DOE/ID/12795--1

DE90 006304

ENERGY CONSERVATION THROUGH RECYCLING OF FACTORY ASPHALT ROOFING WASTE

Philip B. Shepherd, Project Director	**Manville**	**John Hardy**	**Bird Roofing**
Thomas J. Powers	**Manville**	**Richard Maloof**	**Bird Roofing**
		Clifford Patenaude	**Bird Roofing**
		Joseph Zilfi	**Bird Roofing**

December 31, 1989

Work Performed Under Cooperative Agreement DE - FC07 - 88ID12795

Prepared for
U. S. Department of Energy
Idaho Operations Office, Idaho Falls, Idaho
Sponsored by the Office of the Assistant Secretary for
Conservation and Renewable Energy
Office of Industrial Programs
Washington, D. C.

Prepared by
Manville Sales Corporation
Manville Technical Center
P. O. Box 5108
Denver, Colorado 80217-5108
and
Bird Roofing

ABSTRACT

Prior DOE laboratory research showed that it was possible to recover the energy resource represented in factory shingle waste. This waste could be processed and recycled into the asphalt composition used to make new shingles. This bench-scale research concluded that factory experiments were all that were needed to provide a basis for commercial implementation. The project reported here completed that full scale research. Factory fiber glass shingle waste was processed to a form suitable for recycling. The processed waste was then mixed into the asphalt used to make new shingles. Process parameters and shingle quality were measured to provide a basis for commercial implementation.

Nine tons of factory waste were processed through a Banbury[R] Mixer and a two roll mill to prepare the waste for recycling. The processed waste was then added to the asphalt composition used to make new shingles. The experiments used three different ratios of waste to asphalt plus a waste free baseline mixture. Processing was considered normal in all respects. Waste in concentrations of up to 20% was easily mixed into the asphalt and had no effect on the shingle manufacturing operation. Over 48,000 square feet of shingles were made at each of the waste ratios of 5%, 10%, and 20% in the asphalt composition. Detailed measurements of waste and shingle processing variables showed that this technology is commercially feasible and will have no adverse impact on shingle manufacture.

The shingles were tested for physical properties and performance related attributes. The shingles containing waste were judged to be equal to a baseline lot of shingles containing no waste.

Economic analysis showed that commercial implementation of this technology should be of interest to all manufacturers of asphalt shingles. The financial projections included internal rates of return ranging from 49.5% to 4.3%. Payback periods ran from 1.9 years to 7.4 years. The major variables influencing the financial results were the annual amount of waste generated and the disposal cost at each factory.

Recycling of factory shingle waste would have a favorable environmental impact. The load on the nation's landfills would be reduced by about 500,000 cubic yards annually.

The energy resource recovery from the replacement of virgin raw materials was estimated to be about 3.3×10^{12} Btu annually. This estimate was based on 90% implementation of the recycling of factory waste shingles and granule-surfaced rolls. Bird, Inc. has developed a commercialization and marketing plan aimed at reaching this goal.

Additional laboratory and factory research is needed to extend and apply this technology to the recycling of worn out roofing which represents a much larger energy resource.

[R] *Registered trademark of Farrel Corp.*

ACKNOWLEDGEMENTS

This report was prepared with the support of the U. S. Department of Energy (DOE) under Cooperative Agreement No. DE-FC07-88ID12795. However, any opinions, findings, conclusions, or recommendations expressed herein are those of the authors and do not necessarily represent the views of DOE.

Notice of intent to perform this research relative to section 6 (a) of the National Cooperative Research Act of 1984, 15 U.S.C. § 4301 et seq. was filed with the U.S. Attorney General and the Federal Trade Commission.

Preparation of the factory roofing waste was done at the Laboratory of the Farrel Company in Ansonia, Connecticut. The expert assistance of the following Farrel personnel contributed to the success of this portion of the research.

Frank J. Borzenski - Manager, Process Development
George W. Eighmy - Sales Manager
Peter M. Giles - Sales Engineer
William F. Flaherty - Product Manager

The roofing waste was converted to shingles at the Bird Roofing Factory in Norwood, Massachusetts. In addition to the authors, Bird personnel who made valuable contributions included the following.

David R. Fletcher - Plant Engineer
Gerald S. Chase - Production Superintendent
Bruce E. Guild - Engineer
John Giordano - Quality Control Supervisor
Dennis T. Kennedy - Accounting Manager
Virginia Cronin - Administrative Assistant
Evelyn McNamee - Secretary

Outdoor exposure tests were volunteered by the 3M Company and the GAF Chemicals Corporation. Mr. Charles R. Lea, Division Quality Manager of 3M Company's Industrial Mineral Products Division, arranged for exposure of the shingles at its test location in Houston, Texas. Mr. David Little, National Sales Manager of GAF Chemicals Corporation Mineral Products, arranged for exposure of the shingles at its test location in Hagerstown, Maryland.

Three major roofing manufacturers have volunteered some of the test data obtained in their private evaluation of the shingles. These companies and their cooperating representatives are:

Dr. Michael J. Noone, Vice President-Technology, of the Certainteed Corporation.

Mr. Brian Hayden, Operations Manager of Georgia Pacific.

Mr. Rudolph H. Kizer, Vice President-Manufacturing, of the Owens-Corning Fiberglas Corporation, Roofing Products Division.

Mr. Ed Nelson, Manager, Manville Sales Corporation, arranged for installation of the experimental shingles on house roofs in the Savannah, Georgia area. Mr. Roger Straight, Senior Industrial Engineer, supervised and mapped those roof installations. Small areas of each lot of shingles were also installed at the Manville factory.

Mr. Richard D. Snyder, CAE, Executive Vice President of the Asphalt Roofing Manufacturers Association, provided much valuable updating of information and a survey of waste disposal costs.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

SUMMARY

Factory scale tests confirmed the technical and economic feasibility of recycling fresh, factory waste fiber glass shingles and mineral surfaced roll roofing into the coating asphalt used to produce new fiber glass shingles. Total asphalt roofing products waste has been estimated to represent an energy resource of $7.3x10^{13}$ Btu annually. Roofing waste is also a significant waste disposal problem with over 9 million tons or 11 million cubic yards landfilled each year. Factory shingle and roll roofing waste represent about 5% of these amounts.

Commercial implementation of this research seems assured and has the potential to recover $3.3x10^{12}$ Btu annually in the near term. Conventional process equipment will be used to implement this technology. The process for preparing factory waste for recycling has been patented by Bird, Inc. who has developed a plan for commercializing this process to manufacturers of asphalt roofing products.

Field waste (worn out roofing) has a much greater potential for resource recovery. The successful research on factory waste may set the stage for next step in research to recycle field waste. The first step in such research should address such technical problems as removing nails and rejuvenating weathered asphalt.

Investigation

This commercial scale study of recycling factory fiber glass shingle waste was divided into four active tasks. The first task was to prepare several tons of factory shingle waste for recycling into new shingles and to analyze the processing operation. The second task was to produce fiber glass based asphalt shingles with three different levels of the processed waste contained in the asphalt constituent and to analyze the production process. The third task was to conduct laboratory and field tests to compare the quality of shingles containing waste to the quality of baseline conventional shingles. The fourth task was to evaluate the results of the technical activities related to shingle waste processing, waste bearing shingle production, and product quality testing in terms of the effect on commercial implementation.

Preparation of Shingle Waste

Nine tons of mixed fiber glass shingle waste types were processed for recycling at the Process Development Laboratory of the Farrel Corporation in Ansonia, Connecticut. The processing was done in accordance with U.S. Patent 4,726,846.

The waste was first placed in a Banbury^R Mixer which is a powerful, kneading type of mixer. This operation converted the waste roofing to a soft, homogenous mastic having a temperature of about 200F. Cycle time for the Banbury^R Mixer operation was two minutes.

The soft, hot mastic was immediately dropped into the nip formed by counter rotating rolls of a two roll mill with the clearance between rolls set at 0.000 inches prior to adding the waste. Three passes through the nip of the rolls reduced all granular material in the waste to a powder having approximately the same particle size as the mineral filler used in the manufacture of the asphalt composition contained in new shingles. The processed waste was cooled, packaged, and shipped to the Bird factory in Norwood, Massachusetts for conversion into fiber glass based asphalt shingles.

Manufacture of Shingles

Approximately 5-1/2 tons of processed waste was placed in an agitated and heated tank for melting over a weekend. This was the quantity of waste needed to produce the planned amount of shingles. The very high ratio of filler material in the waste made it too viscous to be pumped, so fresh asphalt was added to the waste in the melting tank. The waste was diluted to a pumpable viscosity by controlling the amount of added asphalt so that the filler content in the diluted waste matched that of the asphalt composition used in the manufacture of shingles.

The diluted waste was pumped to the manufacturing process and mixed with the fresh asphalt composition to achieve waste ratios of 5%, 10%, and 20% by weight of total asphalt coating composition. Engineering calculations, physical measurements, electronic controls, and laboratory tests ensured that the target waste concentrations were achieved.

Shingle manufacture proceeded in a manner normal to this factory. Over two hundred "squares" (a sales unit) of each of four lots were manufactured. The asphalt composition used to make each lot contained waste in the ratios of 0%, 5%, 10%, and 20% respectively.

Quality Tests

Each of the lots of shingles was tested and the shingles containing waste were compared to the baseline shingles containing no waste. All of the testing methods were representative of those used in the roofing industry. Some of the methods were standard American Society For Testing And Materials (ASTM) while others were unique to some roofing manufacturers. The qualities which were tested included:

Weather Resistance
Tear Strength
Tensile Strength and Strain
Stiffness
Wind Resistance
Nail Pull
Dimensional Stability
Handleability
Granule Adhesion

Results

Factory scale experiments, laboratory tests, and financial analysis showed the recycling of factory roofing waste to be both technically and economically feasible. The magnitude of the benefits should make this technology attractive to nearly all manufacturers of fiber glass asphalt shingles.

Factory waste was readily processed through a Banbury^R Mixer and two roll mill to render it suitable for mixing into the asphalt composition used to make new shingles. Processing time, temperature, and energy consumption were reasonable and this procedure will provide the basis for a commercial process. The machinery used is conventional process equipment which is readily available.

Shingles containing processed waste in the asphalt were made following conventional procedures. Normal methods were followed and no unusual circumstances were observed or measured. The additional energy required to introduce waste into the process was very small.

Laboratory tests showed that waste had no effect on the shingles' performance-related or physical properties.

Economics

A detailed financial analysis was made using three representative values each for waste disposal cost and annual waste tonnage. The principal measures used were return on investment and payback. The internal rate of return ranged from 49.5% to 4.3%. Pay back periods ran from 1.9 years to 7.4 years. The results showed that recycling of waste should be of significant financial benefit to most roofing factories. Additional financial responses calculated included such statistics as gross savings and savings per units of waste and production.

Energy

The potential annual energy saving to be achieved by substituting factory waste shingles and granule surfaced rolls for virgin raw materials was estimated to be 3.3×10^{12} Btu. This energy saving was calculated from available data and the assumption of 90% commercial implementation in the near term. Research to extend this successful program to the recycling of field waste (worn out roofing) holds the promise of a national annual energy saving of much of the 7.3×10^{13} Btu per year represented in all asphalt roofing waste.

Environment

Factory roofing waste is a significant burden on our landfills. It was estimated that recycling of this waste would reduce the annual amount of material hauled to landfills by about 400 thousand tons or about 500 thousand cubic yards .

Commercial Implementation

The favorable financial results and the use of conventional process equipment should interest nearly all roofing manufacturers in implementing this technology. Bird, Inc. has a patent on the process for preparing factory waste for recycle. They have developed a marketing plan for implementing this technology. The plan includes provisions for making the process available to small and large manufacturers on a basis which will be designed to suit the needs and desires of each manufacturer who is a potential customer. The flexibility built into the marketing plan will include options ranging from a simple license of the patent to a full turnkey installation including license. A sales/ marketing specialist will be identified and he will have the responsibility for commercial success of this technology.

Future Research

The successful development of a commercial process for recycling factory fiber glass shingle waste provides a foundation for research leading to the recycling of field waste. Worn out roofing now hauled to landfills represents a potential energy source of about 95% of the $7.3x10^{13}$ Btu per year in total roofing waste. Problems which must be addressed in research to capture this energy resource include:

Nails must be removed from the roofing waste.

The paper fibers common in old roofing must be suitably broken down.

Formulations must be developed for coating asphalt composition containing worn out roofing. This may require the use of rejuvenating agents for the weathered asphalt in the waste. This formulation research should also measure the maximum amount of waste which could be recycled.

INTRODUCTION

Asphalt roofing waste was identified as a potentially valuable and recoverable resource in a prior DOE study.[1] Total asphalt roofing waste was estimated to represent about 7.3×10^{13} Btu annually. Roofing also represents a major waste disposal problem of growing significance. Annual asphalt roofing waste from factory and field sources accounts for more than 9 million tons. It was estimated that about 95% of all roofing waste is deposited in landfills which means that roofing waste contributes over 11 million cubic yards to the nation's landfills each year. Data taken from the first DOE study referenced above and a subsequent report[2] were used to develop the following chart which summarizes the waste problem and estimated energy content of asphalt roofing waste. These data presumed annual sales of 70 million squares of asphalt shingles. Factory wastes consist of all products and trim cuts rated as not suitable for sale. Field wastes are all products removed from roofs in the process of reroofing.

	FACTORY WASTE		FIELD WASTE		TOTAL
	Shingles	Rolls	Shingles	Rolls	
Energy,Btu/yr $\times10^{13}$	0.34	0.09	5.3	1.6	7.3
Waste,MM cu yd/yr	0.44	0.13	8.4	2.4	11.4
Waste,MM ton/yr	0.35	0.10	6.7	1.9	9.1

Annual production of shingles has increased to a little over 80 million squares since these data were calculated.

The first DOE study reviewed ten concepts for recovering the energy in asphalt roofing waste.[3] A second laboratory study demonstrated the technical feasibility of recycling asphalt roofing waste into the asphalt used to produce new roofing.[4] This study concluded that recycling of field waste required additional research on quality, formulation and performance. Recycling of factory waste, on the other hand, required only research on the process and the evaluation of commercial quality shingles. This prior laboratory research using factory waste was limited to quality and performance tests on asphalt compositions containing processed waste. The results showed that asphalt compositions containing up to 20% waste had acceptable performance. However, experimental production of shingles containing factory waste was not within the scope of that study. Factory research to confirm the process on a commercial scale and to obtain shingles for quality and performance evaluation was clearly the next and final step leading to commercial implementation of the concept.

----

[1] *Desai, S., G. Graziano, and P. B. Shepherd; "Recovery and Reuse of Asphalt Roofing Waste"; DOE/CE/40558-T1; February 2, 1984.*

[2] *Shepherd, P. B. and T. J. Powers: "Recovery and Reuse of Asphalt Roofing Waste- Recycling Roofing Waste to New Roofing"; DOE/ID/12560-4: June 1987.*

[3] *Desai; Op Cit*

[4] *Shepherd; Op Cit*

Process

A better understanding of this research may be obtained by first reviewing how asphalt roofing products are manufactured. The following description is taken from Chapter 2 of the publication, "Residential Asphalt Roofing Manual", 1980, and is reproduced with the permission of the Asphalt Roofing Manufacturers Association.

> The manufacture of asphalt roofing begins with the processing of raw materials into the principal product components, namely, the asphalt saturants and coatings and the organic or fiber glass base materials. These components are then combined during the production process. Other production line operations apply mineral surfacings, cut, trim and package. The in-process results are constantly monitored and inspected to ensure the quality of the finished product.
>
> **Asphalt**
>
> Asphalt is a unique building material which occurs both naturally and as a by-product of crude oil refining. Because the chemical composition of crude oils differs from source to source, the physical properties of asphalts derived from various crudes also differ. However, these properties can be tailored by further processing to fit the application for which the asphalt will be used. Softening point, ductility, flash point and viscosity-temperature relationship are only a few of the properties of asphalt that are important in the fabrication of roofing products.
>
> Asphalt intended for roofing must be tailored to perform two separate functions. The first is to saturate the organic base material. This requires that the asphalt be very fluid at processing temperatures so that it can totally impregnate the base material. The second is to coat the saturated roofing and serve as the medium for adhering mineral surfacing to the roofing. In the manufacture of roofing on a fiber glass base material, the saturation step is eliminated because the coating acts as its own saturant.
>
> When it arrives from the refinery, asphalt is soft and sticky and referred to as 'flux.' Saturants and coating asphalts are both made from the same flux by a process known as 'blowing.' During this process, air is bubbled through a large tank containing the hot flux. Heat and oxygen cause chemical reactions which change the characteristics of the asphalt. Steam and/or catalysts which produce saturants or coatings having slightly different properties may also be used. The process is continually monitored and the blowing stopped when the correct properties are produced. The asphalt is then pumped to a storage tank prior to delivery to the roofing production line.
>
> As a final step, coating asphalt is reinforced with a mineral stabilizer such as finely ground limestone, slate or trap rock. The stabilizer increases the coating asphalt's resistance to fire and weathering and adds durability.
>
> **Organic and Fiber Glass Bases**
>
> For years the traditional supporting membrane for asphalt roofing has been a modified paper known as 'felt.' Thicker and more absorbent than conventional paper, felt is composed primarily of cellulose fibers derived from recycled

waste paper or converted wood chips. At one time cotton or wool fibers derived from rags comprised up to one-third of the felt content, giving rise to the term 'rag felt.' Since 1942 these rags have become virtually unobtainable and their use has been discontinued. However, the term 'rag felt' still persists in roofing jargon.

To manufacture a cellulose or organic felt, the various raw materials are first fed into beaters and other types of paper processing equipment to produce a pulp (a suspension of fibers in water). This pulp is then formed into the felt which is dried, slit to the desired width and wound onto 'jumbo' rolls measuring approximately 6 feet in diameter.

Inspectors constantly check the quality of the felt by measuring such properties as moisture content, weight, tensile strength, tear resistance and absorbency. Keeping these properties within specifications is vital to the felt's ability to function properly.

The period since the late 1950's has seen the introduction of inorganic base materials as an alternate to those made with organic fibers. Instead of cellulose fibers, inorganic bases consist entirely of glass fibers of various lengths and orientations. Since the late 1970's, improved technology has made the fiber glass mat competitive with the traditional product and helped it become established in the market place.

The weight and thickness of a fiber glass mat is usually much less than that of an organic felt. For example, a fiber glass mat may be .030 inches thick versus .055 inches for an organic felt and weigh 2 to 3 pounds per 100 square feet versus 12 pounds for the organic felt.

The mat is formed by either a dry or wet process that uses glass filaments oriented in a controlled manner to obtain the desired properties of the finished mat. The filaments are used as single strands or in association with bundles of fibers.

The dry process usually uses single strands of glass filaments as the body of the mat with continuous strands of glass rovings as a reinforcement. In the dry process, glass filaments are formed by blowing or spinning molten glass into fibers which are sprayed with a binder. These fibers, along with the continuous strands of glass rovings, are then formed into a mat which is pressed and passed through an oven to cure the binder.

The wet process uses chopped strands of glass rovings as a reinforcement. In the wet process, chopped strands are dispersed in water and formed into the mat. The binder is then cured and the mat dried by heat.

Finally, the mat from either process is slit to desired width and wound onto jumbo rolls for conversion to asphalt roofing products.

Quality control is as important to fiber glass mats as it is to organic felts. Uniform weight and fiber distribution must be checked continually as must proper tear resistance to prevent breaks on the production line.

Manufacturing Process

The manufacture of asphalt roofing products is a continuous process performed on a roofing machine that begins at one end with a roll of base material and concludes at the other with the finished product. The sequence of operations in between builds the product up in stages, adding materials along the way and monitoring their application. Figure 1 illustrates the sequence of events. The roofing machine components and principal steps that comprise the manufacturing process include the following:

Dry Looper--To begin the process, a roll of base material is placed on a reel and unwound onto a dry looper or accumulator. The looper acts as a reservoir of base material and allows for continuous operation of the roofing machine. Because of the accumulator, it is not necessary to shut down the entire production line when a new roll of base material is being added to the line.

Saturator--If an organic felt is being run, it must first be saturated with asphalt. To accomplish this, the felt enters a presaturation chamber where hot asphalt is sprayed onto one side to drive out any moisture that might be trapped in the fibers. The dry felt then goes into a saturator tank where it is immersed in hot saturant to impregnate the fibers and fill the voids between them. In some plants, the spray chamber is eliminated and the felts impregnated through a series of immersions in the saturator tank.

Wet Looper--The organic felt leaves the saturator tank with an excess of saturant on its surface and enters a wet looper where the asphalt is drawn into the material as it cools to obtain an even higher degree of saturation.

Coater--Next, the felt moves to a coater where a mineral-stabilized coating asphalt is applied to the top and bottom surfaces simultaneously. The clearance between the coating rolls regulates the amount of asphalt applied. Most roofing machines are equipped with automatic scales that keep the product within weight specifications.

If a fiber glass mat is being run, the coating asphalt both coats the fibers and fills the voids between them. As a result, fiber glass mats do not have to pass through the saturator or wet looper.

Mineral Surfacing--After the asphalt coating is applied, both sides of the base material sheet receive a mineral coating. If smooth-surfaced roll roofing is being manufactured, both sides are covered with talc, mica or similar minerals of fine consistency. The sheet passes over a series of rollers to adhere the fine flakes of mica or talc to the asphalt and to cool the material.

If granule-surfaced products are being manufactured, the top surface of the sheet is covered with mineral granules of specified color. Sand, talc or mica is applied to the back surface. A series of cooling drums and rollers under controlled pressure embed the granules in the coating asphalt.

Finish or Cooling Looper--At this point, the sheet is accumulated on a finish looper. Here the material is allowed to cool down to a point where it can be cut and packaged.

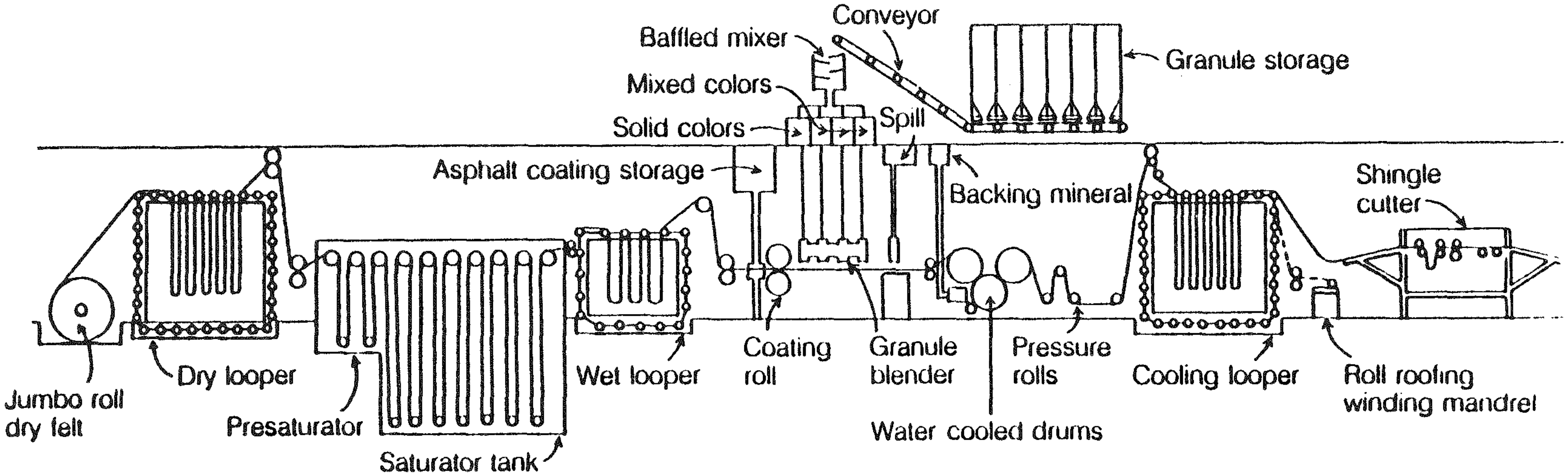


Figure 1: Representative flow diagram of roofing machine running an organic felt base material

Shingle Cutter--If shingles are being manufactured, the material moves from the finish looper onto a shingle-cutting machine which cuts the sheet from the back or smooth side. The shingles are mechanically separated and stacked to form a bundle of the appropriate weight and quantity. They are then moved to packaging equipment where the bundles are wrapped and labeled before being stored in the warehouse or shipped.

