it is carried around the dryer drums, and when it enters the higher temperature (365°F) section at Drum #34, the felt has about 25% moisture; as it exits the dryer, the moisture content is less than 8%. The felt is wound after the calender stack flexes and presses the felt for better surface finish. When a roll is wound and the next one is started, the felt is rewound, at a faster speed, while it is slit and trimmed to 3 or 4 foot widths for shipment to the roofing mills.

The pilot installation is also shown in Figure 1. It basically consists of a roofers' kettle for heating and pumping the asphalt and a circulating line. Initially five spray manifolds spraying a 9" wide area were installed. Later these were lengthened to spray a 36" wide area, and finally, a sixth manifold was added with the spray area of all the manifolds lengthened to 42" wide.

The kettle is trailer mounted and has a capacity of 230 gallons. It is manufactured by Aeroil Products Co., Inc. - Model #KE-T-230P7. Its 7½ hp. pump engine as well as the heating torch are powdered by LP gas for safety in a well ventilated indoor area. Optional safety equipment, such as thermostatic controls and an automatic gas shut-off, have been added. A dial thermometer directly reads the temperature of the saturant.

At full load, the internal pump operates at 35 gallons per minute. It is connected to a 2 inch schedule 40 black iron circulating line which is steam traced and insulated. A pressure gauge is located just after the first header take-off. Normal operating pressure is about 5 psi. The original 0-200 psi gauge was replaced with a 0-15 psi unit after Run #3 to provide more accurate readings. Pressure is controlled with a flow valve where the asphalt returns to the kettle. The manifolds are made of 1" pipe with a series of drilled holes.

During some of the later runs (#8, 9, 12, 14, 15, 17 & 18) at the felt mill, a device for applying asphalt at the winder was used. By adding asphalt at this point, the percent saturation could be significantly increased and the final percent saturation controlled. The extra added asphalt soaked into the felt during the 10-60 minute period between initial wind-up of the felt and subsequent rewinding for trimming and slitting. During this period, roll temperatures are about 150-200°F.

Asphalt application temperature during the spray saturation trial runs was maintained at approximately 450°F. The asphalt softening point was 115-125°F (R&B).