Roll Roofing Winder--If roll roofing is being manufactured, the material moves from the finish looper onto a winding mandrel which measures the length of the sheet as it turns. When the proper length of the roll has been wound, the sheet is cut. The roll is then banded, removed from the mandrel and moved to the packaging equipment before warehousing or shipment.

Note that the saturator and wet looper shown in Figure 1 are not used during the manufacture of fiber glass shingles because the supporting web of glass fibers becomes impregnated at the coating roll.

The process for preparing factory waste for recycling is patented by Bird, Inc. and was described in the previous research.[5] A Banbury[R] Mixer was used to homogenize the waste and a roll mill reduced the coarse rock particles to dust which was dispersed within the resulting asphaltic mastic. A diagram showing how this process might be integrated with the production of asphalt composition used to manufacture new shingles was developed during the prior research and is reproduced as Figure 2 on the next page.

Materials

Factory fiber glass shingle waste accounts for the greatest proportion of factory waste. The ratio of waste which must be added to the filled asphalt coating composition used to manufacture new roofing is about 10% by weight to fully utilize all waste at a presumed waste generation rate of 5% of total production. Adding up to 20% by weight percent of waste would allow sufficient flexibility in factory operation to use all waste on a convenient basis. Prior research showed this to be a feasible goal since the processed waste contains the same sort of ingredients as the fresh coating asphalt composition: asphalt and filler. Filler is usually a pulverized rock dust such as limestone, syenite, traprock, etc.[6] The amounts of fresh asphalt and filler should be adjusted to maintain the desired ratio of ingredients in the composition which contains waste.

Recycling factory roofing waste into new roofing was perceived to offer several benefits for resource recovery.

- Investment was estimated to be low.

- Operating costs were estimated to be low.

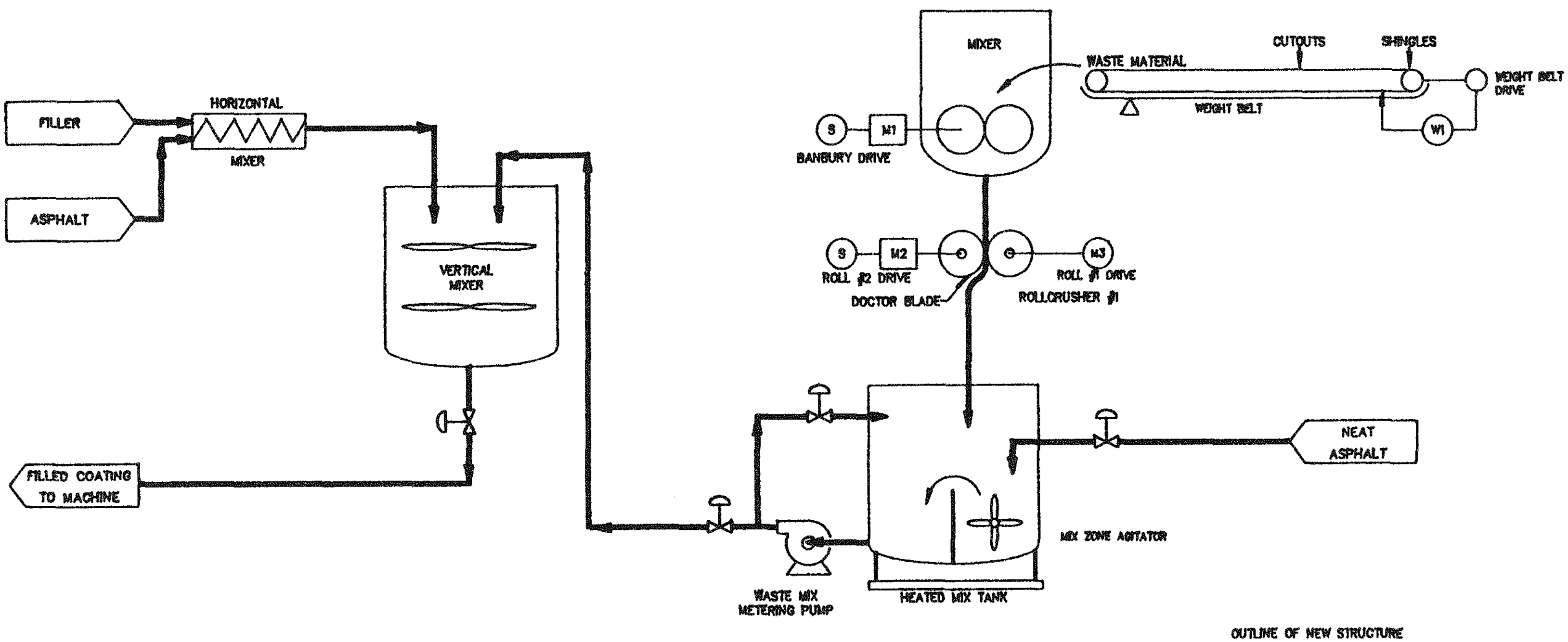
- The energy recovery cost was estimated to be very low.

- The manufacturers' cost savings were estimated to be very high.

----

[5] *Shepherd;Op Cit.*

[6] *Shepherd; Op Cit.*



WASTE RECOVERY

SCHEMATIC DIAGRAM

FIGURE #2

Research

The laboratory studies indicated that additional research was needed to answer the following questions:

What are the operating parameters of the waste processing equipment?

What are the operating parameters of the roofing machinery when processed waste is introduced?

What is the quality of shingles which contain waste?

What will be the cost to install commercial scale equipment in a roofing factory?

What will be the financial benefit to a roofing manufacturer?

A plan to take the final step in research leading to commercial implementation was designed having the stated objective, "to obtain process data and to measure shingle quality attributes which will provide a sound technical basis for the commercialization of the direct recycling concept." This objective was to be achieved in a project plan consisting of five tasks.

Task 1. Prepare factory roofing waste for recycling into new shingles and analyze the operation.

Task 2. Produce fiber glass based asphalt shingles with processed factory asphalt waste contained in the asphalt constituent and analyze the process.

Task 3. Conduct tests to compare the quality of shingles containing waste to the quality of baseline conventional shingles.

Task 4. Evaluate the results of the technical activities related to waste processing, shingle production, and product quality in terms of the effect on commercial implementation.

Task 5. Provide project coordination and production of project deliverables.

This report presents the results of the research and the information needed for technology transfer leading to commercialization of the recycling of factory asphalt roofing waste. The contents include a description of the Technical Investigation, Technical Analysis, Economics and Energy Analysis, Conclusions, and Recommendations.

TECHNICAL INVESTIGATION

Processing of Roofing Waste

The objective of this task was to prepare factory asphalt shingle waste for recycling into new shingles and to analyze the processing operation. The processing was to follow the method disclosed in U. S. Patent 4,726,846 and described in a previous DOE report.[7] This process involves adding the roofing waste to a Banbury^R Mixer whose counter rotating kneaders produce a uniform mastic. This mastic is then passed through the nip between counter rotating rollers, which pulverize the granular constituents and glass mat to the same particle size range which is used as filler in the asphalt composition.

Identification of Waste

Waste and simulated waste shingle materials were of three types. The first was so-called cutouts or fingers which are the small, 1/4 in. by 5 in. pieces cut from shingle strips to simulate the appearance of individual shingles on the roof. Next were full bundles of waste shingles about 12 in. by 36 in. by 3 in. and weighing about 75 pounds. Finally, mineral surfaced roll roofing was identified to simulate the sheets of shingle stock wasted on a roofing machine during production upsets. Mineral surfaced roll roofing is shingle-like material sold in rolled up sheets 36 in. wide. A side benefit of including these rolls would be confirmation of the recyclability of mineral surfaced roll roofing. All materials were selected from the Bird Roofing Division Factory in Norwood, Massachusetts during the fall of 1988.

Selection and Transport of Waste

Materials were selected to be representative of a typical factory operation. The following quantities were collected.

cutouts	2,000 lb
shingles	14,000 lb
rolls	2,200 lb

The cutout pieces were packed loosely in fiber cartons used to package asphalt. These cartons were selected because they had a non-stick treatment on the inside and could be reused to ship the processed waste back to the Bird Roofing Factory. Shingles and rolls were handled in the manner normally used for commercial shipment. The waste material was shipped by truck to the Farrel Corporation in Ansonia, Connecticut for processing.

Process Equipment

The Farrel Corporation operates a process research laboratory containing the two pieces of equipment required to prepare the shingle waste for recycling: a Banbury^R Mixer and a two roll mill.

The Banbury^R Mixer is an internal batch mixer with non-intermeshing rotors typically used for mixing rubber, plastics, floor tile and similar materials. A Banbury^R Mixer is pictured in Figure 3. The Banbury^R Mixer used in this research was a model F80 with a capacity of 80 liters.

----

[7] *Shepherd; Op cit; C-1.*

A two roll mill is shown in Figure 4. The two roll mill used here had 22 in. diameter rolls, 60 in. long with 12 in. diameter journals. The rolls had been drilled for maximum heat transfer capabilities and steam heat.

Additional support equipment needed for process control testing was shipped to Farrel from Bird Roofing as follows:

Muffle Furnace
RoTap Sieve Shaker and Sieves
Brookfield RVT Thermosel Viscometer.

Description of Procedure

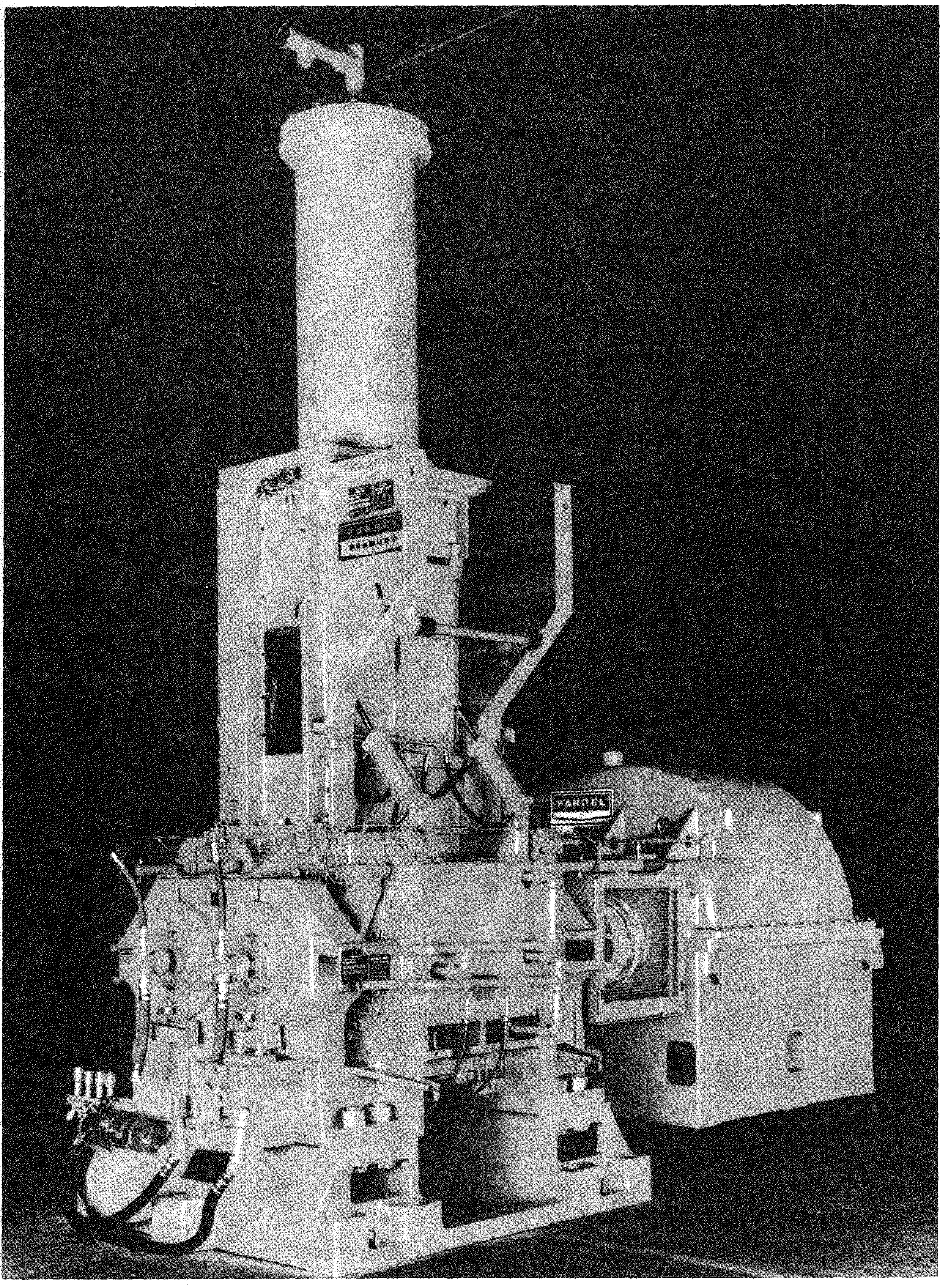
Key process parameters identified prior to the experiments were granule size reduction, viscosity of the mastic that was the product of the process, and sieve analysis of the mineral matter in the processed waste. The planned process steps were to add the waste to the Banbury^R Mixer to produce a uniform dispersion of shingle ingredients and raise the temperature of the resulting mastic for processing on the two roll mill. The spacing between the two rolls was set as close as possible to crush the granular material in the shingles down to a powder approximately the size of the filler in the asphalt coating composition contained in the shingles.

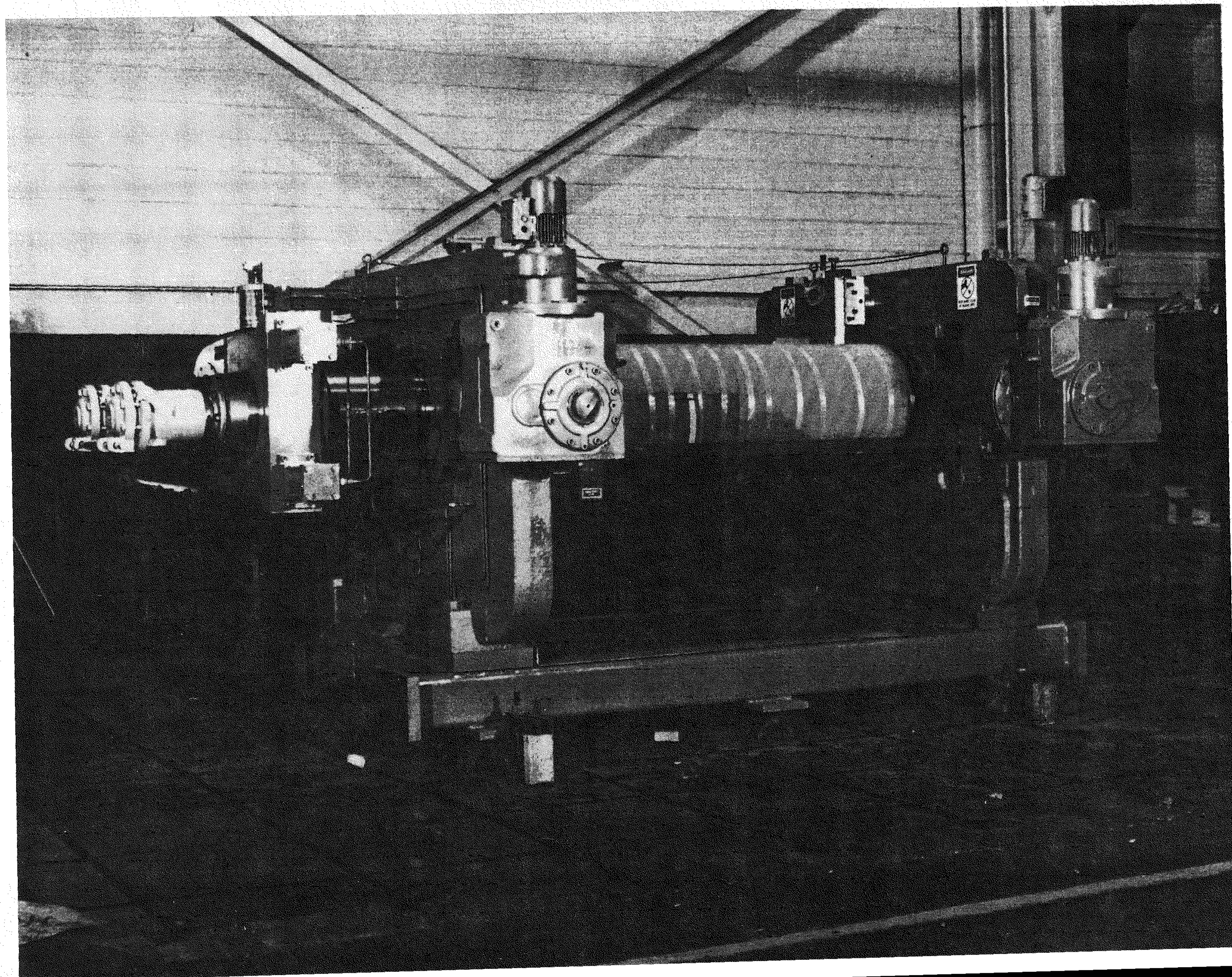
Preliminary Tests - The first day of waste processing was devoted to preliminary tests designed to identify equipment operating conditions for achieving the desired quality of processed waste. None of the waste processed as the first four batches met the goal for granular particle size reduction. However, these four preliminary tests showed that the goal could be achieved, and equipment set-up and operating conditions were identified. Operating conditions are shown in Appendix A. Processed waste properties are shown in Appendix B.

Waste Processing - Equipment set-up and operating conditions for achieving the desired particle size reduction of 98% passing a No. 70 USS Sieve were determined to be as follows.

Batch size, lb waste to Banbury^R	200
Cycle time in Banbury^R, min	2
Temperature of mixed waste, F	200
Temperature of back roll, F	240
Speed of back roll, fpm	125
Temperature of front roll, F	222
Speed of front roll, fpm	125
Passes of waste through rolls	3
Gap between rolls unloaded, in	0.000
Gap between rolls loaded, in	0.005-maximum

All of the data collected on mixing during seven days of operation are copied from Farrel Corporation records in Appendix A, Table A-1. Table A-2 shows typical mixing conditions and Table A-3 shows typical roll mill operating conditions. Properties of the processed wastes are shown in Tables B-1, B-2 and B-3.


FARREL
BANBURY
FARREL



Waste materials were weighed into 200 pound batches of each type and each batch was hand loaded into the Banbury^R mixer. This mixer was highly instrumented and could be programmed to vary independently the mixing time, temperature, and rate of power consumption. It was determined that shingle waste could be processed according to temperature or time as these two conditions nearly coincided from batch to batch. The opening to the Banbury^R Mixer was large enough to accept a full bundle of shingles or a full roll. However, it was decided to cut each in half for ease in handling during these manually operated experiments. It was observed that there was a very slight reduction in mixing time as the size of the feed material was reduced. All three types of roofing waste used during these tests were mixed well by the Banbury^R and produced a mastic composition of acceptable quality.

A door in the bottom of the Banbury^R Mixer was opened at the completion of each cycle and the hot, 200F, mastic was discharged down onto the counter rotating rolls of the mill. The 200F temperature was reached partly by heat generated by the mixing process and partly by a thermal jacket on the mixer. The hot mastic was quickly spread out over the full width of the rolls' surfaces. It was determined that some heating of the rolls by steam within the rolls' cores was needed and that a 15F temperature difference between rolls was also needed to ensure transfer of the material from one roll surface to the second. The rolled mastic was removed from the front roll by a doctor blade held tightly across the full surface of the roll. The rolled mastic was again placed, this time by hand, onto the roll mill after all material had passed through the rolls and the process was repeated again so that all of the waste had passed through the nip of the rolls three times. It was determined that the mastic could not be allowed to remain on the roll mill and travel around the circumference many times because much of the mastic would never pass through the roll nip for crushing of the granular particles. Continuous removal of the mastic from the front roll was needed.

The processed waste was regularly tested for crushed mineral particle size distribution, asphalt content and viscosity. The product was allowed to cool somewhat and then was placed in paperboard containers for shipment back to Bird Roofing.

Results

Qualitative - The roofing waste of all three types processed well with no observed batch-to-batch variation. All of the material produced met the goal for granular particle size reduction. The process conditions and set up were easily translatable to the design of commercial scale, continuous production operations. This may include tandem two roll mills for achieving the granule crushing without the need for recycling the mastic. Two passes through specially designed roll mills were determined to be sufficient based on the results of these tests and experiments on small scale mills.

The Banbury^R Mixer and roll mill were inspected for wear and damage at the conclusion of seven days' of production. There was no visible effect on the Banbury^R Mixer. The surfaces of the rolls showed a very slight dimpling that was probably caused by the granular particles being crushed in the nip. The rolls were turned true and smooth following the experiments and 0.001 in. of steel was removed to achieve this. The dimpling had no effect on the quality of the processed waste. The commercial, long - term implications of this dimpling were judged to be minor as waste crushing rolls may be surfaced and hardened for this special application. The rolls used for this work, while hardened to a depth of 1/2 in. by chill casting, were designed for processing relatively soft, less abrasive mastics such as rubber and plastics.

Quantitative - Seven days were needed to process the 18,200 pounds of waste at a research rate of 400 pounds per hour. Approximately 11,000 pounds of usable, processed waste were made. About 7,200 pounds were lost in the first day of experiments on machine set-up and in normal experimental production losses.

The processed waste met the goal of 98% of the mineral matter passing a No. 70 sieve and the asphalt content of the processed waste was 24.9% as an average of the seven days of production. The testing results for each batch appear in Appendix B. The process conditions used to achieve the objectives were listed on page 23.

The energy expended in processing the waste was determined from the recorded data to be

Banbury[R] Operation	0.00876 KWH/lb
Roll Mill Operation	0.031 KWH/lb.

Roofing waste preparation for recycling therefore required 79.5 KWH per ton of waste. This was estimated to be typical of a commercial operation.

Manufacture of Shingles

The objective of this task was to produce fiber glass based asphalt shingles with factory shingle waste contained in the asphalt constituent and to analyze the production process. The processed asphalt shingle waste received from the Farrel Corporation was introduced into the conventional asphalt coating mixture which was then used to manufacture Wind Seal 80[R] shingles at the factory of Bird Roofing in Norwood, Massachusetts. The reader is referred to pages 14-18 and especially Figure 1 for a description of the process.

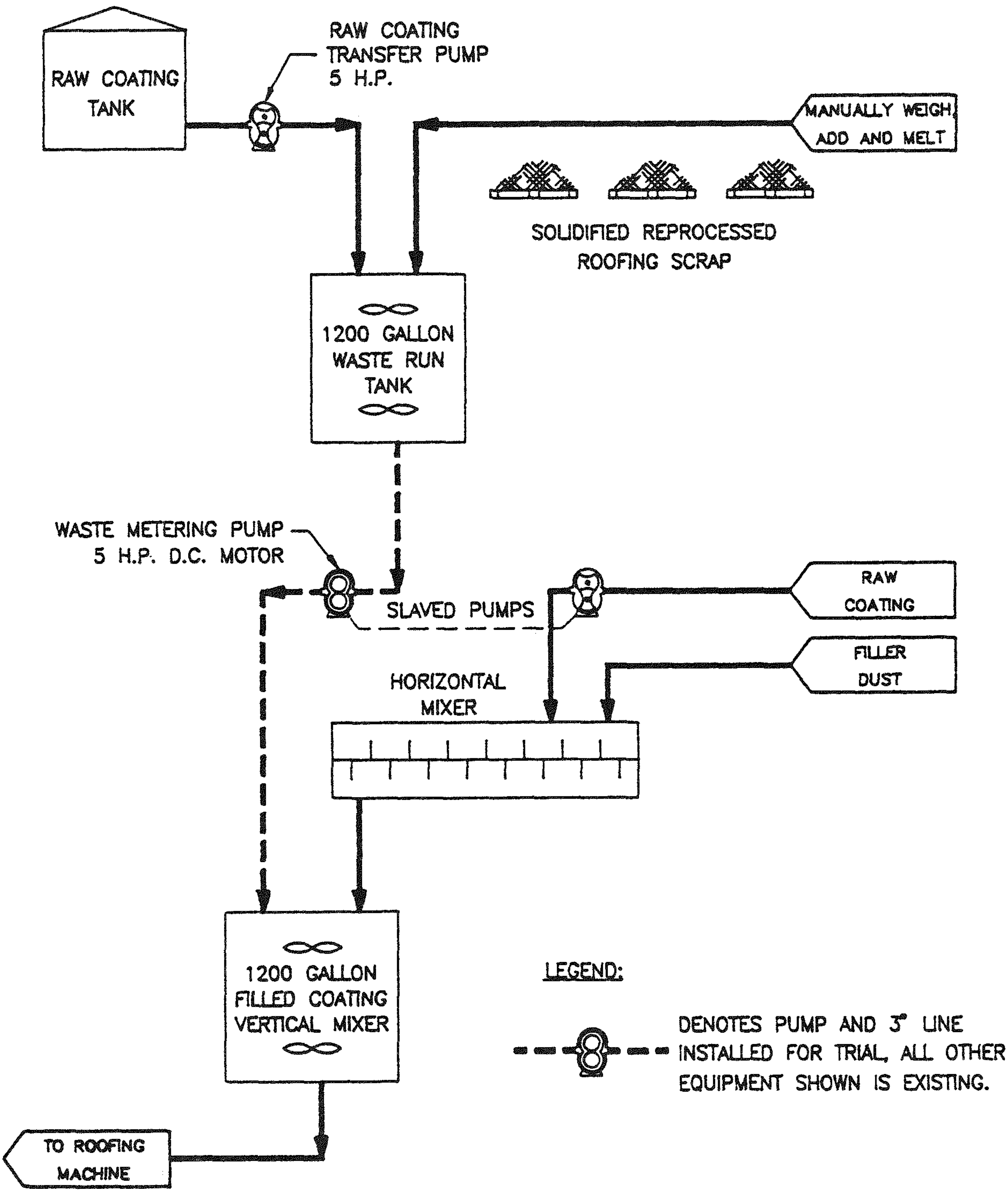
Equipment

The equipment employed to achieve the goals of this factory research was set up external to the shingle manufacturing machine so as not to interfere with normal production. An existing heated tank equipped with counter rotating agitators was used to melt the processed waste and dilute the waste with pure asphalt. A gear pump with a variable speed drive was installed at the bottom and outside of the tank. This pump conveyed the mixture through a jacketed pipe to the asphalt shingle manufacturing machinery and introduced the mixture into the process at the point called, "Asphalt coating storage", in Figure 1. The mixing and melting tank, the pump, and much of the piping was located in a room separated from the shingle manufacturing operation. The pump was electrically interfaced with the shingle machinery drive and controls so that automatic control of waste proportioning could be achieved. The equipment set up is depicted in Figure 5.

Plan

The plan for this factory research called for producing four lots of shingles containing different amounts of factory asphalt shingle waste. Effects on the process and on shingle quality attributes were to be observed and measured. The four different shingle lots were to be made with their asphalt coating composition containing waste in the percent concentrations of 5, 10, and 20. A baseline lot of shingles was to be made without waste in the asphalt (0%). The goal was to maintain a concentration of 60 $\pm$ 10% filler in the asphalt composition based on the total weight of asphalt plus filler.

[R] *Registered trademark of Bird, Inc.*



SCHEMATIC OF FULL SCALE SHINGLE PRODUCTION
TRIAL UTILIZING REPROCESSED ROOFING SCRAP

FIGURE 5

Approximately 250 "squares" of each shingle lot was to be manufactured. A "square" is a roofing industry term describing the amount of roofing product needed to cover 100 square feet of roof area when installed as specified.

Description of Operations

The processed asphalt shingle waste was accurately weighed and manually placed into the 1200 gallon melting tank two days prior to the scheduled production. Viscosity tests had shown that the melted waste would be so viscous as to be unpumpable. Pure, molten asphalt was then added to the tank to render the mixture easily pumpable. The amount of asphalt was carefully apportioned to achieve a filler concentration of 61-63 percent in the waste-asphalt mixture. All of the mineral filler in the tank came from processed waste. The 61-63 percent ratio had been selected as the narrow target within the planned range of 60 $\pm$ 10% range. This was also the target for shingle production and the filler ratio in the melt tank would match the filler concentration in the asphalt coating produced for shingle manufacture. This approach simplified the calculations and control of waste mixture and asphalt proportioning. The procedure described here proved to be very convenient for experimental purposes, but might not be representative of a fully automated and instrumented commercial operation.

Melting of the waste and mixing continued for nearly two days until the mixture appeared uniform and had reached a usable temperature of 440F. Engineering calculations were made involving material balances to properly set the electronic controls for maintaining the desired ratio of waste in each of the manufacturing experiments. Additionally, criteria were set for monitoring by measuring the changing liquid levels in the melting tank and asphalt coating storage (Figure 1). Details appear in Appendix C. The first production day was spent in checking out the operation of the waste mixture pump, the valves and piping, and the electronic interface between the new and existing equipment.

Shingle production started on the second day. Appendix C contains a detailed description of the calculations and methods used to achieve and maintain the target waste ratios in the filled coating asphalt composition. Waste content in the asphalt coating storage was adjusted to the desired specification by measuring the liquid level in each of the two working tanks prior to each experiment. Automatic controls were set to maintain the desired waste content during each trial. Waste pump operation followed the control signal exactly as planned throughout the operations. Before and after measurements of liquid levels confirmed that the target waste ratio was achieved in each of the experiments. Quantitative chemical analysis of the mixtures was not feasible because the waste ingredients were chemically identical to the asphalt coating composition ingredients except for a very minor amount of pulverized glass fiber.

The four lots of shingles were produced in the order of:

0% waste
5% waste
10% waste
20% waste

This sequence was followed to ensure that no trace of waste would be in the baseline shingles and to simplify the material balance calculations and machine control programming.

The following quantities of shingles were produced:

200 squares of 0% waste
210 squares of 5% waste
209 squares of 10% waste
271 squares of 20% waste.

The shingles were conventional asphalt fiber glass shingles. Production and inspection data appear in Appendix C. No differences in machine operation or inspection results were noted. Operators reported that the machine ran just as it always does and that the products seemed no different from normal.

Results

Qualitative - Manufacturing operations during the production of asphalt fiber glass shingles were observed to be normal in all respects. Supervisory and operations personnel reported no deviations from daily operating conditions and no changes were noted as the concentration of waste in the asphalt was increased. All machinery was inspected following production. No settling of waste was found in the fluid asphalt sections of the machinery and no wear was noted on any of the moving parts.

A slight odor of glass mat binder was noted in the vicinity of the waste melting tank after several days heating. It might prove desirable to provide ventilation over such a tank in a commercial operation. Roofing factories have ventilating systems which would likely have the capacity to handle these vapors should they be generated when the waste is heated for the brief period of time encountered in a continuous operation.

Quantitative - Operating and inspection data are in Appendix C. Included are such machine operating parameters as pump motor loads, machine line drive motor loads, cooling requirements, and other critical factors. These data show that the addition of processed waste had no measurable effect on machine operating conditions or on product properties.

Electrical energy expended to introduce the waste into the process appears in Appendix C and is summarized here.

5% waste	1401 lb used	96.4 KWH
10% waste	2229 lb used	153.0 KWH
20% waste	4071 lb used	279.4 KWH

The heat energy expended to melt the waste and heat it to operating temperature was calculated to be 890M Btu or 94 Btu per pound of waste. This energy was not used in the analysis starting on page 66 because the long heating period used in this experiment would not be typical of a commercial operation. It was reasoned that a nearly identical amount of energy would be used to melt and heat the displaced raw materials on a commercial basis.

All of the goals of this operation were achieved and uniform product quality was maintained at all times.

Testing of Shingles

The shingles were tested using accepted American Society for Testing and Materials (ASTM) standard methods in most cases. Some test methods were unique to the roofing industry or an individual roofing company. Special test methods are described in Appendix G. The testing regimen was designed to evaluate the potential field performance of fiber glass shingles containing processed factory waste in the asphalt coating composition and compare the performance of these shingles to a base line set of shingles containing no waste. Shingles containing waste were not significantly different from baseline, waste-free shingles in any of the tests.

The proposed testing regimen was discussed with the Research Committee of The Asphalt Roofing Manufacturers Association. This was presented by Mr. C. Patenaude of Bird Roofing on September 28, 1988. Mr. Robert Metz of Celotex offered the only suggested change which was to add a proposed ASTM standard method for testing water absorption and dimensional stability. This method, supplied by Celotex, was included in the testing program.

All of the testing data and statistical analyses of these data appear in Appendix D. Special test methods are described in Appendix E.

Weather Resistance

Some may regard the service life of shingles as the ultimate test of their quality. It is not within the scope of this project to investigate test results, since a shingle's service life will number many years. The accelerated weathering life of the asphalt composition used to produce a shingle is regarded by others as a useful indicator of the shingle's potential longevity. Such tests are much shorter in duration; usually lasting less than one year.

Natural Weathering - The shingles were installed on the roofs of three or four houses in each of several parts of the country. Shingles were installed on most houses in a predetermined pattern selected from a table of random numbers to ensure a valid comparison of performance. The houses were located in the following states:

Massachusetts
Colorado
Georgia

The exact location of each house and the pattern of shingle lot installation appears in Appendix F. These houses are available for inspection by the Department of Energy, assuming that the home ownership does not change or that new owners will permit occasional inspection. Others will find many of these roofs to be easily inspected from the street, but home owners are under no obligation to permit other parties an on-the-roof inspection. An effort was made to select buildings with one major roof face easily viewed from the street.

Small quantities of each lot of shingles were also exposed at the outdoor testing facilities of the 3M Company, the GAF Corporation, and Manville Sales Corporation. These locations are in Texas, Maryland, and Georgia. The exact locations and persons to contact for additional information or a first hand inspection also appear in Appendix F.

Accelerated Weathering - The coating asphalt compositions used in the production of each of the shingle lots were tested for weathering durability in a WeatherOmeter. This device subjects the asphalts to a controlled sequence of exposure to heat, ultraviolet light, and cold water spray. This test method is designed to simulate the effects of natural weathering in an accelerated manner. The test does not predict the actual weather resistance of asphalt but is a valuable tool for rating the comparative weather resistance of different asphalts. The test method is described in ASTM D529, Standard Practice for Accelerated Test of Bituminous Materials, Daily Cycle A. The specimens for testing were prepared according to ASTM D1669, Standard Method for Preparation of Test Panels for Accelerated and Outdoor Weathering of Bituminous Coatings. The failure point for each sample was measured according to ASTM D1670, Standard Test Method for Failure End Point in Accelerated and Outdoor Weathering of Bituminous Materials.

Results - The failure end point was taken to be the number of daily cycles elapsed to the time where 25% of the test specimen's surface displayed cracks through the entire thickness of the specimen. The average times to failure were:

0% waste	126 cycles
5% waste	126 cycles
10% waste	129 cycles
20% waste	126 cycles

The results clearly showed that the substitution of processed waste for virgin asphalt and filler had no effect on the accelerated weathering durability of filled asphalt coatings sampled during shingle production.

Tear Strength

The tear strength of shingles may be related to their resistance to damage when handled during installation and when subjected to extreme wind forces after installation. Each lot of shingles was tested at room temperature and at 35F with the tearing resistance recorded in both the long and short dimensions of the shingles. The testing device is called an Elmendorf Tearing Tester and the testing protocol is described in ASTM D1922 modified according to D3462.8.1.2.

Results - Table 1 summarizes the testing results.

TABLE 1: TEAR STRENGTH OF SHINGLES

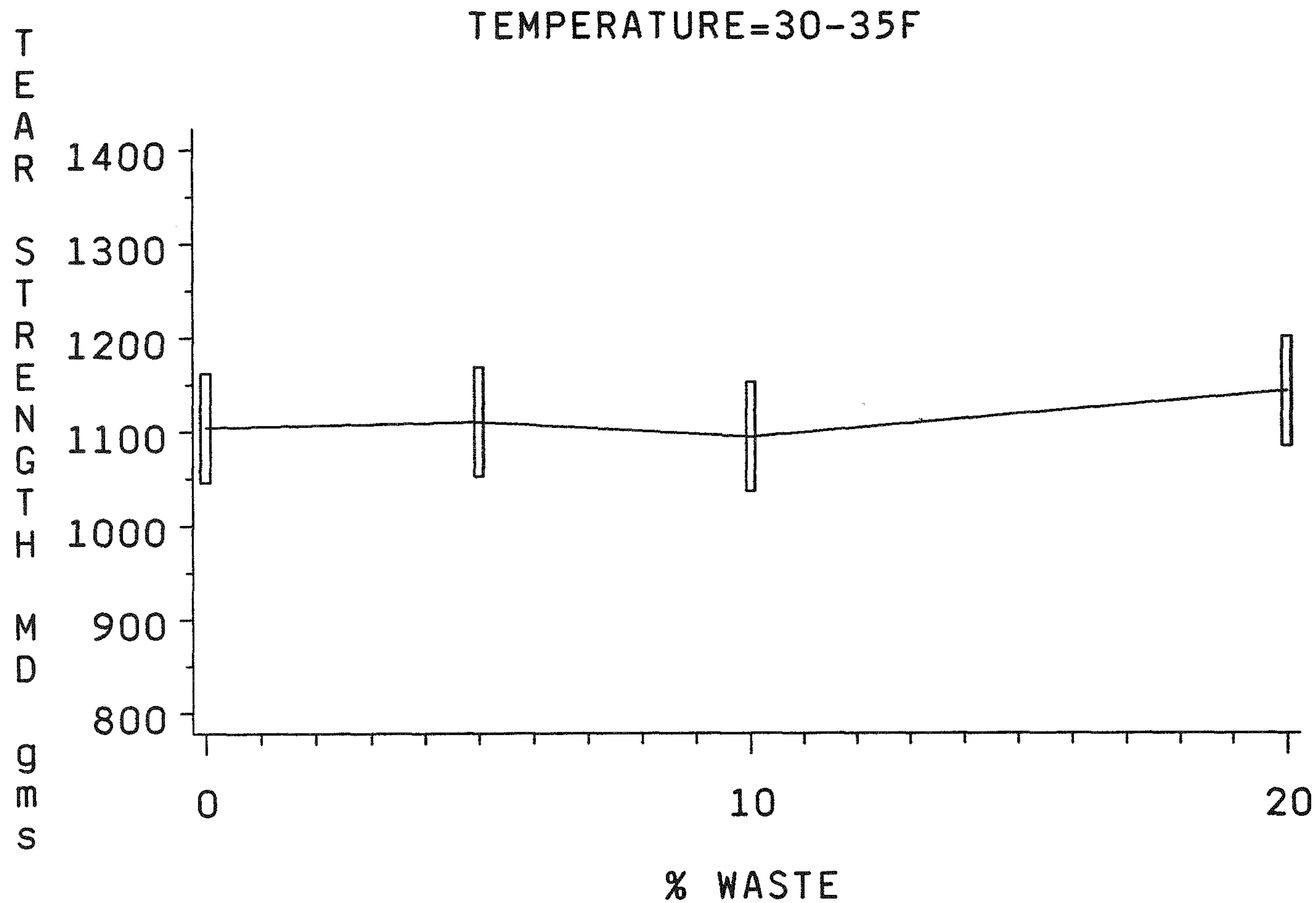
	% Waste in Shingles			
at 70-75F	0	5	10	20
Tear Strength, grams				
MD	1220	1250	1150	1150
CD	1380	1340	1310	1280
at 30-35F				
Tear Strength, grams				
MD	1150	1120	1090	1120
CD	1280	1220	1220	1250

MD = parallel to shingle's long dimension
CD = parallel to shingle's short dimension

The results were analyzed using the analysis of variance procedure in Statistical Analysis Systems (SAS). An alpha error of 0.01 was selected to generate tests for significant differences using the Student-Newman-Keuls (SNK) method for multiple comparisons. No significant differences among lot means were found at either temperature. The results are plotted in Figures 6, 7, 8, and 9. The line on the graphs passes through each lot mean and the rectangles represent the 95% confidence limits for each mean ($\pm$2 standard errors around the mean).

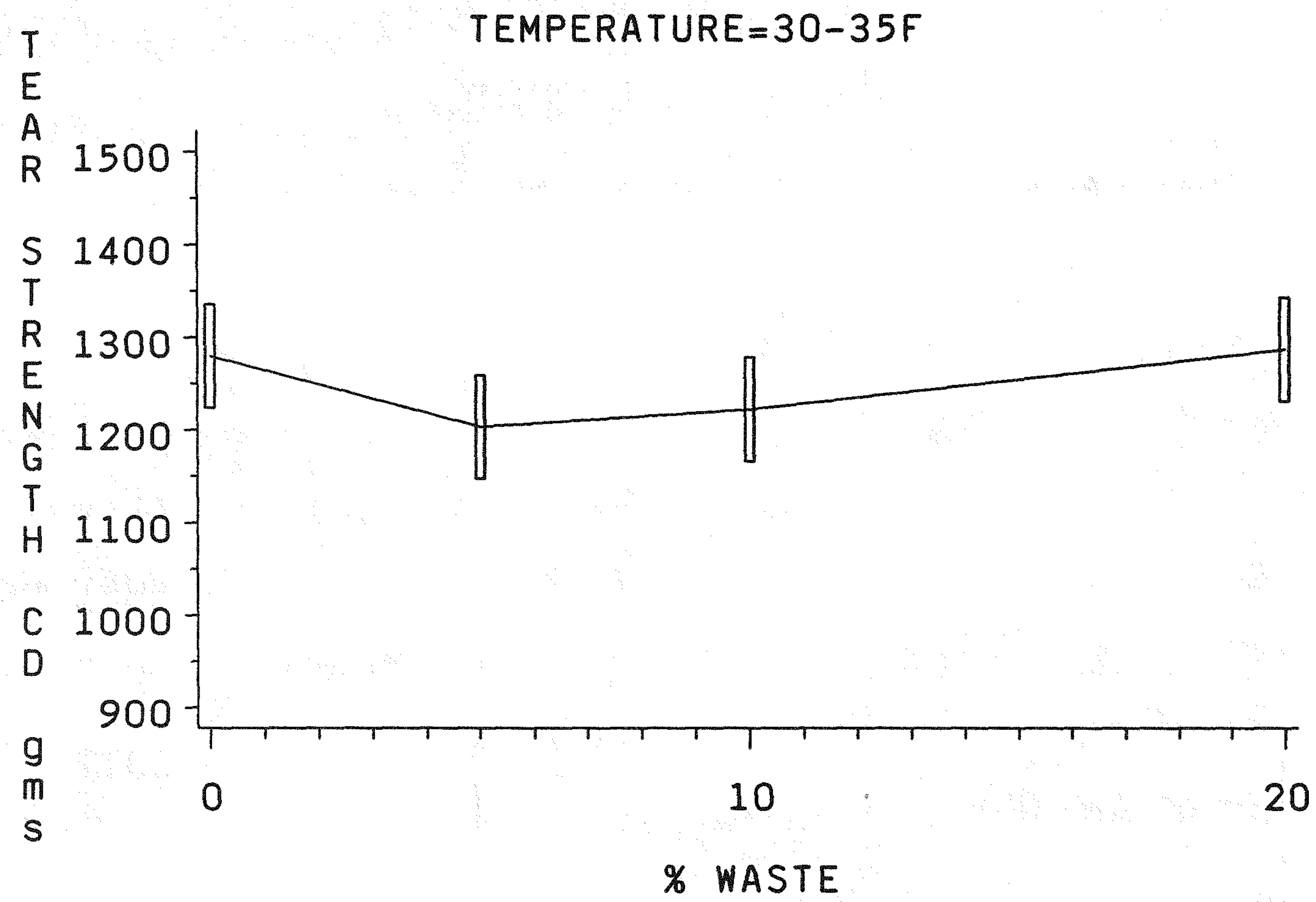
Tensile Strength and Strain

The tensile strength of shingles and their ultimate elongation in tension may be related to the shingles' resistance to cracking when exposed to the weather. Each of the lots of experimental shingles was tested at room temperature and at 30 - 35F with strength and strain recorded in both the long and short dimensions of the shingles. Each sample piece was 3"x10" with 6" the span between securing clamps of the testing machine. The jaws of the testing machine were pulled apart at a rate of 2" per minute. The testing method is described in ASTM D146.13.1 modified according to column 2.