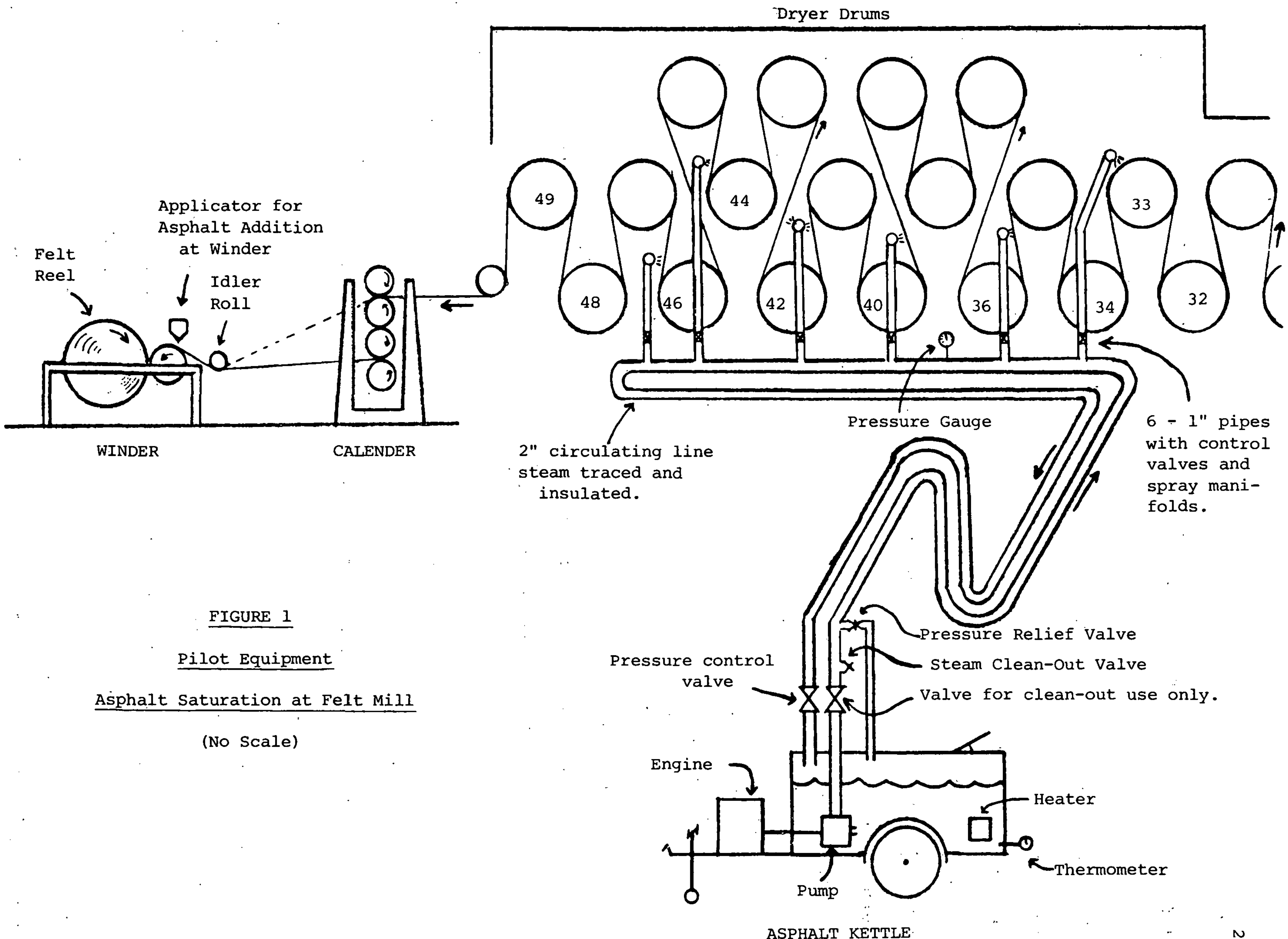

FIGURE 1

Pilot Equipment

Asphalt Saturation at Felt Mill

(No Scale)

Laboratory Testing and Trial Runs:

Details of the initial exploratory felt machine tests, of the laboratory studies of saturation variables, and of the first seven trial runs on the felt machine using the pilot asphalt spraying equipment were given in the Phase I report.

Trial runs #8-18 at the felt mill and the two trial runs at the roofing plant took place during the period January-September 1980. These runs demonstrated that:

1. Spray saturation in the felt mill can achieve the required level of asphalt saturation in organic felt for use in built-up roofing, for use as facers on urethane board insulation for built-up roofing, for use as shingle underlayment felt, and for use in shingles.
2. Felt saturated in the felt mill can be converted into shingles at the roofing plant.
3. Felt saturated in the felt mill contains 1-2% moisture, which may cause foaming if applied in hot asphalt on a built-up roof.
4. Equipment changes, such as a cooling looper at the felt mill and modifications to the roofing mill unwind stand, will be required.
5. Areas of risk exist which require additional work to fully evaluate prior to commercialization. These are listed after the details of the trial runs.

Trial Run Details:

Run #8 - All five manifolds were expanded from a nine inch spray width to 36". All new holes were 7/64" diameter, with holes on 2" centers on the first manifold and staggered 2-3/4" and 3" on the others. Asphalt was applied on a 7 inch width at the winder, with a more accurate metering pail. Percent saturation varied up and down between 110% and 160% with 60 running feet between 140% and 160%. The problem was caused by the pump drawing in air when the kettle is less than half full. There was "singing" but no sticking when the test roll was later unwound.

Run #9 - A 38" long trough was fabricated to apply asphalt over the full width at the winder. Material made averaged 140% saturation and contained 1.3% moisture. There was better coverage at the first manifold (but no puddle) and spillage at the third and fourth. This saturated felt was used in the first roofing plant test run to make shingles. Also, lower saturated felt was made for testing as urethane board insulation facers, but this heavier 55# felt was unacceptable.

Run #10 - For Runs #10 through #12, new manifolds were installed with new hole sizes and spacings. The goal is to get equal sized puddles after each manifold, an indication of maximum absorption without overflow or excessive spreading. The sequence of turning on the manifolds was carefully timed so that the start of these runs had individual manifold sprays or were sprayed cumulatively from the first to last or last to first manifold. Run #10 produced its goal of 110-120% saturation for urethane facers.

Run #11 - Similar to Run #10. It produced 140% saturated 55# felt for urethane facers.

Run #12 - Shingle felt saturation goal was achieved. The run produced a 3-foot wide by over 100 ft. long section that averaged 172% saturation. Its success was due to the new manifolds and the addition of asphalt at the winder. However, a trim cut at the rewinder and slitter was not made and the feathered edge, with droplets of asphalt, adhered to itself when the roll was wound. There was no equipment available to rewind again and make the cut, so the roll was unusable for another shingle plant run.