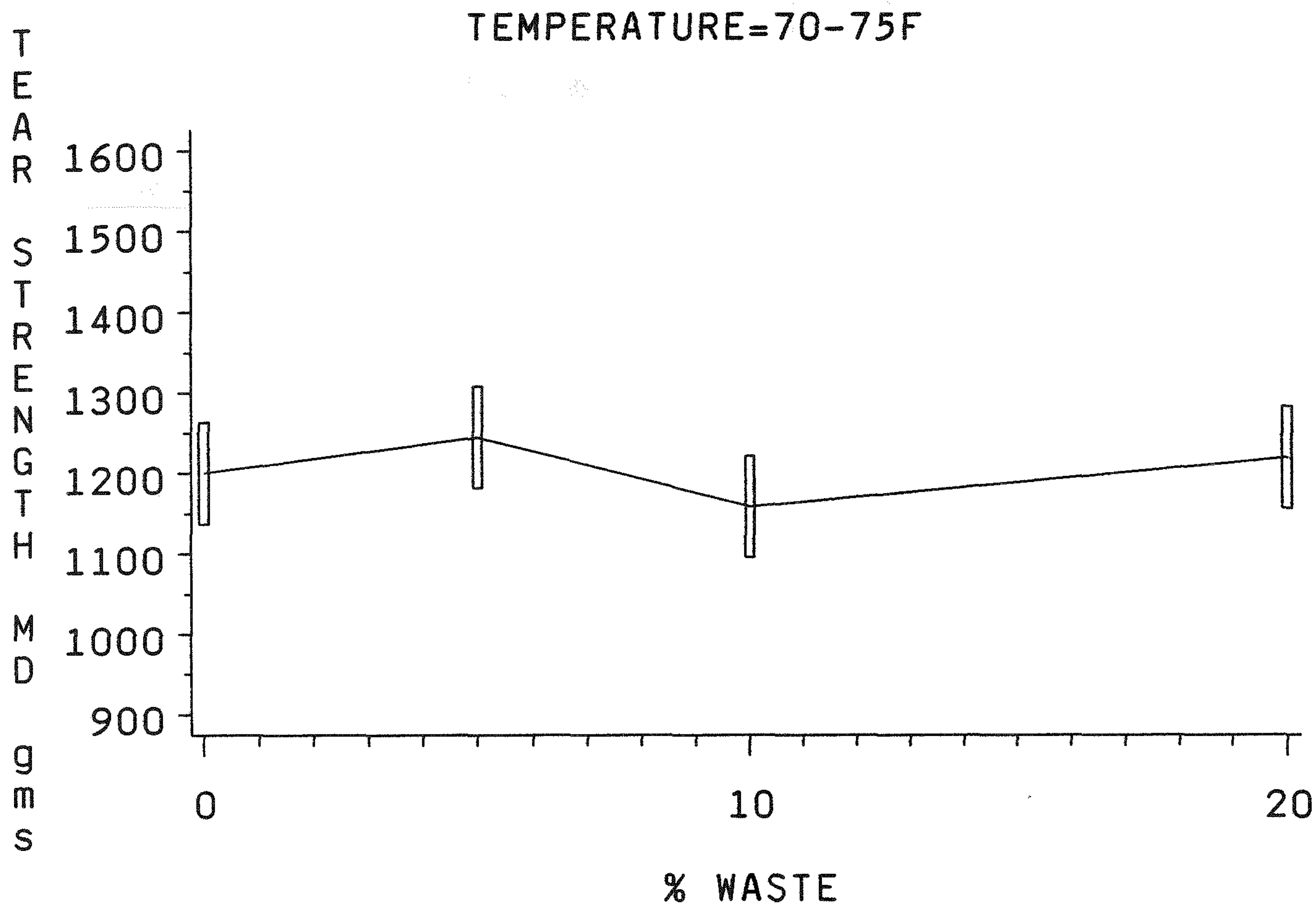
TEAR STRENGTH OF SHINGLES

MACHINE DIRECTION
FIGURE 6



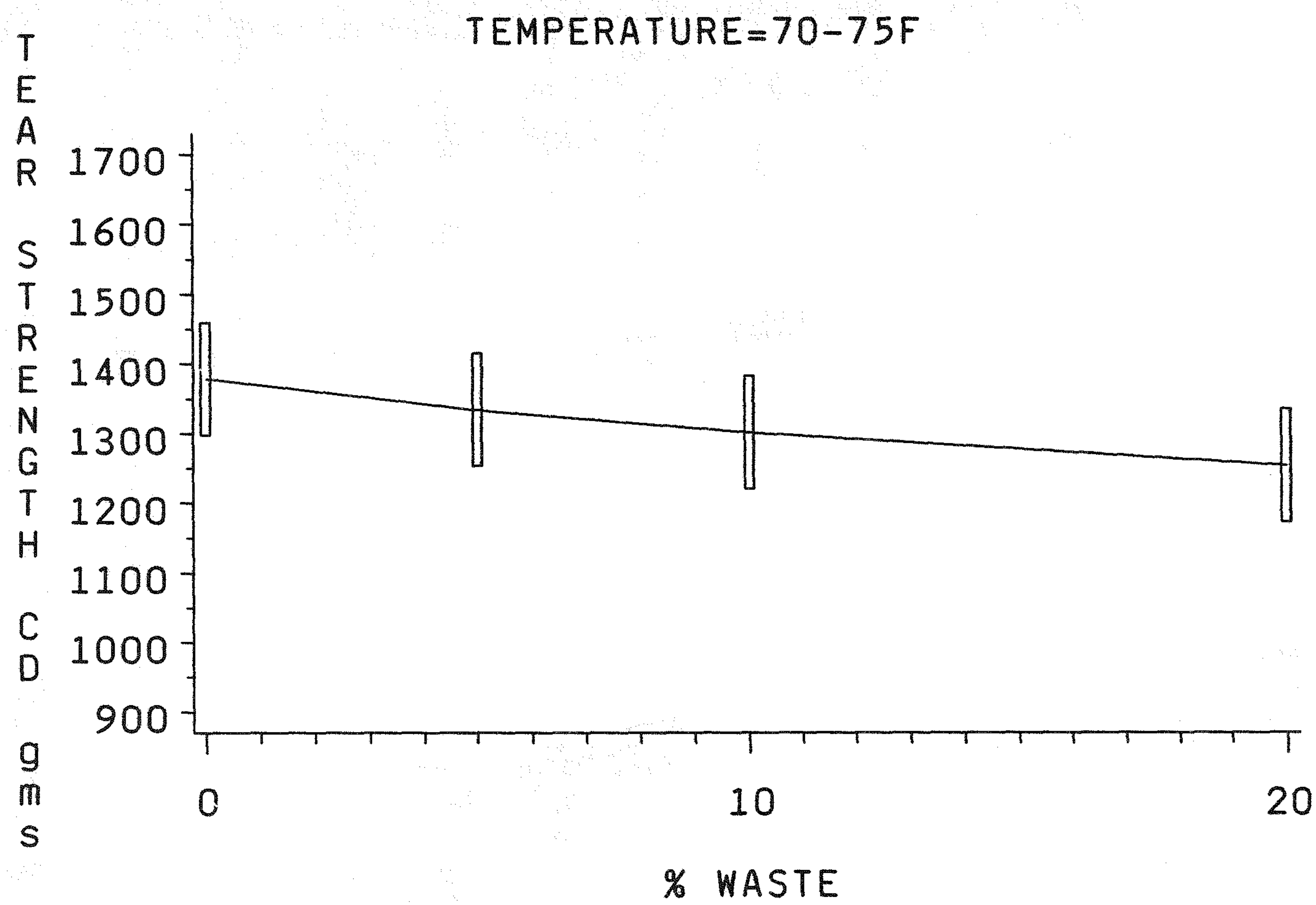
TEAR STRENGTH OF SHINGLES

CROSS MACHINE DIRECTION
FIGURE 7



TEAR STRENGTH OF SHINGLES

MACHINE DIRECTION
FIGURE 8



TEAR STRENGTH OF SHINGLES

CROSS MACHINE DIRECTION
FIGURE 9

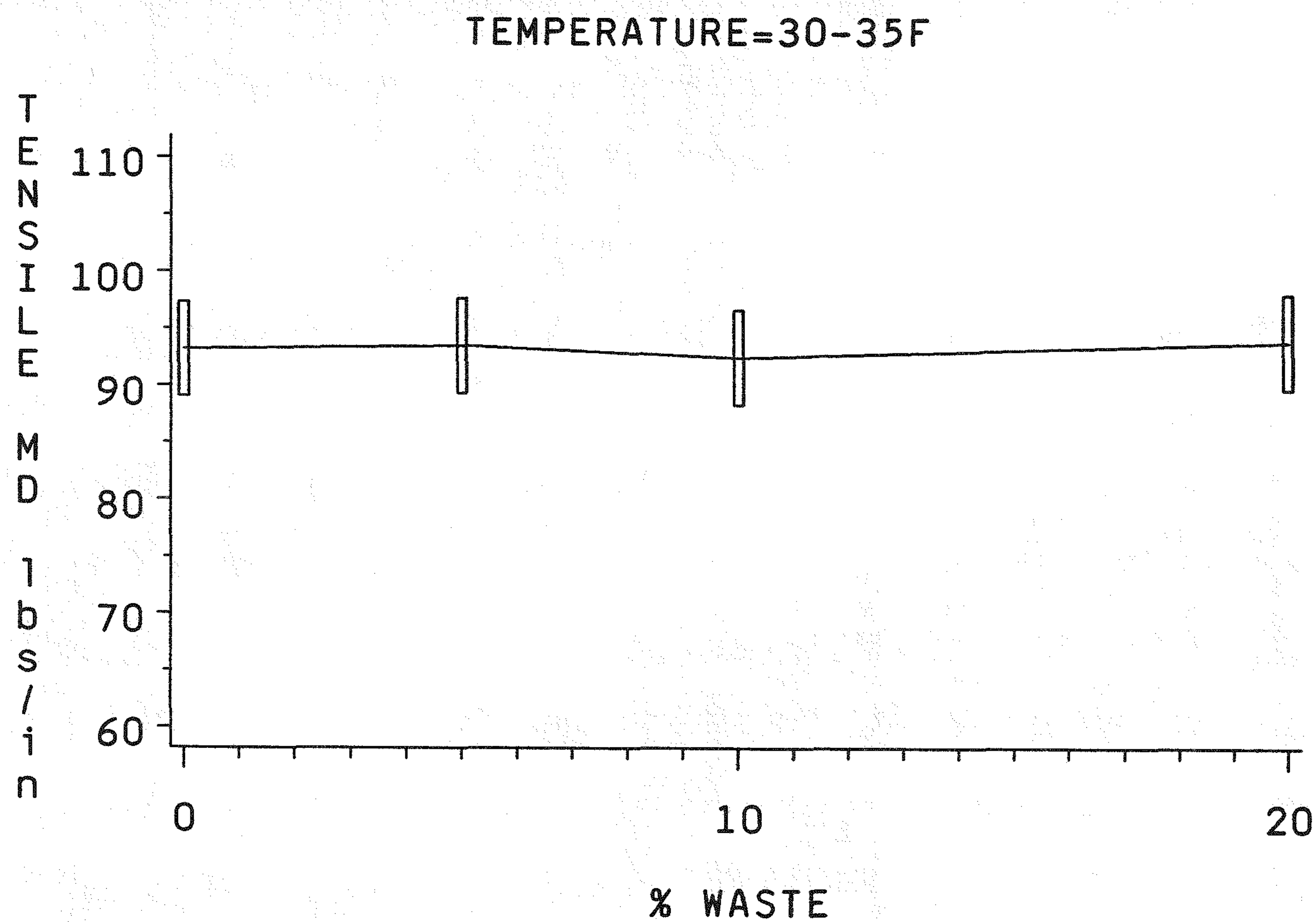
Results - Table 2 summarizes the testing results.

TABLE 2: TENSILE STRENGTH AND STRAIN OF SHINGLES

	% Waste in Shingles			
at 70-75F	0	5	10	20
Tensile Strength,lb/in width				
MD	68	72	75	65
CD	54	52	60	57
Strain,% of length				
MD	2.4	2.3	2.3	2.4
CD	2.3	2.2	2.4	2.3
at 30-35F				
Tensile Strength,lb/in width				
MD	93	94	92	94
CD	78	66	72	68
Strain,% of length				
MD	1.9	1.9	2.0	2.0
CD	1.7	1.6	1.8	1.6

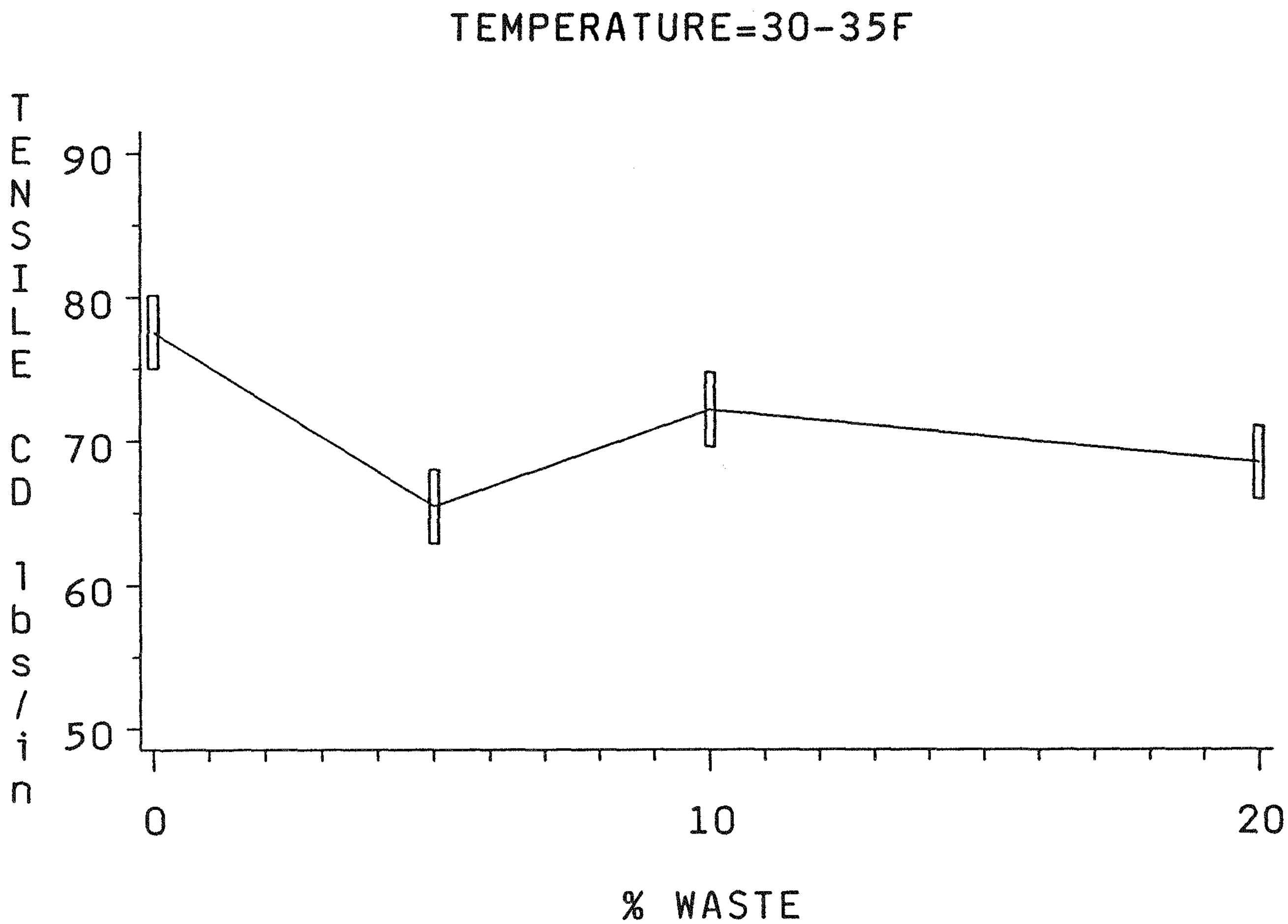
MD = parallel to shingle's long dimension
CD = parallel to shingle's short dimension

SAS analysis showed no significant differences between lots of shingles at room temperature. The shingles containing 5% waste had a lower strength than the baseline shingles in the cross machine direction at 30-35F but no differences were measured in any other case. The results are plotted in Figures 10 through 17.



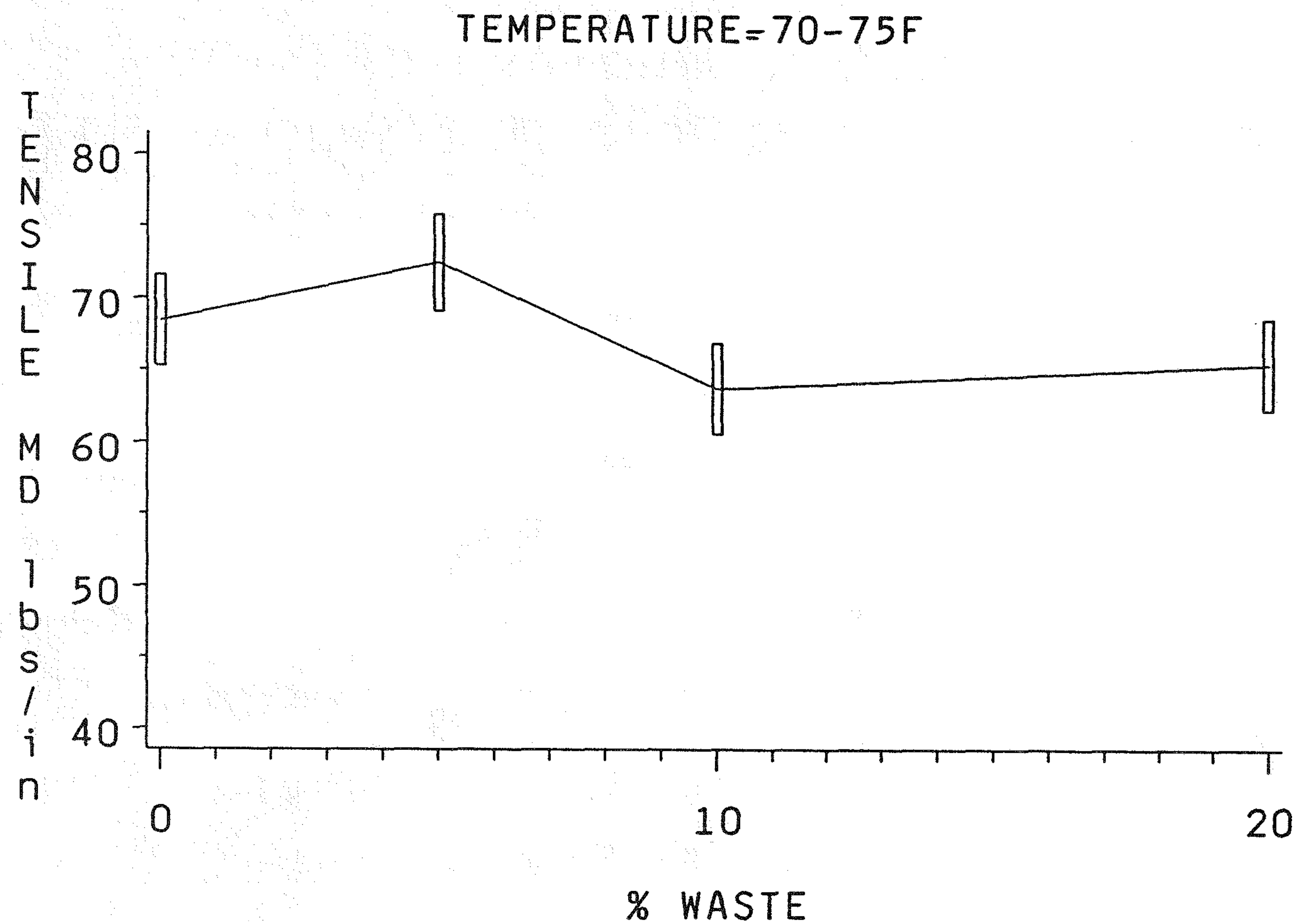
TENSILE STRENGTH OF SHINGLES

MACHINE DIRECTION
FIGURE 10



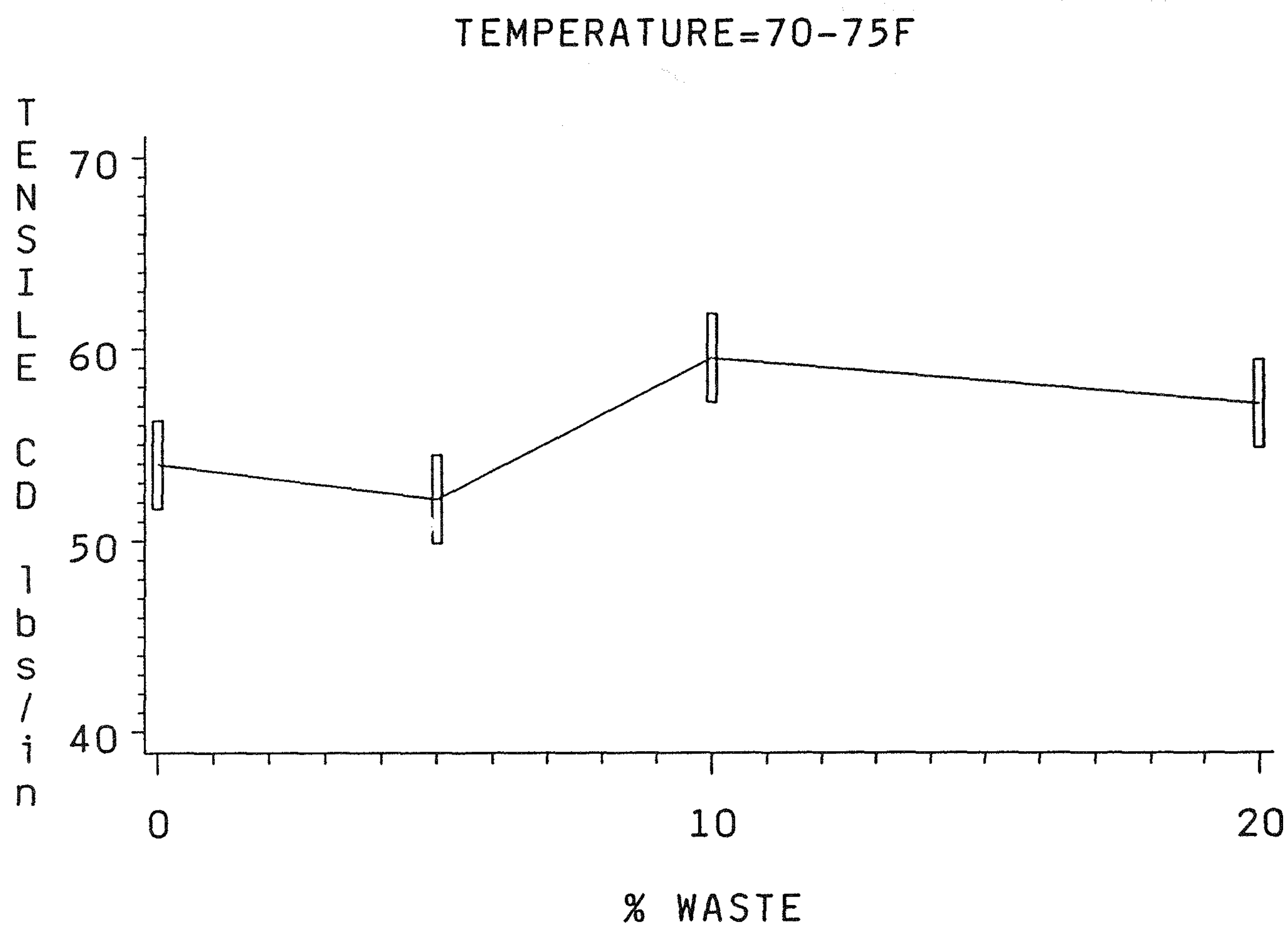
TENSILE STRENGTH OF SHINGLES

CROSS MACHINE DIRECTION
FIGURE 11



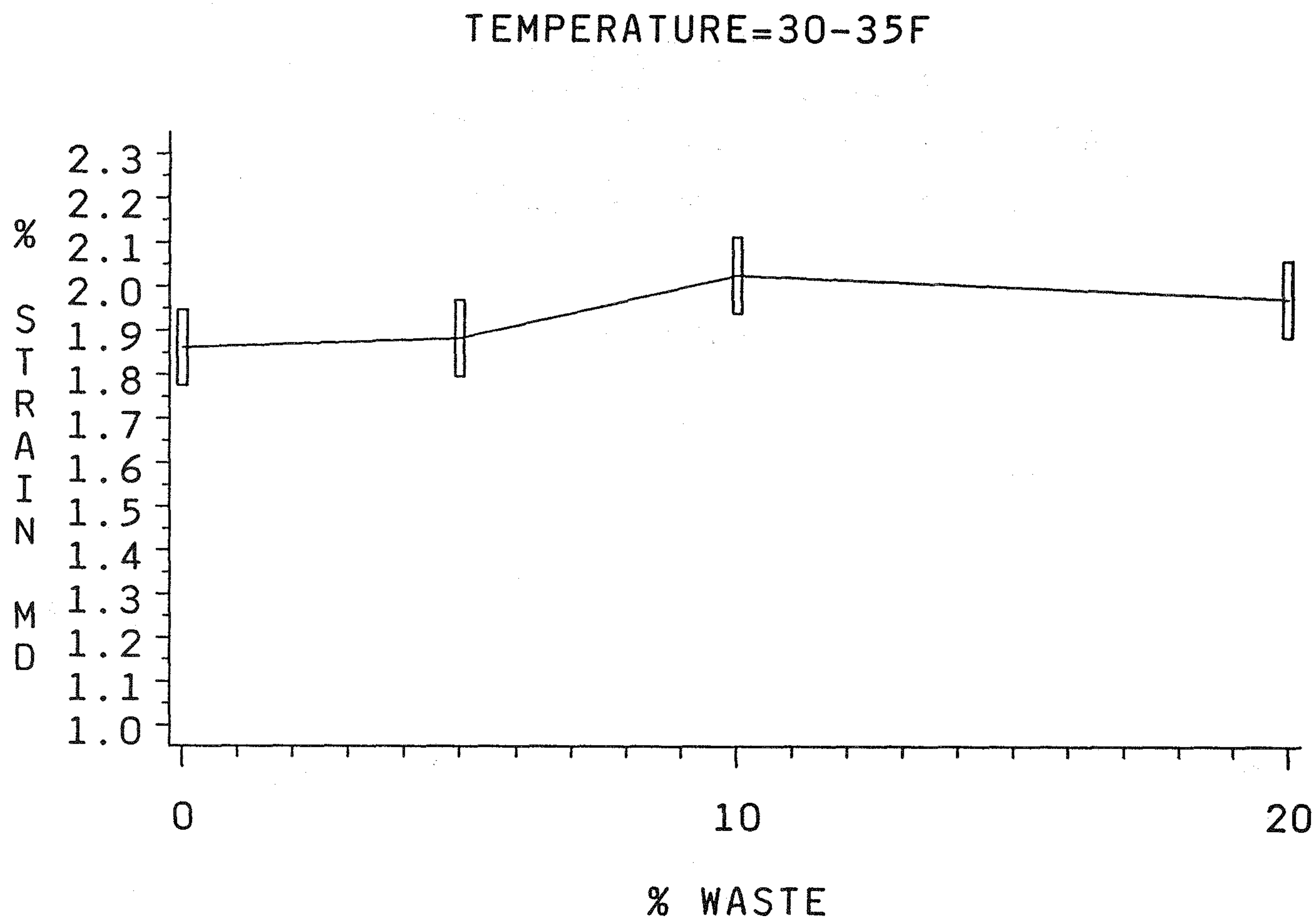
TENSILE STRENGTH OF SHINGLES

MACHINE DIRECTION
FIGURE 12



TENSILE STRENGTH OF SHINGLES

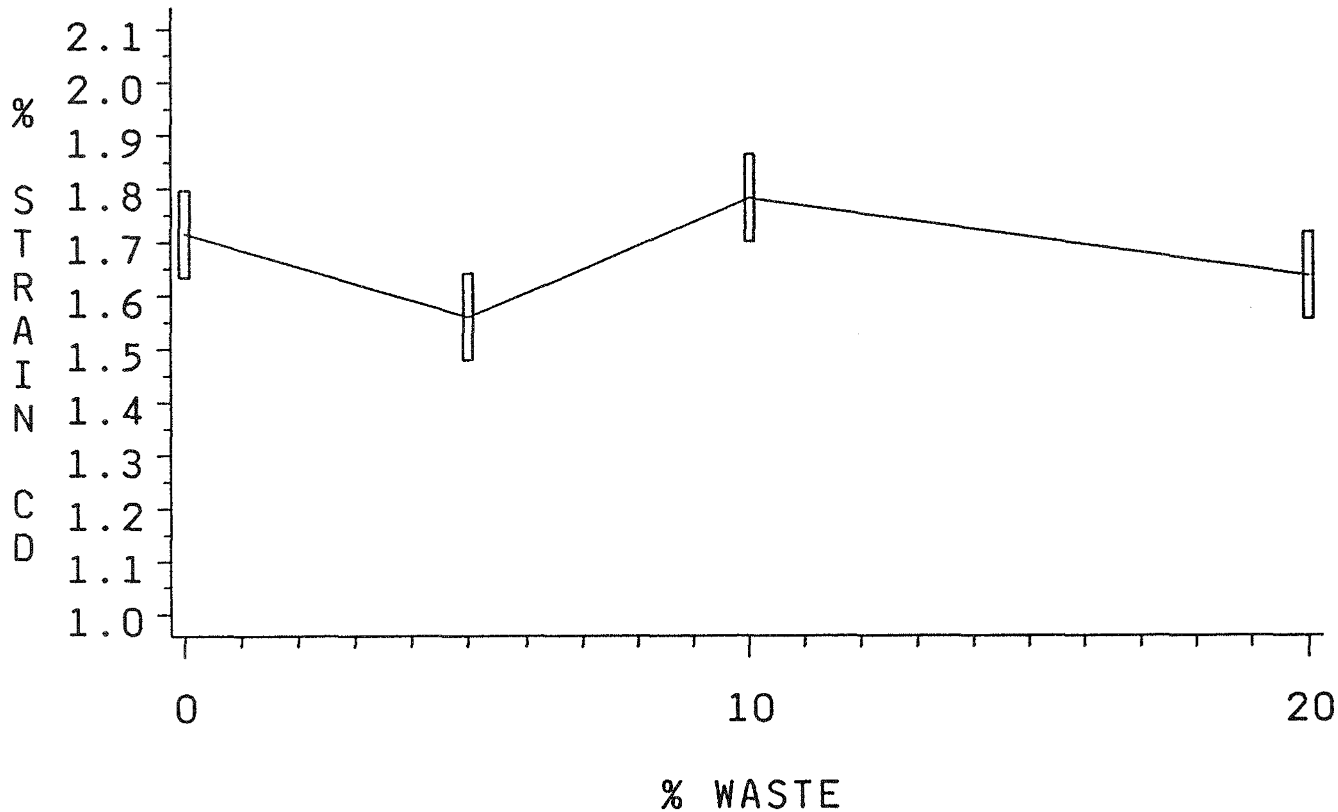
CROSS MACHINE DIRECTION
FIGURE 13



TENSILE STRAIN OF SHINGLES

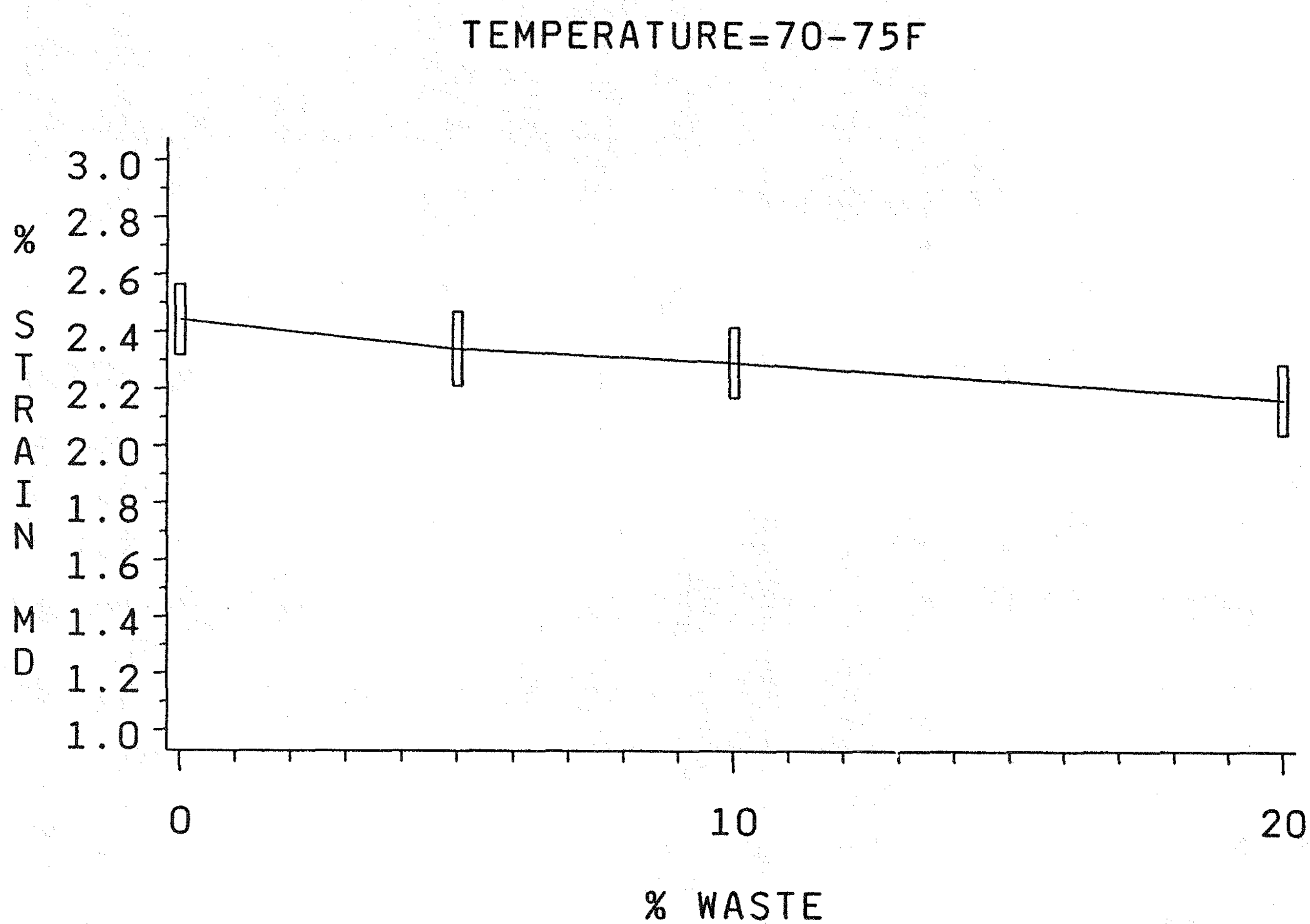
MACHINE DIRECTION
FIGURE 14

TEMPERATURE=30-35F



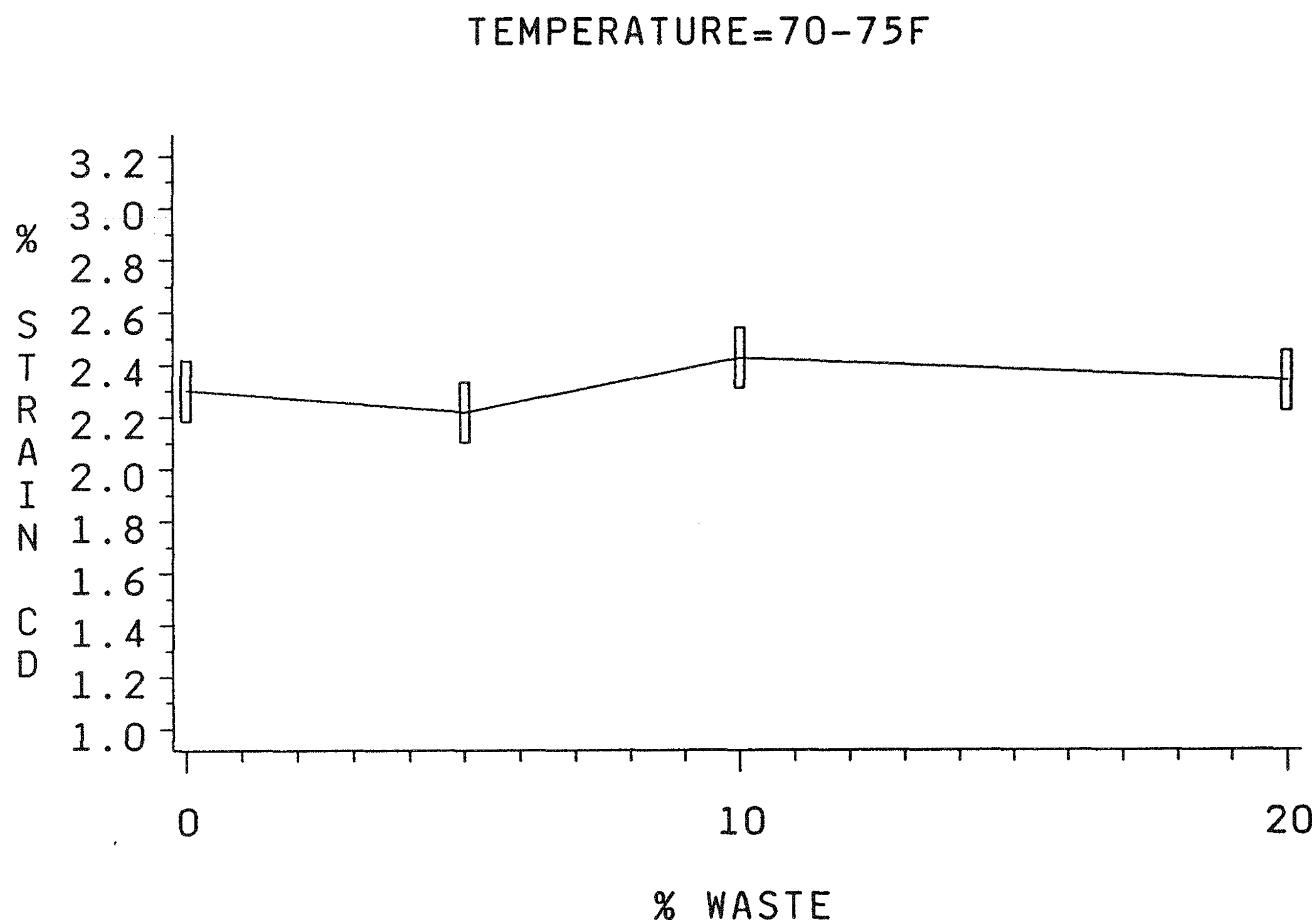
TENSILE STRAIN OF SHINGLES

CROSS MACHINE DIRECTION
FIGURE 15



TENSILE STRAIN OF SHINGLES

MACHINE DIRECTION
FIGURE 16



TENSILE STRAIN OF SHINGLES

CROSS MACHINE DIRECTION
FIGURE 17

Pliability

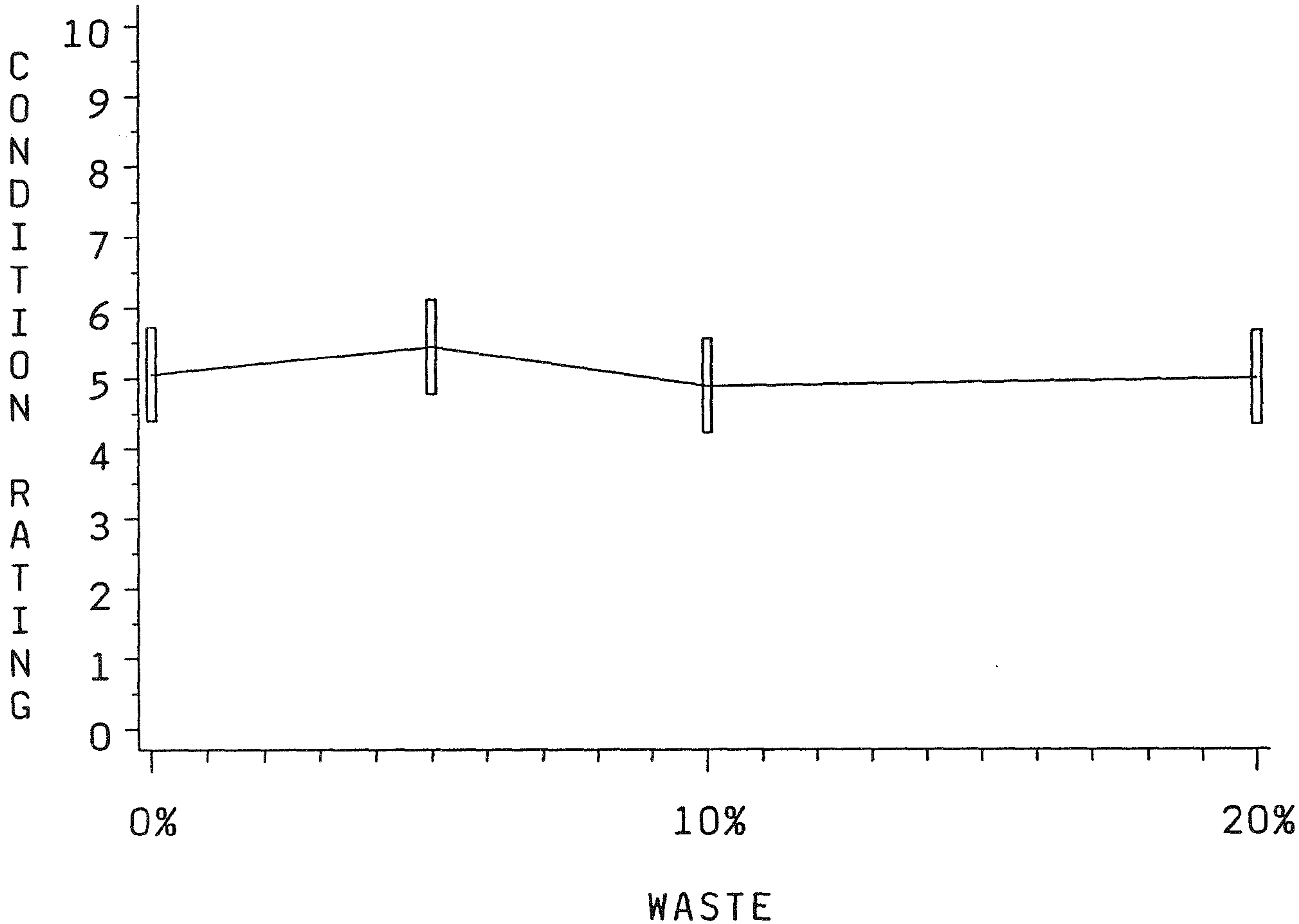
The pliability test is designed to compare shingles' ability to be installed without cracking when bent over angles as occur at the ridges and hips of roofs. The test method was derived from ASTM D 146, section 14 and appears in Appendix G.

Results - Table 3 summarizes the testing results.

TABLE 3: PLIABILITY RATING OF SHINGLES

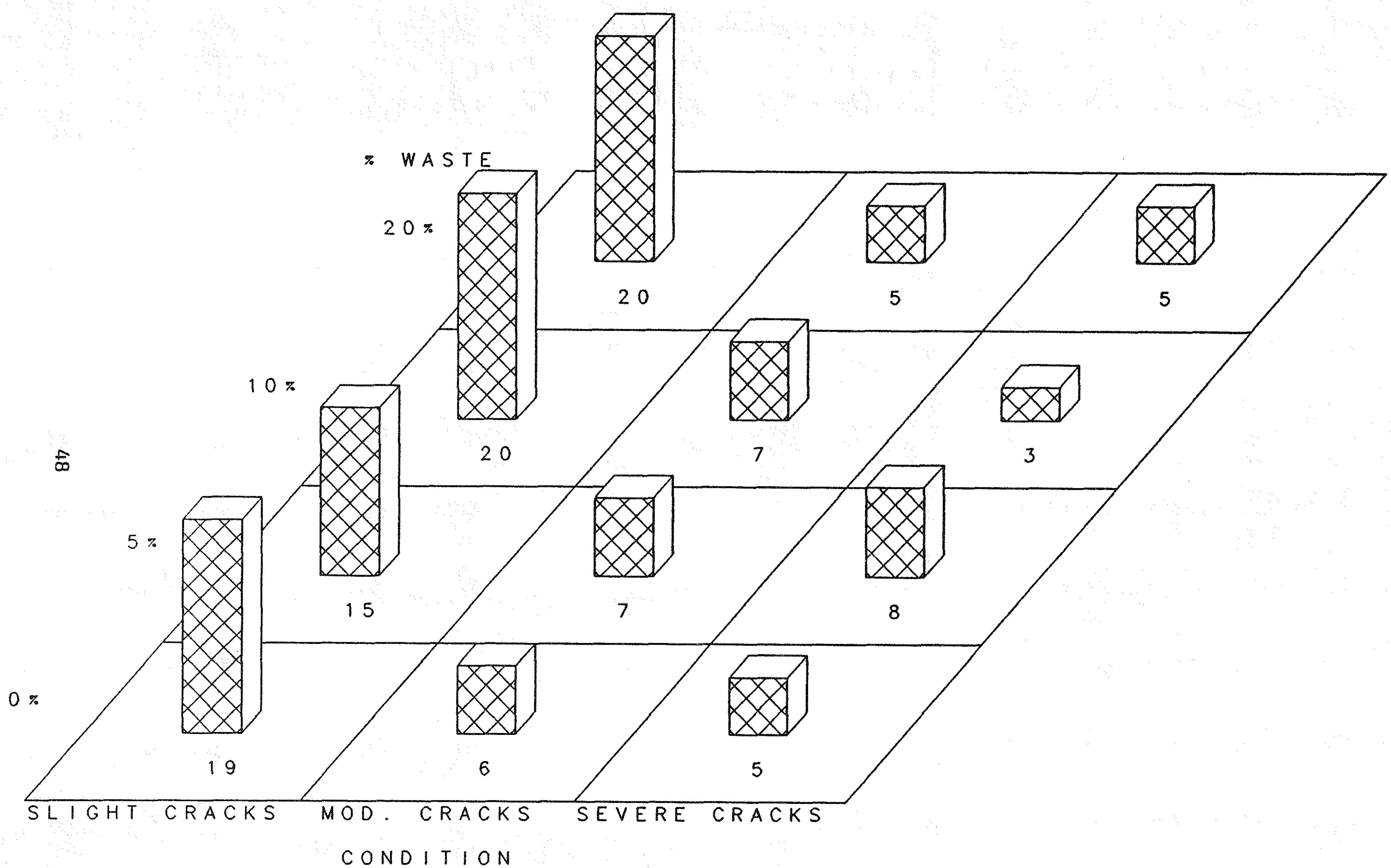
	% Waste in Shingles			
at 40F	0	5	10	20
Pliability Rating Number	51	55	49	50

SAS analysis was used and there was no significant difference between lots of shingles. The graph of results appears as Figure 18. The qualitative results are displayed in Figure 19.



THE PLIABILITY RATING OF SHINGLES

FIGURE 18



THE PLIABILITY OF SHINGLES

FIGURE 19

Stiffness

The stiffness of shingles may be related to such performance attributes as handleability during installation, resistance to wind forces and conformability when applied to a roof. The test method used to measure shingles' stiffness was an adaptation of a procedure used to evaluate sheet packing materials and the method is described in Appendix G.

Results - Table 4 summarizes the testing results.

TABLE 4: STIFFNESS OF SHINGLES

	% Waste in Shingles			
	0	5	10	20
at 70-75F, CD				
stiffness, in lb / (deg/in)in	0.046	0.043	0.044	0.052
yield angle,deg	75	71	70	69
yield moment, in lb / in	0.58	0.52	0.52	0.57
at 30-35F, CD				
stiffness, in lb / (deg/in)in	0.192	0.219	0.174	0.216
yield angle,deg	50	50	55	50
yield moment,in lb / in	1.76	2.04	1.70	2.10

Stiffness characteristics reported here are derived from graphed data and are not adaptable to the type of statistical analysis program used. Experience permits a valid comparison of the results. There is no difference between shingle lots in any of the three stiffness attributes reported at each temperature.

Wind Resistance

This is a performance test which applies a fan induced wind of incrementally increasing velocity to a roof section surfaced with the test shingles. The minimum wind velocity required to lift a shingle segment from its' installed horizontal position is recorded as the failure point. The test method is described in ASTM D3161. The heat conditioning specified in section 6.2 was deleted so that shingles were tested in an unsecured condition. Testing of each lot of shingles was done at room temperature and at 30-40F.

Results - Table 5 summarizes the testing results.

TABLE 5: WIND RESISTANCE OF SHINGLES

	% Waste in Shingles			
	0	5	10	20
Failure Velocity,mph				
at 70-75F				
tab lift	33	33	33	33
at 30-35F				
tab lift	33	33	33	33
shingle damage	75	66	75	75

Detailed observations appear in Table D-3. The four lots of shingles were judged to be equal and waste had no influence on the performance of the shingles.

Nail Pull Resistance

This test simulates the resistance of a shingle to a nail head pulling through the shingle when subjected to an extreme suction force caused by a strong wind blowing over the ridge of a roof. There is no standard test method for this attribute. The method used in this research is described in Appendix G.

Results - Table 6 summarizes the testing results.

TABLE 6: NAIL HEAD PULL THROUGH OF SHINGLES

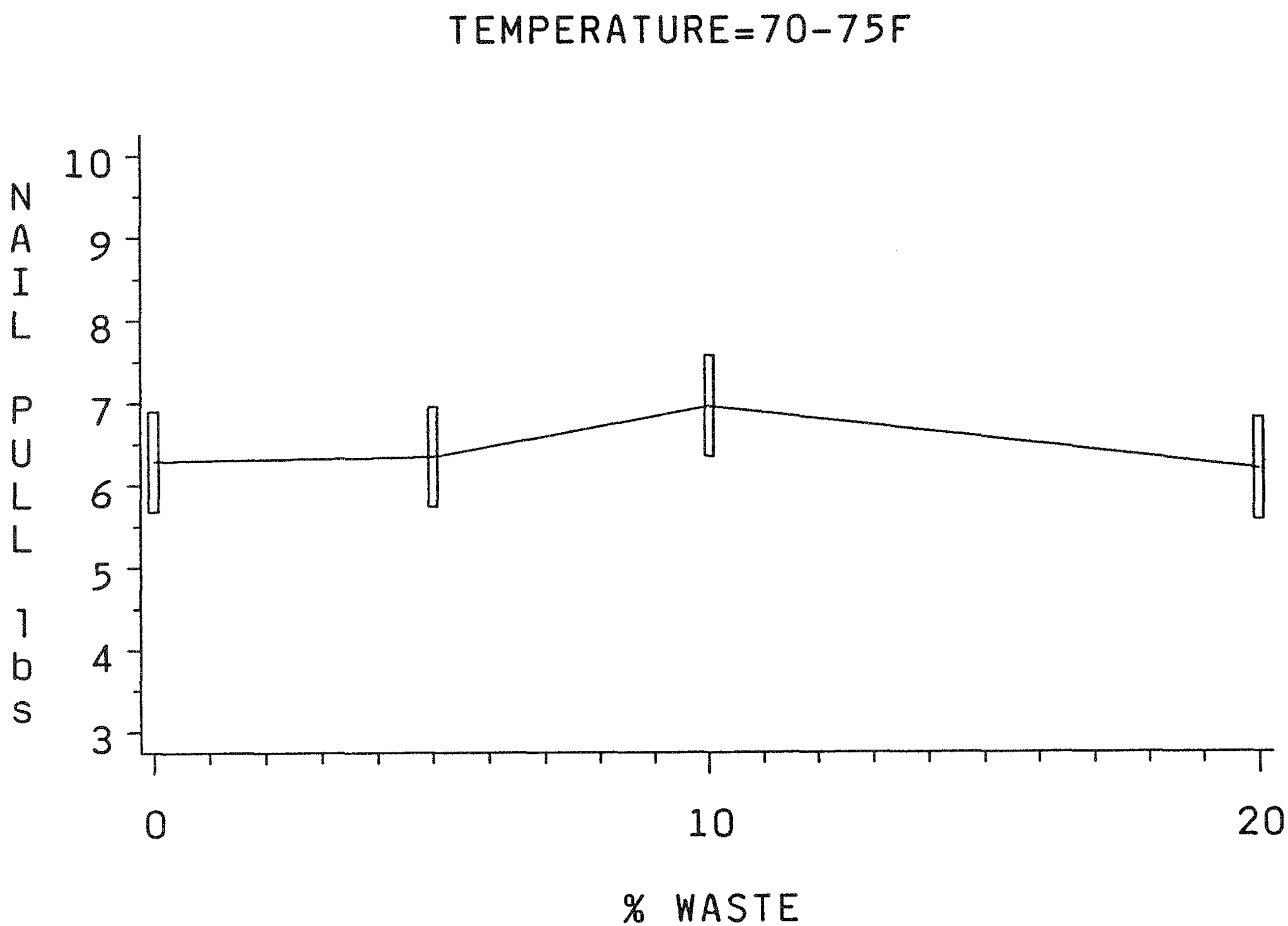
	% Waste in Shingles			
	0	5	10	20
at 70-75F				
Nail Pull Strength,lb	6.3	6.4	7.0	6.2

Statistical analysis of variance showed that there was no difference between lots of shingles in this test. The results are plotted in Figure 20.