Run #13 - This run was aborted twice due to steam condensation accidentally mixing with the asphalt. Six new manifolds, spraying 42" wide, with new hole sizes and spacings were then installed across the dryer, replacing five cantilevered ones. The 42" spray area makes one full 36" wide roll for plant runs and a 6" saturated area on the adjoining roll for lab testing. A new top spray was added upstream and the penultimate manifold was changed from top to bottom. When it was discovered that the new manifolds were not mounted properly and could not be changed except on a plant down day, Run #13 was cancelled and the next run was proclaimed to be Run #14.

Run #14A and #14B - Run #14A tested the new manifolds individually. During the preparation for the trial, asphalt started spraying on the sheet due to an incorrectly installed valve. During the run, another faulty valve opened by itself and remained on after the trial. However, useful data was collected from samples of the individual manifolds. Run #14B, which followed #14A by a few minutes, was hampered by the extra depletion of asphalt. During the run, the pump drew in air, as happened in Run #8, and the saturated felt was unacceptable.

Run #15 - Doctor blades in the dryer section were raised to cut down spreading of asphalt on the dryer drums. Pressure was raised to 5.0 psi from 4.5 psi to compensate for visually poor spraying from individual manifolds. The result was a total 240% saturation, considerably over the min. 175% goal. As in Run #14B, asphalt, at a 35% saturation rate, was added at the winder. The oversaturation caused problems at the rewinder and slitter and it took 2½ hours for clean-up and felt start-up. The felt was unusable as it could not be unwound.

Run #16 - This run was on the lighter 27# felt for urethane facers. Felt was saturated to 108%, near the 110% target, by using the top four manifolds only. While the average saturation was 108%, the saturation was uneven, with gray and black stripes. The making of good material would require new manifolds with smaller and closer holes or another application system.

Run #17 - Similar to Run #15, except manifold pressure was lowered to 4.8 from 5.0 and only the first 3 (top) and last 2 (bottom) manifolds were used. Shingle felt saturation was 137%, short of the 170% goal. The lower saturation is attributed to lower flow at some manifolds, apparently due to hardened, dust coated asphalt having cut down the effective hole sizes. The manifolds were cleaned after the run.

Runs #18A and #18B - These were made a week after Run #17. During that time, the plant was in continuous operation. Previous runs had been separated by a down day, during which the dryers and doctor blades were cleaned. When the doctor blades were raised for Run #18, some hardened asphalt from the previous run fell off unnoticed and stuck to some dryer drums, causing sheet distortion and punctures on each drum revolution. After holes were noticed during Run #18A, the asphalt flow was stopped. Run #18B started a few minutes later, when the sheet was nearly free of asphalt and the drums were cleaned. Run #18B was saturated to 170% and was used to later make shingles (Shingle Run #2).

Roofing Plant Run #1 - Although the percent saturation was not up to specification (140% avg. vs. U.L. minimum 165%), the test run went smoothly and shingles were made with no visible defects. Unwinding was identified as a potential problem due to the tacky surface. The saturator was bypassed. There was no foaming of the asphalt at the coater, even though the felt moisture content was 1.6%.* Shingles were made with larger #9 colored granules. Eight bundles were made. Felt was from Felt Mill Run #9.

Roofing Plant Run #2 - Same procedure as Roofing Plant Run #1. Felt from Run #18A broke repeatedly before the coater, due to punctures in the felt. Shingles for evaluation were made from Run #18B. Moderate sticking at the unwinder was of concern, but the sheet did not tear. The test run was made at 1/3 normal production speed to allow more observation time. The breakdown analysis of the shingles produced is given in Table 3.

The shingles from this run along with control shingles from normal production are on exposure in New Jersey, Florida, and Puerto Rico to evaluate weathering characteristics. These have been out for only a few months so no results are available at this time.

Spray saturated shingles from Roofing Plant Run #2 were evaluated for blistering potential and were found to be not significantly different from regular production shingles.

Laboratory tests subject the sample shingles and control samples to conditions likely to cause blisters which would normally occur only after years of outdoor exposure. The shingles are then measured for the amount and size of blisters on a standard scale of one to ten, which was developed by the Asphalt Roofing Manufacturers Association.