Dimensional Stability

Dimensional stability is a characteristic which may relate to a shingle's ability to remain flat after being installed on a roof. There is no accepted, public test method. However, a method is presently being considered by ASTM and this method was followed based on a recommendation given following a meeting of the Research Committee of the Asphalt Roofing Manufacturers Association. The test method has been reproduced in Appendix G.

Results - Table 7 summarizes the testing results.



NAIL PULL RESISTANCE OF SHINGLES

FIGURE 20

TABLE 7: DIMENSIONAL STABILITY OF SHINGLES

	% Waste in Shingles			
at 70-75F	0	5	10	20
after 28 days				
change in length, %	0.0	0.0	0.0	0.0
water absorption, %	3.2	3.2	2.9	3.4

There was no significant difference among lots of shingles according to the analysis of variance. Figure 21 displays the results.

Fire Resistance

The fire resistance of shingles is frequently specified in the nation's building codes and packages of shingles are labelled according to their fire resistance. ASTM E108 is the test method used to rate fire resistance. Class C is the lowest degree of fire resistance. Class B is more fire resistant. Most fiber glass based asphalt shingles are rated Class A which is the highest degree of fire resistance. The protocol for each rating contains three tests; burning brand resistance, flame spread resistance, and intermittent flame exposure. Burning brand and flame spread are regarded by many experts as being more severe than flame exposure and these two tests were used to compare the lots of experimental shingles.

Results - Table 8 summarizes the testing results.

TABLE 8: FIRE RESISTANCE OF SHINGLES

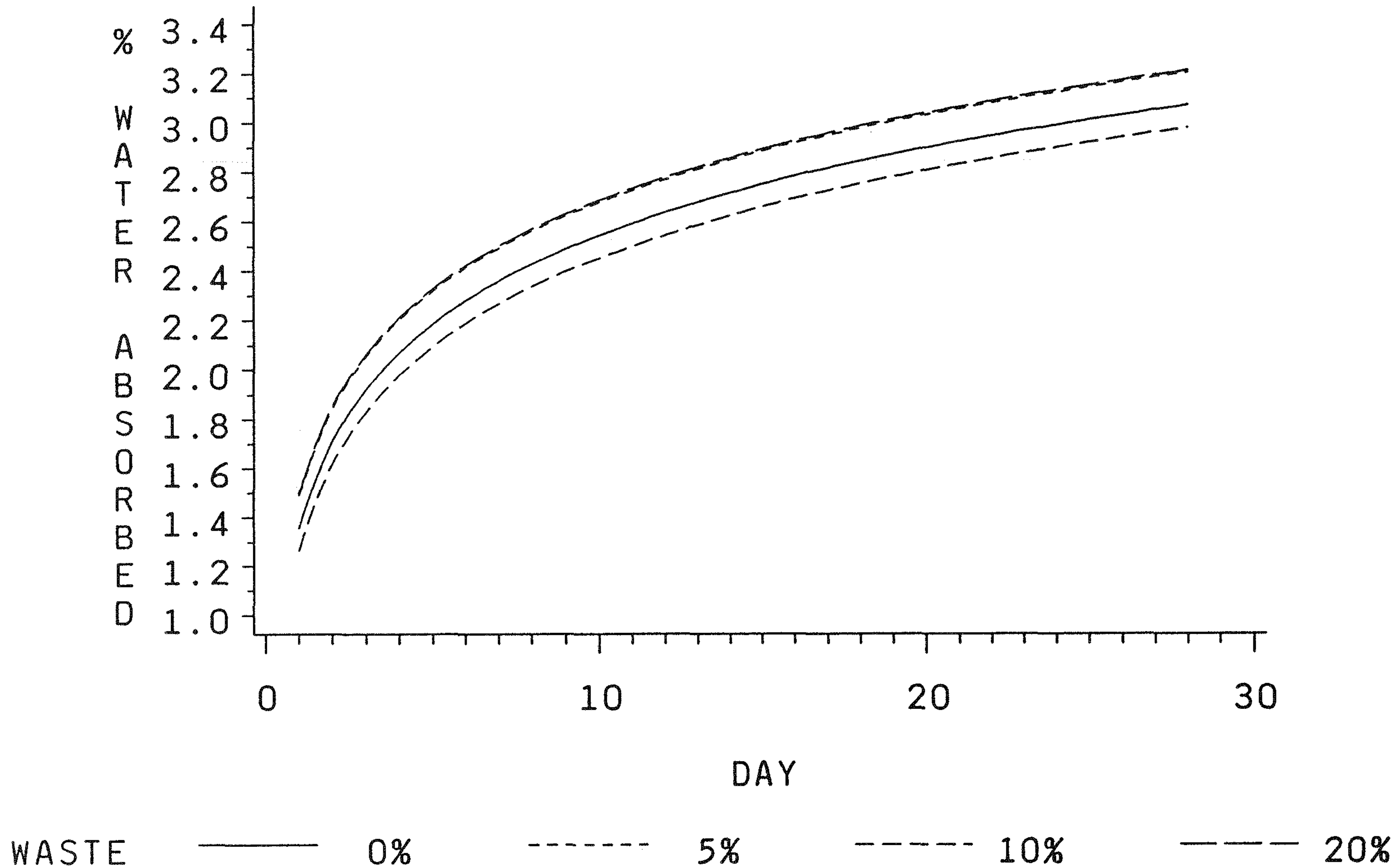
	% Waste in Shingles			
	0	5	10	20
Spread of Flame, ft/in	4/7	5/10	5/5	5/4
Burning Brand	--------no burn through-------			

Table D-4 shows the results in more detail. The shingles containing waste performed in the same manner as the base line shingles.

Handleability

This characteristic is rated on a highly subjective basis. The result, it is believed, may relate to how a professional roofing installer may perceive the shingles. No formal test method exists, but the procedure followed here appears in Appendix G.

Results - Four observers noted no differences in the handling qualities of the four lots of shingles at room temperature. Some differences were noted at 30-35 F, but these could not be attributed to waste content.



DIMENSIONAL STABILITY OF SHINGLES

FIGURE 21

Granule Adhesion

The adhesion of the decorative and protective colored stones to the asphalt on the surface of shingles is an important quality attribute. Good adhesion is essential to the longevity of shingles. The test method is shown in Appendix G.

Results - Table 9 summarizes the testing results.

TABLE 9: GRANULE ADHESION TO SHINGLES

	% Waste in Shingles			
at 70-75F	0	5	10	20
Granule Loss, grams				
fresh shingles	0.5	0.8	0.5	0.7
one month old	0.4	0.7	0.8	0.8
two months old	0.4	0.5	0.6	0.5

The small differences observed were well within the range of testing error. No differences could be attributed to waste content nor to aging of the shingles. Statistical analysis was not used because of the close similarity between all lots tested.

Independent Tests

Three manufacturers of asphalt roofing volunteered their private testing data on the experimental shingles.

Certainteed Corporation - No significant differences attributable to waste content were noted. The testing regimen included many standard tests plus one proprietary test designed to accelerate the aging of the shingles.

Georgia Pacific - Most of the testing was similar to that reported on the previous pages and similar results were obtained. A novel test involved soaking the shingles in warm water followed by freezing. The test cycling of freeze/thaw was continued for six weeks and the shingles were tested for cracking resistance at the end of each week. No differences between baseline and waste-containing shingles were noted at any time.

Owens Corning Fiberglas Corporation - All of the testing was similar to that reported on the previous pages and similar results were obtained. No significant differences between baseline and waste-containing shingles were reported.

TECHNICAL ANALYSIS

The factory research and laboratory testing described in this report were designed to answer a number of questions which are repeated here.

What are the operating parameters of the waste processing equipment?

What are the operating parameters of the roofing machinery when processed waste is introduced?

What is the quality of shingles containing waste?

What will be the estimated cost to install commercial equipment in a roofing factory?

What will be the financial benefit to a roofing manufacturer?

The research provided answers to all of the questions. The results of this research provide a firm technical and financial basis for technology transfer and commercial implementation of the recycling of factory asphalt shingle and granule surfaced roll roofing waste.

Feasibility

Commercial quality fiber glass asphalt shingles were successfully produced with asphalt coating composition containing processed shingle and roll roofing factory waste. The quality of shingles containing waste was measured to be equal to the quality of baseline shingles containing no waste. The technical feasibility of recycling factory shingle waste into new shingles was clearly confirmed.

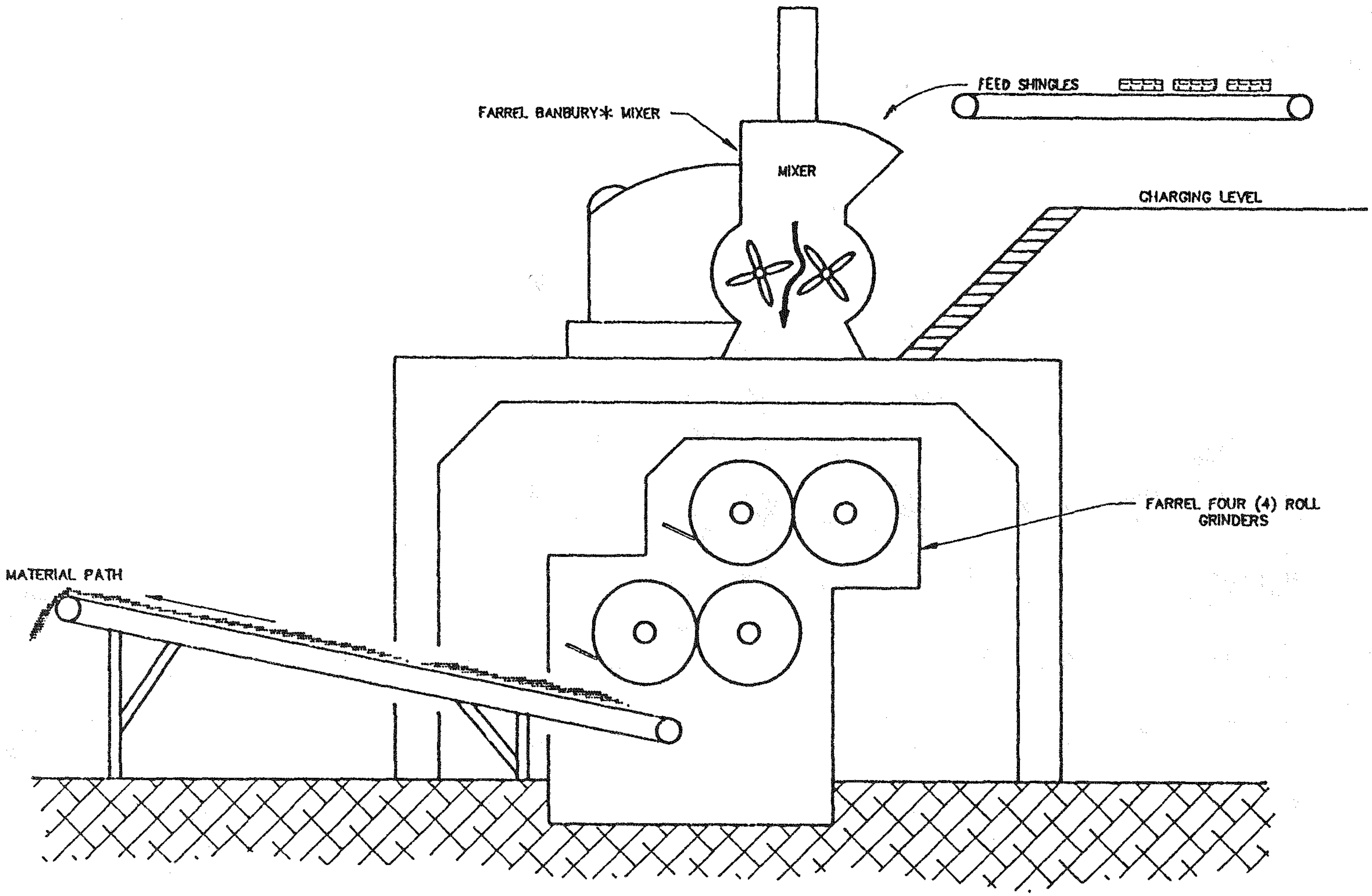
Financial feasibility was also shown by using a number of conventional criteria such as return on investment and pay back. Recycling of factory asphalt shingle waste should be an attractive investment for roofing manufacturers whose waste rates exceed 6600 tons per year or whose disposal cost exceeds $20 per ton. These figures are representative of a very small or highly efficient factory which also has a disposal cost equal to about the lowest reported in the industry.

Effective technology transfer of these results should ensure the commercial adoption of factory waste recycling by nearly all roofing manufacturers.

Waste Processing

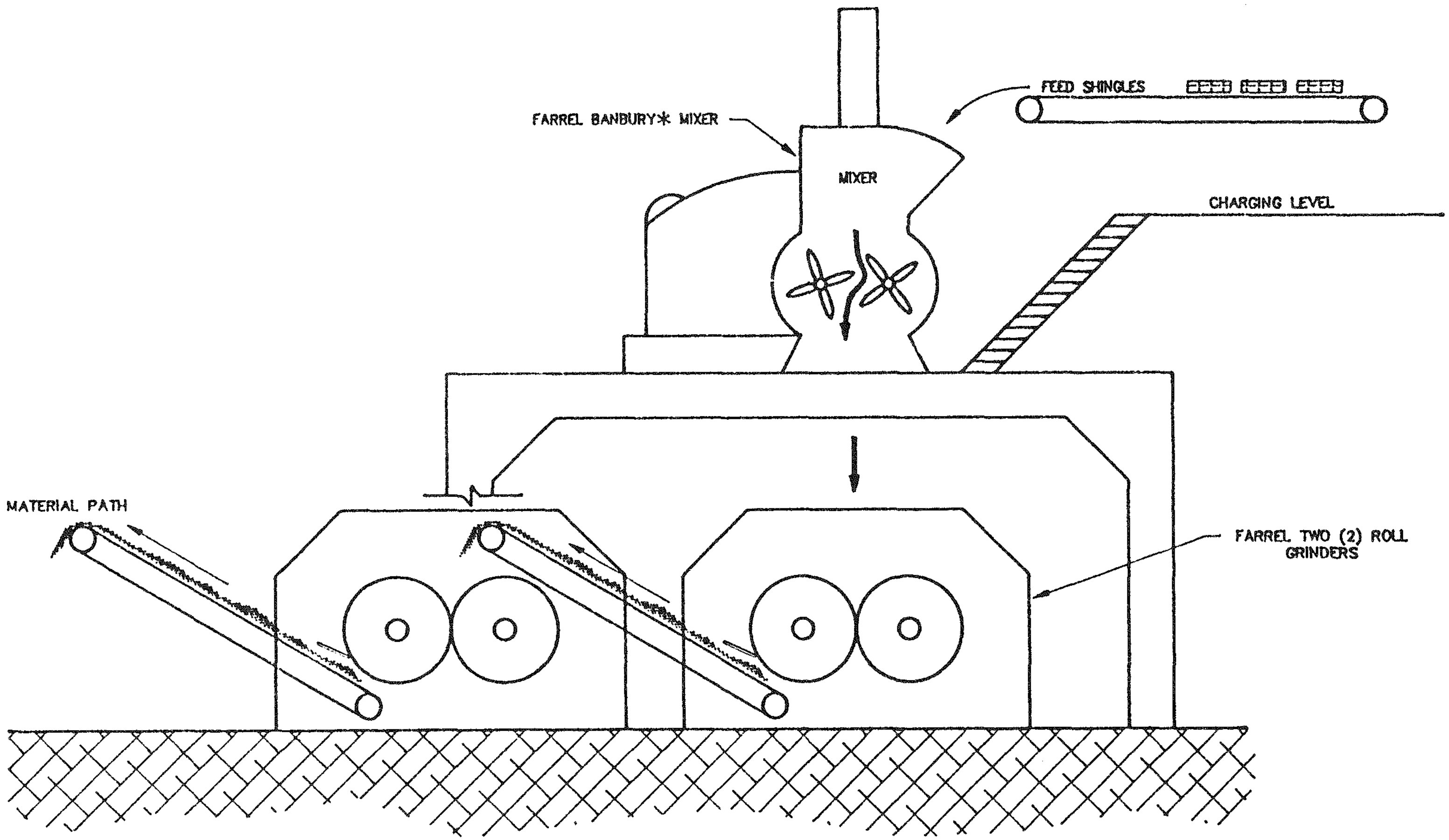
Seven days of production showed that factory asphalt shingle waste can be rendered suitable for recycling into the asphalt coating composition used to produce new shingles. A Banbury® Mixer will make a homogeneous mastic out of waste shingles and a roll mill will crush all of the granular mineral in shingles to a powder like the filler used in the asphalt coating.

The two critical parameters for waste processing are the gap between the rolls (0.005 in maximum) and the number of passes through the roll nip (3). It will be possible to design equipment for two pass operation as illustrated in Figures 22 and 23.



* A REGISTERED TRADEMARK OF THE FARREL CORPORATION.

FIGURE #22



* A REGISTERED TRADEMARK OF THE FARREL CORPORATION.

FIGURE #23

All other operating conditions were measured and will provide a sound basis for the construction and operation of commercial scale equipment with annual capacities up to 50,000 tons per year and perhaps more.

Temperatures, mass processing rates, and energy consumption were recorded and provided a basis for the financial and energy analyses shown elsewhere in this report.

A slight amount of dimpling of the rolls' surfaces was observed following production. Specially hardened rolls will reduce this on commercial units. Nevertheless, a high maintenance cost of $5.00 per ton was used in the financial analysis partly as an allowance for roll wear.

Manufacture of Shingles

The processed waste was easily introduced into the coating asphalt composition used to make new fiber glass shingles at the Bird Roofing factory in Norwood, MA. Conventional process equipment was used to melt, dilute, pump, and mix the waste into the normal asphalt composition. All equipment used was considered common in roofing factories.

Production of shingles with asphalt containing three levels of waste addition (5%, 10%, & 20%) was measured and observed to be normal in all respects. The quantity of shingles manufactured and the several hours of production experience provided a valid commercial test of this waste recycling technology. No differences were noted which would be attributable to the presence of waste or to different concentrations of waste.

Normal in-process quality checks showed the shingles with waste to be equal to baseline shingles containing no waste.

Performance of Shingles

Laboratory testing was used to judge the potential performance of shingles. Outdoor exposure tests and test roofs on eleven houses will provide confirmation of the laboratory results in the future.

No differences were measured among the four lots of shingles containing 0%, 5%, 10%, and 20% waste in the asphalt coating. The following tests were used to measure and compare the qualities of the four lots of shingles.

- tear strength
- tensile strength
- pliability
- stiffness
- wind resistance
- nail pull through
- dimensional stability
- fire resistance
- handleability

These tests are representative of those methods used in the roofing industry.

The Statistical Analysis System (SAS) computer program was used to evaluate those results represented by numerical answers. Analysis of variance (ANOVA) showed no significant differences attributal to waste among lots of shingles for each characteristic.

The tests of stiffness, handleability, wind resistance, and fire resistance do not lend themselves to statistical analysis. Results of these tests were evaluated by persons with long experience who judged that there was no difference between the four lots of shingles.

Addition of fiber glass shingle waste to the asphalt used to make new shingles had no effect on the physical or performance-related attributes of the shingles.

Environmental Impact

National Environment

The success of the research described in this report holds the potential for a desirable environmental impact on the nation's waste disposal. Commercial implementation of the recycling of factory asphalt shingle waste will eliminate the landfilling of a large amount of material. It is estimated that the annual national reduction in landfill load will be about 500,000 cubic yards, which is about 400,000 tons. This estimate was calculated using the following data.

> Nationwide annual production of asphalt shingles is about 80,000,000 squares (a sales and production unit). This statistic was obtained from information provided by the Asphalt Roofing Manufacturers Association.
>
> Each square weighs about 220 pounds.
>
> Factory scrap generation may be about 5% of annual production.[8]
>
> Ninety percent of roofing factories may implement this technology.[9]

Production and scrap rates may vary somewhat from year to year. The effects of possible variations are illustrated in the following two charts where the mid-point represents the projected, most likely result.

TABLE 10: 1000's OF TONS PER YEAR LANDFILL REDUCTION

Annual Production MM Squares	Factory Scrap Rate 2%	5%	8%
70	138	347	555
80	158	**396**	634
90	178	446	713

[8] *Shepherd; Op Cit; 21.*

[9] *Shepherd; Op Cit; 42.*

TABLE 11: 1000's OF CUBIC YARDS PER YEAR LANDFILL REDUCTION

Annual Production MM Squares	Factory Scrap Rate 2%	5%	8%
70	173	434	694
80	198	495	793
90	223	558	891

This research showed that granule surfaced factory roll roofing waste may also be recycled. The results in the above tables will be increased by about 6-2/3% if roll roofing is included.

Factory Environment

Observations made during the production of shingles containing the waste detected an odor from the waste melting tank. This odor was characteristic of overheated binder which is a constituent in glass fiber mat used to produce the shingles. The waste had been heated over a weekend (more than two days) to a temperature of 440°F so that some degradation of the binder might have been anticipated. This long heating period would be uncharacteristic of a commercial operation. However, this research did not permit a meaningful estimate of the potential for odor generation when processed waste is melted for recycle. The odor might be a concern in a factory environment and might require a simple exhaust system to control the workplace atmosphere. This should be investigated on an individual basis, as the many manufacturers of glass fiber mat have different proprietary recipes for binder. Therefore, different products will have differing tendencies to create odors when shingle waste is heated for long periods of time.

Technology Transfer and Commercial Implementation

Technical and business presentations of the results of this research were made in April 1989 to the Asphalt Roofing Manufacturers Association committees on Manufacturing and Research.

Farrel Corporation developed two commercial designs for waste processing equipment based on these experiments. These are shown in Figures 22 and 23. Figure 24 shows a schematic for the entire waste processing operation.

Bird, Inc. holds a U.S. Patent 4,726,846 and has developed the following plan for marketing the recycle technology to other manufacturers of asphalt fiber glass shingles.

Commercialization will flow from an effective technology transfer program and an effective sales and marketing effort. Technology transfer has been underway since April 1989 when presentations were made to the Manufacturing and Research Committees of the Asphalt Roofing Manufacturers Association. Additional presentations to other influential committees had been planned during 1989. These presentations were made jointly by the Manville Technical Center, Bird Roofing, and the Department of Energy. This report is another important facet of technology transfer. The marketing effort which will follow technology transfer has the necessary flexibility to make this technology available to all roofing manufacturers on a basis to appeal to each roofing manufacturer.

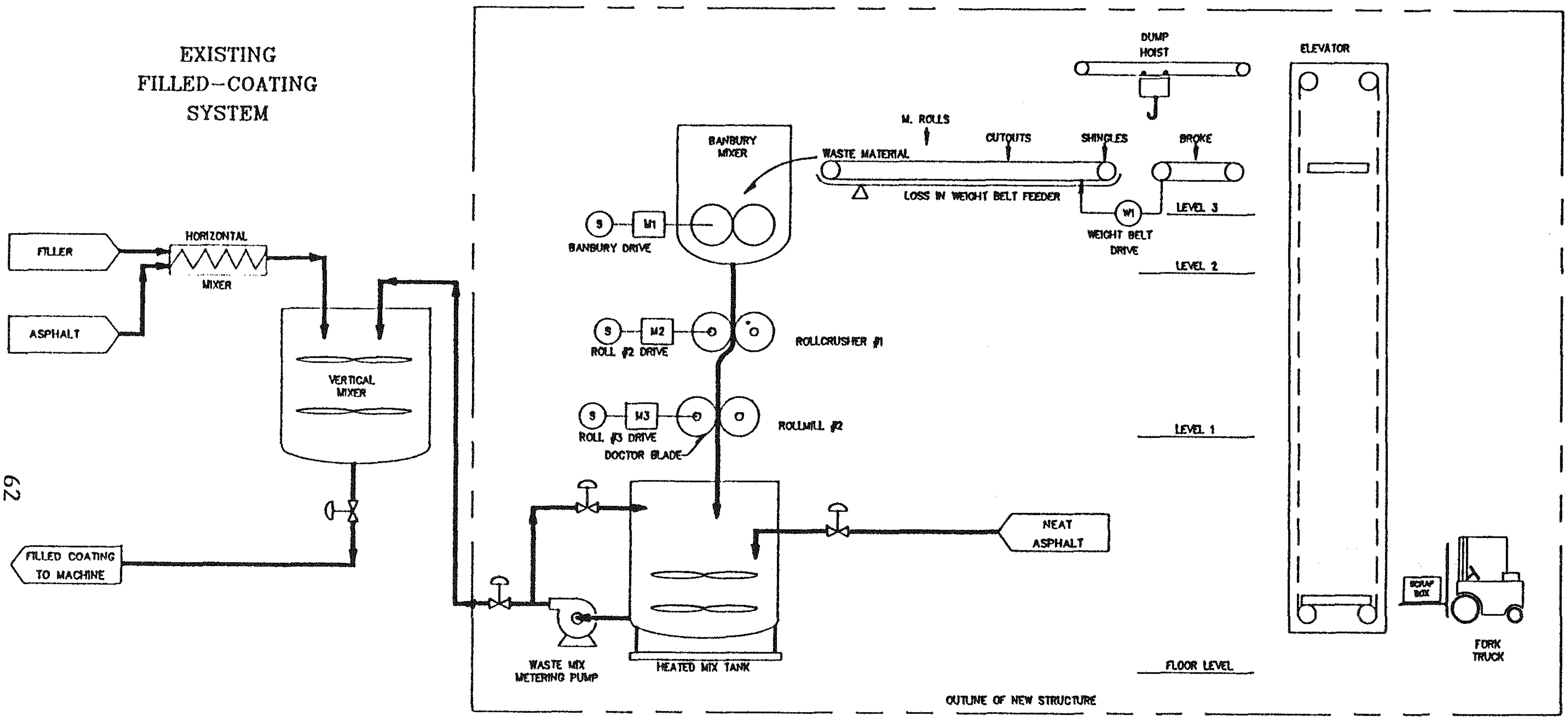
The marketing plan has been designed to allow each potential customer to acquire a recycling facility in a manner which best suits him. Examples of some of the options are described here.

> Small manufacturers or others who may not wish to be involved in design and construction will be offered a full, turnkey installation with license to practice the Bird patent. This may be purchased from Bird, Inc. For those who may not choose to deal directly with a competing manufacturer, arrangements will be made to offer the technology through a competent, third-party engineering firm.

Some major roofing companies maintain large engineering staffs and may wish to undertake some or all of the design and construction. Such potential customers will have options ranging from a simple license of the patent to engineering and design assistance of any type they may desire.

An engineering sales specialist, working for Bird Roofing, will establish contact with shingle manufacturers who have not been exposed to technology transfer because they are not members of the Association or, perhaps, were unable to attend the technology transfer meetings. This representative will work with all potential customers to help them select the option which best suits the customer's needs and desires. Assistance may be offered in obtaining financing should this be appropriate, and guidance may be available for obtaining financial assistance in states which have programs to support energy conservation and/or landfill waste reduction programs.

A detailed description of the marketing plan appears as Appendix H.



WASTE RECOVERY
SCHEMATIC DIAGRAM

FIGURE 24

ECONOMICS AND ENERGY ANALYSIS

Economics

A financial analysis of recycling roofing waste was previously made using only one national typical disposal cost.[10] Disposal costs have increased markedly since that study and there is now a very wide difference in disposal costs among various regions of the country. The financial benefit of recycling factory asphalt roofing waste is strongly influenced by both disposal cost and the annual quantity of waste generated in each factory. The analysis presented here is shown using a matrix of variable waste disposal cost and waste generation rate. The ranges of calculated financial and economic results is tabulated below:

Internal Rate of Return, %	4.3	-	49.5
Discounted Return on Investment, %	17.5	-	48.5
Simple Payback, years	1.9	-	7.4
Discounted Payback, years	2.3	-	>10.0
Gross Savings, $/ton waste	70.60	-	150.60
Gross Savings, $/Sq shingles	0.24	-	1.25
Added Net Income, $/ton waste	(14.68)	-	55.73
Added Net Income, $/sq shingles	(0.05)	-	0.46

The reader may look at the summary tables starting on page 65 and quickly determine the magnitude of financial benefit applicable to his own situation. These and additional financial response matrices are shown in Appendix F. Roofing manufacturers will probably choose to make their own confirming analysis based upon their actual costs and systems for financial analysis. The benefits consist of reducing the quantity of virgin asphalt and filler and reducing landfill costs. Costs include the capital, labor, and energy to process the waste and introduce the processed waste into the roofing manufacturing operation.

Operating Assumptions

The following data were excerpted from a prior DOE study.[11] Some of these data have been updated based on new information received during 1989.

- Factory size/capacity = 220,000 tpy = 2.0 MM squares of shingles

- One square of shingles = 220 lbs, weighted average

- Filled coating composition = 130 lbs per square, weighted average

- Asphalt filled coating composition is assumed to be 35% asphalt and 65% rock dust filler. Substituting processed factory waste results in new annual average filled coating formulas which are a function of each factory's waste generation rate as illustrated below. The formulas were calculated using the average 24.9% asphalt content measured on sixty-two lots processed for this research.

----

[10] *Shepherd; Op Cit; 36-39.*

[11] *Shepherd, P. B. and T. J. Powers; "Recovery and Reuse of Asphalt Roofing Waste. Recycling Roofing Waste to New Roofing"; DOE/ID/12560-4; 36-38; July 1987.*

	Annual Rate of Waste Generation			
	0% (baseline)	3% 6600 t/yr	5% 11000 t/yr	7% 15400 t/y
	Formula - % by Weight			
Asphalt	35.0%	33.7%	32.9%	32.0%
Filler	65.0%	61.2%	58.6%	56.1%
Scrap	0.0%	5.1%	8.5%	11.9%

- Acquisition of on-site factory waste = $ 0.35/ton

- Disposal of factory waste = $100.00/ton high
  = $ 60.00/ton med
  = $ 20.00/ton low

These factory disposal costs were excerpted from a study conducted by the Asphalt Roofing Manufacturers Association for the Department of Energy.

- Asphalt coating = $134.00/ton
- Filler = $ 22.80/ton
- Variable annual, added costs depend on the quantity of waste processed.

National average energy costs provided by the U.S. Department of Energy, Idaho Operations Office, were used as follows:

Industrial No. 2 Fuel Oil	$.053/gal $3.82/MM Btu
Industrial Natural Gas	$2.83/Mcf $2.75/MM Btu
Industrial Electricity	$0.0456/KW $13.36/MM Btu

	Annual Rate of Waste Generation		
	3% 6600 t/yr	5% 11000 t/yr	7% 15400 t/yr
Electricity	$ 25943	$ 43238	$ 60533
Fuel	2378	3963	5548
Labor	45000	45000	45000
Maintenance	60040	82040	104040
Total	133361	174241	215121

- Insurance = $ 500 yr
- Equipment cost for scrap processing, handling, and mixing

	Annual Rate of Waste Generation		
	3% 6600 t/yr	5% 11000 t/yr	7% 15400 t/yr
Capital	2085000	2515000	2850000
Operating funds (borrowed)	160000	200000	245000

The details of the capital costs appear in Appendix G.

Financial Assumptions

- Base year is Year 0
- Future dollar values are not discounted for inflation
- 100% external financing
- 10% interest on borrowed funds
- 12% discount rate
- 10 year debt life
- 7 year depreciation life, assume accelerated depreciation
- 40% overall tax rate on taxable earnings

Analysis

The financial results are strongly dependent on a factory's scrap generation rate and disposal costs. Each analytical result shown in Tables 12-15 is, therefore, presented in a matrix of waste rate and disposal cost. The detailed financial calculations from which these tables were derived appear in Appendix G.

TABLE 12: INTERNAL RATE OF RETURN - %

	Waste Generation Rate		
	3% 6600 t/yr	5% 11000 t/yr	7% 15400 t/yr
Disposal Cost:			
$100/ton	26.8	39.5	49.5
$ 60/ton	16.7	27.0	34.8
$ 20/ton	4.3	12.6	18.4

TABLE 13: DISCOUNTED RETURN ON INVESTMENT - %

	Waste Generation Rate		
	3% 6600 t/yr	5% 11000 t/yr	7% 15400 t/yr
Disposal Cost:			
$100/ton	31.0	40.5	48.5
$ 60/ton	24.2	31.2	36.9
$ 20/ton	17.5	21.8	25.3

TABLE 14: DISCOUNTED PAYBACK - YEARS

	Waste Generation Rate		
	3% 6600 t/yr	5% 11000 t/yr	7% 15400 t/yr
Disposal Cost:			
$100/ton	4.4	2.9	2.3
$ 60/ton	6.9	4.3	3.3
$ 20/ton	>10.0	9.5	6.3

TABLE 15: SIMPLE PAYBACK - YEARS

	Waste Generation Rate		
	3% 6600 t/yr	5% 11000 t/yr	7% 15400 t/yr
Disposal Cost:			
$100/ton	3.2	2.3	1.9
$ 60/ton	4.4	3.2	2.6
$ 20/ton	7.4	5.1	4.1

Energy

The research reported here has shown that processed factory roofing waste may be substituted for virgin raw materials in the coating asphalt composition used to manufacture new shingles. The net energy savings that will be derived from this substitution have been estimated on the basis of the embodied energy of the displaced virgin raw materials less the energy expended in the substitution process. Three different groups of energy use have been developed in this report and are summarized here.

1. The energy used in the trial runs described in this report.
2. The energy which has been estimated to be required for full-scale, commercial production.
3. The energy investment required to achieve the energy resource recovery described in the following paragraphs.

The energy data in the following summary chart were obtained from measurements, calculations, and estimates appearing on pages 26, 29, 30, 68, 69, 148, and 152.

Energy Destination		**Used in Trial Production**	**Needed for Commercial Production**	**Energy Investment**
Banbury[R]	elec heat[1]	0.00876 KWH/lb 4.5 Btu/lb	0.00876 KWH/lb 4.5 Btu/lb	92 Btu/lb 4.5 Btu/lb
Roll Mill	elec	0.031 KWH/lb	0.031 KWH/lb	325.5 Btu/lb
Melt & Heat	elec	94 Btu/lb	55 Btu/lb	0
Agitator	elec	0.0684 KWH/lb	0.0041 KWH/lb[2]	43.6 Btu/lb[2]
Losses	heat	6 Btu/lb	6 Btu/lb	6 Btu/lb
Pumps	elec	0.0004 KWH/lb	2	2

[1] Includes roll mill
[2] Includes pumps

Energy Savings Analysis

The basis of the energy savings estimate is the extent to which recycled factory roofing waste may be substituted for virgin raw materials in the filled coating used to make new roofing. The financial analysis suggests the use of the maximum substitution that is both technically feasible and operationally realistic. The factory tests and laboratory evaluations described in this report showed that factory scrap from fiber glass asphalt shingles and granule surfaced rolls can be added to the filled coating asphalt composition in ratios up to 20 percent by weight. However, a factory's scrap generation rate will be the governing factor in determining how much scrap **will** be added to the coating asphalt. Following is a tabulation of substitution ratios which will be achieved for various scrap generation rates.

Waste Rate % by weight of production	Substitution Ratio % by weight of asphalt coating
2	3.4
4	6.8
5	8.5
6	10.2
8	13.5

A scrap generation rate of 5 percent was selected as the basis for the energy savings calculations. No industry data are available but the 5% figure was identified in a prior report.[12] This seems to remain a valid figure for estimating purposes. Therefore, the substitution ratio from the above chart is 8.5 percent.

---

[12] *Shepherd; Op cit; 39.*

Fiber glass asphalt shingles were selected to provide the basis for the energy analysis. Shingles accounted for about 80 percent of the weight of roofing produced annually according to data supplied by the Asphalt Roofing Manufacturers Association. Including granule surfaced, fiber glass based, asphalt roll roofing would add about 6-2/3 percent to the recovered energy. Granule surfaced roll roofing is shingle-like material which is packaged in three feet wide rolls many feet long rather than in groups of small pieces, as shingles are packaged.

Eighty million squares were used as the annual national sales of shingles. This was identified as a "typical" year; although, there may be significant year-to-year variation.

The average annual formulas for a typical filled asphalt coating and one containing processed waste are shown below. This reflects an 8.5 percent substitution. Twenty percent substitution was shown to be technically feasible and this ratio may be necessary at times to accommodate scrap and production fluctuations. However, a five percent scrap rate leads to the average annual substitution ratio of 8.5 percent.

asphalt	35.0% by weight	32.9% by weight
filler	65.0	58.6
scrap	0.0	8.5

The amount of coating asphalt composition used to produce one square of shingles was reported on page 63 to be 130 pounds. The embodied energy of replaced asphalt in the shingles was reported to be over 18,000 Btu per pound.[13] The embodied energy in the filler may be about 30 Btu per pound based on the energy consumption in mining and processing the rock to the desired particle sizes. Transportation and other energy expenses associated with collecting and handling scrap were assumed to be the same as for the present practice of nearby landfill disposal. The energy expense for preparing, melting, mixing, and pumping the scrap was measured in this research and is shown in detail in Appendix C. These data were used to estimate the energy consumed by a commercial operation which is summarized below.

Banbury^R Mixer Operation	0.00876 KWH/lb	92.0 Btu/lb
Roll Mill Operation	0.0310 KWH/lb	325.5 Btu/lb
Banbury^R/Roll Mill Heat		4.5 Btu/lb
Storage/Piping Heat		6.0 Btu/lb
Mixing and Pumping	0.0041 KWH/lb	43.6 Btu/lb

The net annual national energy savings may now be calculated from the above information.

Calculations

The energy savings per pound of processed waste is calculated below.

Saving From Asphalt Substitution

$$\left\{\frac{18{,}000\ \text{Btu}}{\text{lb asphalt}} \times \frac{(35.0-32.9)\ \text{lb asphalt}}{8.5\ \text{lb waste}}\right\} = \frac{4447\text{Btu}}{\text{lb waste}}$$

---

[13] *Wolsky, A. and L. Gaines; "Discarded Tires, a Potential Source of Hydrocarbons to Displace Petroleum"; Resources and Energy; 3; 195-206; North Holland Publishing Company 1981.*

Plus

Saving From Filler Substitution

$$\left\{\frac{30\ \text{Btu}}{\text{lb filler}} \times \frac{(65.0-58.6)\ \text{lb filler}}{8.5\ \text{lb waste}}\right\} = \frac{22.6\ \text{Btu}}{\text{lb waste}}$$

Less

Energy To Process Waste 422 Btu/lb

Energy to Mix and Pump 50 Btu/lb

(Electrical and heat energy have been combined in both processes.)

The net energy saving per pound of waste is, then, 3998 Btu.

The annual national energy saving was calculated from the 80MM squares of shingles weighing 220 pounds per each square and a 5 percent waste rate.

$$\frac{80{,}000{,}000\ \text{squares}}{\text{year}} \times \frac{220\ \text{lb}}{\text{square}} \times \frac{0.05\ \text{lb waste}}{\text{lb}} \times \frac{3998\ \text{Btu}}{\text{lb waste}}$$

3.5×10^{12} Btu is the annual energy saving.

Analysis

The ratio of net recovered energy (4470 Btu) to energy expense (472 Btu) was 9.5, which is a very impressive figure. The ratio would change only slightly if factory granule surfaced roll roofing were to be added to the calculation.

The 3.5×10^{12} Btu annual energy saving would be increased to about 3.7×10^{12} if the granule surfaced roll roofing were added to the calculation.

The potential maximum energy saving of 3.7×10^{12} Btu per year would require that **all** roofing factories recycle their waste. One hundred percent adoption of a new technology might not occur in the near future. However, the projected cost savings and return on investment are very attractive and should encourage all roofing factories to give favorable consideration to waste recycling. The prior Doe study[14] estimated that at least 90 percent implementation would occur based on similar financial projections. A strong technology transfer program will help to ensure this level of implementation which would then yield an actual annual energy saving of 3.7×10^{12} Btu/yr x 0.90 = 3.3×10^{12} Btu per year.

---

[14] *Shepherd; Op cit.*

FUTURE INVESTIGATIONS

Successful completion of the commercial scale research described in this report should set the stage for additional research leading to the commercial recycling of field waste. Field waste is worn out roofing which is now hauled to landfills. This waste represents a far greater energy resource than factory waste, with worn out shingles alone offering about five of the over $7x10^{13}$ Btu annual potential.

There are several problems which must be addressed in research leading to the commercial recycling of field waste.

> Worn out roofing is mixed with other waste removed from roofs. Sheet metal flashing, wood, insulation and other materials must be separated from the roofing waste.
>
> Worn out roofing contains nails. A process must be developed to dislodge the nails and remove them from the roofing waste.
>
> Much of the old fashioned roofing being removed from roofs was made on a web of paper instead of fiber glass. Bird, Inc.'s independent research was reported to show that the process described in this report would not adequately break down the paper fibers for recycling. Process research is needed to solve this problem.
>
> The asphalt in old roofs is weathered and brittle. Previous research showed that a rejuvenating agent is needed.[15] Formulation research should address this requirement.
>
> Adding paper fibers and weathered asphalt to the asphalt used to make new shingles may be perceived by some to offer a risk that shingles made this way may not perform acceptably. Extensive quality testing will be needed to convince the roofing industry that this technology offers no risks.

----

[15] *Shepherd; Op cit; 29.*

CONCLUSIONS

1. Commercial scale, factory experiments showed that it is technically and financially feasible to add up to 20% factory waste from glass fiber asphalt shingles to the filled asphalt coating composition used to manufacture new glass fiber shingles.

2. Shingles made with asphalt composition containing 5%, 10%, and 20% waste were equal to baseline, waste-free shingles in physical properties and performance - related test results.

3. The granular material, glass mat, and plastic film in shingle waste was reduced to a -70 mesh powder when the waste was processed through a Banbury^R Mixer and roll mill.

4. Adding shingle waste to the asphalt coating composition had no measured or observed effect on the shingle manufacturing process.

5. It may be possible to add significantly more than 20% waste to the asphalt. This is of no practical import with factory waste which can be totally consumed at an average substitution ratio of about 8.5%.

6. Equipment to process factory waste is commercially available.

7. The financial analysis showed that recycling factory waste will be attractive and profitable to most shingle manufacturing facilities. A savings range of $70 - $150 per ton of waste has been projected.

8. It appears that all of a factory's fiber glass shingle and granule surfaced roll roofing waste can and should be recycled.

9. Implementation of factory waste recycling has the potential to reduce the nation's energy requirements by 3.3×10^{12} Btu annually.

10. Implementation of factory waste recycling has the potential to reduce the nation's landfill load by about 500,000 cubic yards per year.

11. It is anticipated that the substitution of factory waste for virgin materials could be implemented in the near term based on the development of a commercial process by Bird, Inc.

12. Field waste (worn out roofing) incorporation into new roofing requires additional research to study the removal of nails and trash, weathering, formulation, treatment of paper fiber felt, and field performance.

RECOMMENDATIONS

1. It is recommended that an effective technology transfer effort be made to educate all asphalt roofing manufacturers about the results of this research. This effort was started with a presentation to the Asphalt Roofing Manufacturers Association and will be continued by Bird Roofing.

2. It is recommended that the benefits of implementing the results of this research ---

   financial

   energy conservation

   landfill load reduction

   be publicized to obtain support of all sectors for implementing the recycling of factory roofing waste. The presentation mentioned above was one step. Publication of this report by DOE is another. Publicity releases to the news and energy media would be useful additional steps. Technical articles in pertinent magazines such as RSI are also suggested.