In the "Vacuum Blister Test", shingle samples are put in an oven at 140^{O}F and 26 inches Hg vacuum for 5 hours. The vacuum encourages blistering without very high temperatures. It was previously known that the spray saturated shingles had a higher moisture content, but it did not affect the

* Initially measured at 1.3% as produced at the felt mill. Just prior to roofing machine run, after 1 month storage, moisture was measured @ 1.6%.

outcome of the test.

The "Wet Blister Test" consists of soaking samples in 77°F water for 48 hours and then hanging them in a 176°F oven for 2 hours. Blisters which are caused are generally the result of water being absorbed into the felt. This frequently happens when the felt is saturated to less then specification.

The "Heat Lamp Test" exposes shingles under infrared lights. A thermometer measures the surface temperature. The lights are adjusted so that the temperature is 165°F. Shingles are rated after each 7 hour day. This method heats the granule surface of the shingles, as happens normally on sunny days.

Blister Tests:	Spray Saturated	Control Shingle
Vacuum Blister	Trace	Trace/Slight
Wet Blister	Severe	Severe
Heat Lamp Test (7 Hrs. @ 165°F)	Severe/Excessive	Severe/Excessive

TABLE 3

SPRAY SATURATED SHINGLES, TEST RUN OF AUGUST 28, 1980

(Roofing Plant Run #2, Material from Gloucester Run #18B)

Breakdown Analysis:

	Lbs./100 Ft.^{2}		
	Test Run	U.L. Spec.	Typical U.L.
Felt (55 Grade)	11.98	11.0 min.	11.5
Saturant	20.12	18.15 min.	19.6
Coating (Asphalt)	15.12	---	14.1
Stabilizer (mixed with coating)	11.62	---	17.3
Granules (colored)	32.15	---	32.0
Sand & Talc (backsurfacing)	3.26	---	3.5
Total	94.25	91 min.	98
% Stabilizer	43.5	60 max.	55
% Saturation	168.0	165 min.	170
Lbs./240 Ft.^{2}	226.0	218.4 min.	235

Areas of Risk in Spray Saturation:

The following items would require additional work to fully evaluate and resolve prior to commercialization:

1. Spray nozzles need to be developed that will not partially clog during production due to hardening of asphalt or dust accumulation. Ideally, a mechanism could be developed to clear the nozzles while the line is running. Normal felt production is 24 hr./day for three weeks before a down day. Nozzles are between dryer drums and relatively inaccessible.
2. Some asphalt will spill as it is squeezed out at the felt edges. It must be gathered, filtered, and recycled. Also, some will drip under the whole 12 foot wide dryer section. The equipment under the dryer cannot interfere with clean-up or rethreading after an infrequent felt break.
3. Saturated felt is heavier and weaker than dry felt. Sheet tension control devices may have to be modified.
4. The high pressure dryer section has a two-rope system for automatic rethreading. These ropes will unavoidably be lubricated with saturant. A three-rope system may be required for a positive grip.
5. Reel changes are made by tearing the felt with a cloth tape. A new procedure may be needed for saturated felt.
6. All later trial runs bypassed the calender stack to avoid unacceptable sheet wrinkling and crushing. The calender normally maintains sheet tension through the end of the dryer section during reel changes.
7. The hot (200°F+) roll must be cooled during rewinding, probably with a roofing plant type looper.

8. A system would have to be developed to edge trim the felt prior to spray saturation. Waste saturated felt could not be reprocessed as is now done with the edge trim from dry felt.
9. A warm, newly made roll may not support itself without becoming egg shaped. Pressure on the bottom of the roll may cause sticking of the saturated felt layers. Possibly the roll will have to be supported by the core. It is unlikely that rolls can be stacked 3 or 4 high in the felt or roofing mill warehouse. A full roll has not been made.
10. Unwinder modifications will be necessary at the roofing mills. Two trial runs at 150 fpm unwound with moderate sticking, but no tearing. Reliable unwinding is necessary at up to 500 fpm.
11. The splicing tape used on roofing machines to splice dry felt together will not hold on saturated felt. Another splicing procedure would have to be used.
12. Felt at the coater will now be much cooler. In steady-state production, coating returning to the surge tank will be cooler. Hot coating helps maintain high filler levels and minimizes production problems.
13. Spray saturated felt has about 1.6% moisture, compared to negligible in dip saturated. While it is not expected that this moisture would cause premature failure of shingles, there is some risk.

Air Pollution Control:

Currently, a dip saturation process is used in the roofing industry. Felt is dipped several times under submerged rollers in a large tank containing about 10,000 gallons of 450°F asphalt saturant. Unavoidable agitation is caused by these multiple passes. There is a large surface area of very hot, freshly saturated felt in the saturator. Initially, the felt is about 6% moisture. This moisture boils away almost instantly. Low boiling point hydrocarbons in the asphalt evaporate.

Most of a roofing plant's fumes are generated at the saturator. The remainder comes mostly from the coating station and the still yard.

The typical method of air pollution control is to duct the fumes to an electrostatic precipitator. Here, particles in the air are charged, attracted to a screen, and removed.

Less common methods are high efficiency filters and fume incinerators. Filters require more maintenance. Filters remove larger particles and gas dispersoids. Electrostatic precipitators can remove the smaller particles that would pass through the filter. A typical efficiency is 99%. Fume incinerators remove odor-causing asphalt vapors as well as smoke particles.

The majority of roofing plants switched from fume incinerators to electrostatic precipitators in the last 10 to 20 years due to an energy savings of over 90%. While the hood, duct, and blower costs do not change, fume incinerators heat all the exhaust air to a high temperature, but electrostatic precipitators expend pulses of electric energy only on particles in the air.

Hot exhaust from fume incinerators can be put through an appropriate heat recovery system. Exhaust from electrostatic precipitators generally is not hot enough to justify heat recovery.

VII. CONCLUSIONS

Saturation of organic roofing felt in the felt mill appears to be technically feasible. Additional work is required to fully explore all the areas of risk which were defined in this project.

If the use of organic felt in asphalt roofing was to remain stable or decline slowly, this project should continue based on the potential energy and economic savings. However, with the rapid increase in the use of fiber glass mat in the asphalt roofing industry, felt mills are being closed. The investment in additional R&D along with the capital equipment cost required to continue this project cannot be justified at this time.

A typical roofing plant has an electrostatic precipitator exhausted to atmosphere. A typical felt mill has a dryer section using steam drums and supplemented by jets of 600^{o}F dry air blown into the moving felt web. This hot air is typically supplied by a gas burner. A common name for the hot air system is "vapor absorption system", because it lowers the humidity and speeds drying.

In the proposed spray saturation system, the exhaust from the dryer section (asphalt fumes and water vapor) will be incinerated and the hot exhaust directly recycled into the vapor absorption system.

Fire Prevention:

Safety has always been a primary concern in all trial runs. Felt mills contain large quantities of combustible raw materials and finished rolls. Massive dryer drums remain hot long after the steam supply is shut off.

At the felt mill trial run location, there are water sprinklers in the dryer section hood and on the ceiling. During trial runs, several CO_2 and dry chemical fire extinguishers are strategically placed around the dryer. Two fire hoses with mist nozzles are unrolled and pressurized. One man is assigned fire watch as his only duty, while the trial runs are conducted by others. People working with hot asphalt are instructed in various safety rules. Everyone is aware of the procedures in the remote event of a fire. Specific instructions have been issued that fire extinguishers should be used before the hoses. Mist nozzles are on the hoses so that the steam pressurized steel dryer drums are not subject to rapid cooling from a stream of water. Any fire in the asphalt kettle would be first controlled by closing the lid (if open) and/or using the fire extinguishers. People are made aware of the danger of directing a stream of water into hot liquid asphalt.

For full-scale production, asphalt heating and storage would be at a remote location outside the plant. A CO_2 fire extinguishing system would be installed in the dryer section. Fire extinguishers and hoses would be available in the area, but not manned by a fire watch person. State-of-the-art safety systems developed and proven at roofing plants will be used.

An area that will require attention is spontaneous combustion. In the existing felt mills, the temperatures of finished dry felt rolls are continually monitored by I.R. thermometers and recorded. If the temperature is too high (150^{o}F), there is a possibility of spontaneous combustion. Any suspect rolls are set aside in a remote location until they have cooled and the danger has passed. The principal cause of too hot rolls is overdrying. This may be caused by slightly slowing production speed before the dryer drum temperatures can respond to a lower setting. Also, a shift to a quicker drying blend of recycled paper fibers will result in overheating unless the temperature or line speed is adjusted.

Spray saturated felt is hotter than dry felt when it leaves the dryer. The chemical composition is different. It is not known what the critical spontaneous combustion temperature of a full jumbo roll of spray saturated felt will be. For full-scale production, a cooling looper will be added before the final winding to air cool the saturated felt.