APPENDIX A

WASTE PROCESSING DATA

#32 — 191

#33 — 194

#34 — 207

6 Dec 88

Batch J

AUTOMATIC REPORT GENERATION

MESSAGE NOT FOUND
MESSAGE NOT FOUND
FARREL F80 MIXER CONTROL

DATE 009:030:088
TIME 010:046:025

COMPOUND NUMBER 002
BATCH NUMBER 006

	TIME MM:SS	TEMP °F	ENERGY KWH*100	TORQUE (FT-LB)/100	ROTOR SPEED	RAM PRESSURE
EVENT.....1	000:000	133	000	000	035	079
EVENT.....2	001:028	190	175	050	036	075
EVENT.....3	000:000	000	000	000	000	000
EVENT.....4	000:000	000	000	000	000	000
EVENT.....5	000:000	000	000	000	000	000
EVENT.....6	000:000	000	000	000	000	000
EVENT.....7	000:000	000	000	000	000	000
EVENT.....8	000:000	000	000	000	000	000
EVENT.....9	000:000	000	000	000	000	000

STANDARD MIX TIME VALUES
COMPOUND NO :002
BATCH NO: 006

	ON EVENT	ON ACKNOWLEDGEMENT
EVENT...1	000:000	001:018
EVENT...2	002:052	000:000
EVENT...3	000:000	000:000
EVENT...4	000:000	000:000
EVENT...5	000:000	000:000
EVENT...6	000:000	000:000
EVENT...7	000:000	000:000
EVENT...8	000:000	000:000
EVENT...9	000:000	000:000

TOTAL MIXING TIME 002:052

FARREL F80 MIXER CONTROL

DATE 009:030:088
TIME 011:046:041

COMPOUND NUMBER 002
BATCH NUMBER 005

	TIME MM:SS	TEMP 'F	ENERGY KWH*100	TORQUE (FT-LB)/100	ROTOR SPEED	RAM PRESSURE
EVENT.....1	000:000	189	000	000	036	079
EVENT.....2	000:000	190	001	000	035	079
EVENT.....3	000:000	000	000	000	000	000
EVENT.....4	000:000	000	000	000	000	000
EVENT.....5	000:000	000	000	000	000	000
EVENT.....6	000:000	000	000	000	000	000
EVENT.....7	000:000	000	000	000	000	000
EVENT.....8	000:000	000	000	000	000	000
EVENT.....9	000:000	000	000	000	000	000

VOID

STANDARD MIX TIME VALUES
COMPOUND NO :002
BATCH NO: 005

	ON EVENT	ON ACKNOWLEDGEMENT
EVENT...1	000:001	000:000
EVENT...2	000:003	000:000
EVENT...3	000:000	000:000
EVENT...4	000:000	000:000
EVENT...5	000:000	000:000
EVENT...6	000:000	000:000
EVENT...7	000:000	000:000
EVENT...8	000:000	000:000
EVENT...9	000:[illegible]	[illegible]

TOTAL MIXING TIME 000:003

FARREL F80 MIXER CONTROL

#6

DATE 009:030:088
TIME 011:057:031

COMPOUND NUMBER 002
BATCH NUMBER 004

	TIME MM:SS	TEMP °F	ENERGY KWH*100	TORQUE (FT-LB)/100	ROTOR SPEED	RAM PRESSURE
EVENT.....1	000:000	185	000	000	035	079
EVENT.....2	001:057	199	175	033	035	079
EVENT.....3	000:000	000	000	000	000	000
EVENT.....4	000:000	000	000	000	000	000
EVENT.....5	000:000	000	000	000	000	000
EVENT.....6	000:000	000	000	000	000	000
EVENT.....7	000:000	000	000	000	000	000
EVENT.....8	000:000	000	000	000	000	000
EVENT.....9	000:000	000	000	000	000	000

STANDARD MIX TIME VALUES
COMPOUND NO :002
BATCH NO: 004

	ON EVENT	ON ACKNOWLEDGEMENT
EVENT...1	000:001	001:007
EVENT...2	003:013	000:000
EVENT...3	000:000	000:000
EVENT...4	000:000	000:000
EVENT...5	000:000	000:000
EVENT...6	000:000	000:000
EVENT...7	000:000	000:000
EVENT...8	000:000	000:000
EVENT...9	000:000	000:000

TOTAL MIXING TIME 003:013

FARREL F80 MIXER CONTROL

#7

DATE 009:030:083
TIME 013:045:036

COMPOUND NUMBER 002
BATCH NUMBER 003

	TIME MM:SS	TEMP °F	ENERGY KWH*100	TORQUE (FT-LB)/100	ROTOR SPEED	RAM PRESSURE
EVENT.....1	000:000	193	000	001	035	079
EVENT.....2	002:[illegible]	175	175	[illegible]	035	079

EVENT.....3	000:000	000	000	000	000	000
EVENT.....4	000:000	000	000	000	000	000
EVENT.....5	000:000	000	000	000	000	000
EVENT.....6	000:000	000	000	000	000	000
EVENT.....7	000:000	000	000	000	000	000
EVENT.....8	000:000	000	000	000	000	000
EVENT.....9	000:000	000	000	000	000	000

STANDARD MIX TIME VALUES
COMPOUND NO :002
BATCH NO: 003

	ON EVENT	ON ACKNOWLEDGEMENT
EVENT...1	000:000	000:027
EVENT...2	002:035	000:000
EVENT...3	000:000	000:000
EVENT...4	000:000	000:000
EVENT...5	000:000	000:000
EVENT...6	000:000	000:000
EVENT...7	000:000	000:000
EVENT...8	000:000	000:000
EVENT...9	000:000	000:000

TOTAL MIXING TIME 002:035

FARREL F80 MIXER CONTROL

#8

DATE 009:030:088
TIME 015:008:059

COMPOUND NUMBER 002
BATCH NUMBER 002

	TIME MM:SS	TEMP °F	ENERGY KWH*100	TORQUE (FT-LB)/100	ROTOR SPEED	RAM PRESSURE
EVENT.....1	000:000	177	000	000	035	079
EVENT.....2	001:008	183	175	059	036	079
EVENT.....3	000:000	000	000	000	000	000
EVENT.....4	000:000	000	000	000	000	000
EVENT.....5	000:000	000	000	000	000	000
EVENT.....6	000:000	000	000	000	000	000
EVENT.....7	000:000	000	000	000	000	000
EVENT.....8	000:000	000	000	000	000	000
EVENT.....9	000:000	000	000	000	000	000

STANDARD MIX TIME VALUES
COMPOUND NO :002
BATCH NO: 002

ON EVENT ON ACKNOWLEDGEMENT

EVENT...1	000:001	001:014
EVENT...2	002:024	000:000
EVENT...3	000:000	000:000
EVENT...4	000:000	000:000
EVENT...5	000:000	000:000
EVENT...6	000:000	000:000
EVENT...7	000:000	000:000
EVENT...8	000:000	000:000
EVENT...9	000:000	000:000

TOTAL MIXING TIME 002:024

FARREL F80 MIXER CONTROL #9

DATE 009:030:088
TIME 016:028:027

COMPOUND NUMBER 002
BATCH NUMBER 001

	TIME MM:SS	TEMP F	ENERGY KWH*100	TORQUE (FT-LB)/100	ROTOR SPEED	RAM PRESSURE
EVENT.....1	000:000	244	000	000	035	079
EVENT.....2	001:038	199	185	062	036	079
EVENT.....3	000:000	000	000	000	000	000
EVENT.....4	000:000	000	000	000	000	000
EVENT.....5	000:000	000	000	000	000	000
EVENT.....6	000:000	000	000	000	000	000
EVENT.....7	000:000	000	000	000	000	000
EVENT.....8	000:000	000	000	000	000	000
EVENT.....9	000:000	000	000	000	000	000

STANDARD MIX TIME VALUES
COMPOUND NO :002
BATCH NO: 001

	ON EVENT	ON ACKNOWLEDGEMENT
EVENT...1	000:001	000:022
EVENT...2	002:002	000:000
EVENT...3	000:000	000:000
EVENT...4	000:000	000:000
EVENT...5	000:000	000:000
EVENT...6	000:000	000:000
EVENT...7	000:000	000:000
EVENT...8	000:000	000:000
EVENT...9	000:000	000:000

TOTAL MIXING TIME 002:002

MESSAGE NOT FOUND
FARREL F80 MIXER CONTROL

#10

DATE 012:012:088
TIME 009:006:046

FINGERS

COMPOUND NUMBER 002
BATCH NUMBER 009

	TIME MM:SS	TEMP °F	ENERGY KWH*100	TORQUE (FT-LB)/100	ROTOR SPEED	RAM PRESSURE
EVENT.....1	000:000	119	000	000	034	079
EVENT.....2	001:019	183	135	054	036	079
EVENT.....3	000:000	000	000	000	000	000
EVENT.....4	000:000	000	000	000	000	000
EVENT.....5	000:000	000	000	000	000	000
EVENT.....6	000:000	000	000	000	000	000
EVENT.....7	000:000	000	000	000	000	000
EVENT.....8	000:000	000	000	000	000	000
EVENT.....9	000:000	000	000	000	000	000

STANDARD MIX TIME VALUES
COMPOUND NO :002
BATCH NO: 009

	ON EVENT	ON ACKNOWLEDGEMENT
EVENT...1	000:000	001:027
EVENT...2	002:047	000:000
EVENT...3	000:000	000:000
EVENT...4	000:000	000:000
EVENT...5	000:000	000:000
EVENT...6	000:000	000:000
EVENT...7	000:000	000:000
EVENT...8	000:000	000:000
EVENT...9	000:000	000:000

TOTAL MIXING TIME 002:047

FARREL F80 MIXER CONTROL

#12

DATE 012:012:088
TIME 010:027:023

COMPOUND NUMBER 002
BATCH NUMBER 008

SINGLES

	TIME MM:SS	TEMP °F	ENERGY KWH*100	TORQUE (FT-LB)/100	ROTOR SPEED	RAM PRESSURE
EVENT.....1	000:000	247	000	000	034	079
EVENT.....2	001:002	193	185	086	035	079
EVENT.....3	000:000	000	000	000	000	000
EVENT.....4	000:000	000	000	000	000	000
EVENT.....5	000:000	000	000	000	000	000
EVENT.....6	000:000	000	000	000	000	000
EVENT.....7	000:000	000	[illegible]	000	[illegible]	000

EVENT.....8	000:000	000	000	000	000	000
EVENT.....9	000:000	000	000	000	000	000

STANDARD MIX TIME VALUES
COMPOUND NO :002
BATCH NO: 008

	ON EVENT	ON ACKNOWLEDGEMENT
EVENT...1	000:000	001:029
EVENT...2	002:032	000:000
EVENT...3	000:000	000:000
EVENT...4	000:000	000:000
EVENT...5	000:000	000:000
EVENT...6	000:000	000:000
EVENT...7	000:000	000:000
EVENT...8	000:000	000:000
EVENT...9	000:000	000:000

TOTAL MIXING TIME 002:032

FARREL F80 MIXER CONTROL

DATE 012:012:088
TIME 010:053:043

COMPOUND NUMBER 002
BATCH NUMBER 007

	TIME MM:SS	TEMP °F	ENERGY KWH*100	TORQUE (FT-LB)/100	ROTOR SPEED	RAM PRESSURE
EVENT.....1	000:000	216	000	000	035	079
EVENT.....2	000:053	194	135	069	035	079
EVENT.....3	000:000	000	000	000	000	000
EVENT.....4	000:000	000	000	000	000	000
EVENT.....5	000:000	000	000	000	000	000
EVENT.....6	000:000	000	000	000	000	000
EVENT.....7	000:000	000	000	000	000	000
EVENT.....8	000:000	000	000	000	000	000
EVENT.....9	000:000	000	000	000	000	000

#17 SHINGLE

STANDARD MIX TIME VALUES
COMPOUND NO :002
BATCH NO: 007

	ON EVENT	ON ACKNOWLEDGEMENT
EVENT...1	000:000	001:053
EVENT...2	002:048	000:000
EVENT...3	000:000	000:000
EVENT...4	000:000	000:000
EVENT...5	000:000	000:000

EVENT...6	000:000	000:000
EVENT...7	000:000	000:000
EVENT...8	000:000	000:000
EVENT...9	000:000	000:000

TOTAL MIXING TIME 002:048

FARREL F80 MIXER CONTROL

DATE 012:012:088
TIME 011:029:023

COMPOUND NUMBER 002
BATCH NUMBER 006

#14 Shingle

	TIME MM:SS	TEMP 'F	ENERGY KWH*100	TORQUE (FT-LB)/100	ROTOR SPEED	RAM PRESSURE
EVENT.....1	000:000	195	000	000	035	079
EVENT.....2	000:055	193	185	086	036	079
EVENT.....3	000:000	000	000	000	000	000
EVENT.....4	000:000	000	000	000	000	000
EVENT.....5	000:000	000	000	000	000	000
EVENT.....6	000:000	000	000	000	000	000
EVENT.....7	000:000	000	000	000	000	000
EVENT.....8	000:000	000	000	000	000	000
EVENT.....9	000:000	000	000	000	000	000

STANDARD MIX TIME VALUES
COMPOUND NO :002
BATCH NO: 006

	ON EVENT	ON ACKNOWLEDGEMENT
EVENT...1	000:000	001:051
EVENT...2	002:048	000:000
EVENT...3	000:000	000:000
EVENT...4	000:000	000:000
EVENT...5	000:000	000:000
EVENT...6	000:000	000:000
EVENT...7	000:000	000:000
EVENT...8	000:000	000:000
EVENT...9	000:000	000:000

TOTAL MIXING TIME 002:048

FARREL F80 MIXER CONTROL

DATE 012:012:088
TIME 012:048:017

COMPOUND NUMBER 002
BATCH NUMBER 005

#15 Shingle

TIME TEMP ENERGY TORQUE ROTOR

	MM:SS	°F	KWH*100	(FT-LB)/100	SPEED	PRESSURE
EVENT.....1	000:000	183	000	000	035	079
EVENT.....2	001:018	193	185	070	035	079
EVENT.....3	000:000	000	000	000	000	000
EVENT.....4	000:000	000	000	000	000	000
EVENT.....5	000:000	000	000	000	000	000
EVENT.....6	000:000	000	000	000	000	000
EVENT.....7	000:000	000	000	000	000	000
EVENT.....8	000:000	000	000	000	000	000
EVENT.....9	000:000	000	000	000	000	000

STANDARD MIX TIME VALUES
COMPOUND NO 002
BATCH NO: 003

	ON EVENT	ON ACKNOWLEDGEMENT
EVENT...1	000:001	001:024
EVENT...2	002:044	000:000
EVENT...3	000:000	000:000
EVENT...4	000:000	000:000
EVENT...5	000:000	000:000
EVENT...6	000:000	000:000
EVENT...7	000:000	000:000
EVENT...8	000:000	000:000
EVENT...9	000:000	000:000

TOTAL MIXING TIME 002:044

FARREL F80 MIXER CONTROL

DATE 012:012:088
TIME 013:014:033

COMPOUND NUMBER 002
BATCH NUMBER 004

#16 Shingle

	TIME MM:SS	TEMP °F	ENERGY KWH*100	TORQUE (FT-LB)/100	ROTOR SPEED	RAM PRESSURE
EVENT.....1	000:000	179	000	000	035	079
EVENT.....2	000:057	191	186	089	036	079
EVENT.....3	000:000	000	000	000	000	000
EVENT.....4	000:000	000	000	000	000	000
EVENT.....5	000:000	000	000	000	000	000
EVENT.....6	000:000	000	000	000	000	000
EVENT.....7	000:000	000	000	000	000	000
EVENT.....8	000:000	000	000	000	000	000
EVENT.....9	000:000	000	000	000	000	000

STANDARD MIX TIME VALUES
COMPOUND NO [illegible]

BATCH NO: [illegible]

	ON EVENT	ON ACKNOWLEDGEMENT
EVENT...1	000:000	001:031
EVENT...2	002:000	000:000
EVENT...3	000:000	000:000
EVENT...4	000:000	000:000
EVENT...5	000:000	000:000
EVENT...6	000:000	000:000
EVENT...7	000:000	000:000
EVENT...8	000:000	000:000
EVENT...9	000:000	000:000

TOTAL MIXING TIME 002:030

FARREL FEU MIXER CONTROL

[illegible]12:088
[illegible]3:038:004

COMPOUND NUMBER [illegible]
BATCH NUMBER [illegible]

#17 Shingle

	TIME [illegible]	TEMP	[illegible]*100	TORQUE (FT-LB)/100	ROTOR SPEED	RAM PRESSURE
EVENT.....1	[illegible]	[illegible]77	000	000	034	079
[illegible]	000:053	190	185	093	036	079
[illegible]3	000:000	000	000	000	000	000
EVENT.....4	000:000	000	000	000	000	000
EVENT.....5	000:000	000	000	000	000	000
EVENT.....6	000:000	000	000	000	000	000
EVENT.....7	000:000	000	000	000	000	000
EVENT.....8	000:000	000	000	000	000	000
EVENT.....9	000:000	000	000	000	000	000

STANDARD MIX TIME VALUES
COMPOUND NO :002
BATCH NO: 003

	ON EVENT	ON ACKNOWLEDGEMENT
EVENT...1	000:000	001:048
EVENT...2	002:043	000:000
EVENT...3	000:000	000:000
EVENT...4	000:000	000:000
EVENT...5	000:000	000:000
EVENT...6	000:000	000:000
EVENT...7	000:000	000:000
EVENT...8	000:000	000:000
EVENT...9	000:000	000:000

TOTAL MIXING TIME 002:043

#18 Shingle

FARREL F80 MIXER CONTROL

DATE 012:012:086
TIME 014:004:012

COMPOUND NUMBER 002
BATCH NUMBER 002

	TIME MM:SS	TEMP 'F	ENERGY KWH*100	TORQUE (FT-LB)/100	ROTOR SPEED	RAM PRESSURE
EVENT.....1	000:000	175	000	000	035	079
EVENT.....2	000:048	190	166	090	035	079
EVENT.....3	000:000	000	000	000	000	000
EVENT.....4	000:000	000	000	000	000	000
EVENT.....5	000:000	000	000	000	000	000
EVENT.....6	000:000	000	000	000	000	000
EVENT.....7	000:000	000	000	000	000	000
EVENT.....8	000:000	000	000	000	000	000
EVENT.....9	000:000	000	000	000	000	000

STANDARD MIX TIME VALUES
COMPOUND NO :002
BATCH NO: 002

	ON EVENT	ON ACKNOWLEDGEMENT
EVENT...1	000:000	001:055
EVENT...2	002:045	000:000
EVENT...3	000:000	000:000
EVENT...4	000:000	000:000
EVENT...5	000:000	000:000
EVENT...6	000:000	000:000
EVENT...7	000:000	000:000
EVENT...8	000:000	000:000
EVENT...9	000:000	000:000

TOTAL MIXING TIME 002:045

FARREL F80 MIXER CONTROL

DATE 012:012:088
TIME 014:031:005

COMPOUND NUMBER 002
BATCH NUMBER 001

	TIME MM:SS	TEMP 'F	ENERGY KWH*100	TORQUE (FT-LB)/100	ROTOR SPEED	RAM PRESSURE
EVENT.....1	000:000	174	000	000	035	079
EVENT.....2	000:055	187	185	093	035	079
EVENT.....3	000:000	000	000	000	000	000
EVENT.....4	000:000	000	000	000	000	000

#19 Shingle

EVENT.....5	000:000	000	000	000	000	000
EVENT.....6	000:000	000	000	000	000	000

EVENT.....7	000:000	000	000	000	000	000
EVENT.....8	000:000	000	000	000	000	000
EVENT.....9	000:000	000	000	000	000	000

STANDARD MIX TIME VALUES
COMPOUND NO :002
BATCH NO: 001

	ON EVENT	ON ACKNOWLEDGEMENT
EVENT...1	000:000	001:041
EVENT...2	002:038	000:000
EVENT...3	000:000	000:000
EVENT...4	000:000	000:000
EVENT...5	000:000	000:000
EVENT...6	000:000	000:000
EVENT...7	000:000	000:000
EVENT...8	000:000	000:000
EVENT...9	000:000	000:000

TOTAL MIXING TIME 002:038

FARREL F80 MIXER CONTROL

DATE 012:012:088
TIME 015:000:049

COMPOUND NUMBER 002
BATCH NUMBER 009

	TIME MM:SS	TEMP °F	ENERGY KWH*100	TORQUE (FT-LB)/100	ROTOR SPEED	RAM PRESSURE
EVENT.....1	000:000	173	000	000	034	079
EVENT.....2	000:054	187	185	102	036	079
EVENT.....3	000:000	000	000	000	000	000
EVENT.....4	000:000	000	000	000	000	000
EVENT.....5	000:000	000	000	000	000	000
EVENT.....6	000:000	000	000	000	000	000
EVENT.....7	000:000	000	000	000	000	000
EVENT.....8	000:000	000	000	000	000	000
EVENT.....9	000:000	000	000	000	000	000

20 Shingle

STANDARD MIX TIME VALUES
COMPOUND NO :002
BATCH NO: 009

	ON EVENT	ON ACKNOWLEDGEMENT
EVENT...1	000:001	001:024
EVENT...2	002:020	000:000
EVENT...3	000:000	000:000
EVENT...4	000:000	000:000

EVENT...5	000:000	000:000
EVENT...6	000:000	000:000
EVENT...7	000:000	000:000
EVENT...8	000:000	000:000
EVENT...9	000:000	000:000

TOTAL MIXING TIME 000:020

FARREL F80 MIXER CONTROL

DATE 012:012:088
TIME 015:030:049

COMPOUND NUMBER 002 #21 Shingle
BATCH NUMBER 008

	TIME MM:SS	TEMP °F	ENERGY KWH*100	TORQUE (FT-LB)/100	ROTOR SPEED	RAM PRESSURE
EVENT.....1	000:000	175	000	000	025	079
EVENT.....2	001:004	191	185	076	036	079
EVENT.....3	000:000	000	000	000	000	000
EVENT.....4	000:000	000	000	000	000	000
EVENT.....5	000:000	000	000	000	000	000
EVENT.....6	000:000	000	000	000	000	000
EVENT.....7	000:000	000	000	000	000	000
EVENT.....8	000:000	000	000	000	000	000
EVENT.....9	000:000	000	000	000	000	000

STANDARD MIX TIME VALUES
COMPOUND NO :002
BATCH NO: 008

	ON EVENT	ON ACKNOWLEDGEMENT
EVENT...1	000:001	001:040
EVENT...2	002:044	000:000
EVENT...3	000:000	000:000
EVENT...4	000:000	000:000
EVENT...5	000:000	000:000
EVENT...6	000:000	000:000
EVENT...7	000:000	000:000
EVENT...8	000:000	000:000
EVENT...9	000:000	000:000

TOTAL MIXING TIME 002:044

FARREL F80 MIXER CONTROL

DATE 012:012:088
TIME 009:015:042

COMPOUND NUMBER 002

BATCH NUMBER 007 #22 Shingle

	TIME MM:SS	TEMP °F	ENERGY KWH*100	TORQUE (FT-LB)/100	ROTOR SPEED	RAM PRESSURE
EVENT.....1	000:000	253	000	000	036	079
EVENT.....2	000:042	199	185	077	036	079
EVENT.....3	000:000	000	000	000	000	000
EVENT.....4	000:000	000	000	000	000	000
EVENT.....5	000:000	000	000	000	000	000
EVENT.....6	000:000	000	000	000	000	000
EVENT.....7	000:000	000	000	000	000	000
EVENT.....8	000:000	000	000	000	000	000
EVENT.....9	000:000	000	000	000	000	000

STANDARD MIX TIME VALUES
COMPOUND NO :002
BATCH NO: 007

	ON EVENT	ON ACKNOWLEDGEMENT
EVENT...1	000:000	001:046
EVENT...2	002:029	000:000
EVENT...3	000:000	000:000
EVENT...4	000:000	000:000
EVENT...5	000:000	000:000
EVENT...6	000:000	000:000
EVENT...7	000:000	000:000
EVENT...8	000:000	000:000
EVENT...9	000:000	000:000

TOTAL MIXING TIME 002:029

FARREL F80 MIXER CONTROL

DATE 012:012:088
TIME 009:041:057

COMPOUND NUMBER 002
BATCH NUMBER 006

	TIME MM:SS	TEMP °F	ENERGY KWH*100	TORQUE (FT-LB)/100	ROTOR SPEED	RAM PRESSURE
EVENT.....1	000:000	240	000	000	035	079
EVENT.....2	000:045	195	186	082	035	079
EVENT.....3	000:000	000	000	000	000	000
EVENT.....4	000:000	000	000	000	000	000
EVENT.....5	000:000	000	000	000	000	000
EVENT.....6	000:000	000	000	000	000	000
EVENT.....7	000:000	000	000	000	000	000
EVENT.....8	000:000	000	000	000	000	000
EVENT.....9	000:000	000	000	000	000	000

23 Shingle

STANDARD MIX TIME VALUES

COMPOUND NO :002
BATCH NO: 006

	ON EVENT	ON ACKNOWLEDGEMENT
EVENT...1	000:001	001:037
EVENT...2	002:024	000:000
EVENT...3	000:000	000:000
EVENT...4	000:000	000:000
EVENT...5	000:000	000:000
EVENT...6	000:000	000:000
EVENT...7	000:000	000:000
EVENT...8	000:000	000:000
EVENT...9	000:000	000:000

TOTAL MIXING TIME 002:024

FARREL F80 MIXER CONTROL

DATE 012:012:088
TIME 010:021:022

COMPOUND NUMBER 002
BATCH NUMBER 005

#24 R062

	TIME MM:SS	TEMP °F	ENERGY KWH*100	TORQUE (FT-LB)/100	ROTOR SPEED	RAM PRESSURE
EVENT.....1	000:000	205	000	000	036	079
EVENT.....2	001:013	197	185	062	035	079
EVENT.....3	000:000	000	000	000	000	000
EVENT.....4	000:000	000	000	000	000	000
EVENT.....5	000:000	000	000	000	000	000
EVENT.....6	000:000	000	000	000	000	000
EVENT.....7	000:000	000	000	000	[illegible]	000
EVENT.....8	000:000	000	000	000	[illegible]	000
EVENT.....9	000:000	000	000	[illegible]	000	[illegible]

STANDARD MIX TIME VALUES
COMPOUND NO :002
BATCH NO: 005

	ON EVENT	ON ACKNOWLEDGEMENT
EVENT...1	000:[illegible]	[illegible]:018
EVENT...2	[illegible]	000:000
EVENT...[illegible]	[illegible]	000:000
EVENT...4	[illegible]	[illegible]
EVENT...5	000:000	[illegible]
EVENT...6	000:000	[illegible]
EVENT...7	000:000	[illegible]
EVENT...8	000:[illegible]	[illegible]
EVENT...9	[illegible]	[illegible]

25 ROLL

					[illegible] SPEED	RAM PRESSURE
				000	035	079
			[illegible]55	063	035	079
			000	000	000	000
	[illegible]00:000	000	000	000	000	000
[illegible]	000:000	000	000	000	000	000
EVENT.....6	000:000	000	000	000	000	000
EVENT.....7	000:000	000	000	000	000	000
EVENT.....8	000:000	000	000	000	000	000
EVENT.....9	000:000	000	000	000	000	000

STANDARD MIX TIME VALUES
COMPOUND NO :002
BATCH NO: 004

	ON EVENT	ON ACKNOWLEDGEMENT
EVENT...1	000:001	001:012
EVENT...2	002:025	000:000
EVENT...3	000:000	000:000
EVENT...4	000:000	000:000
EVENT...5	000:000	000:000
EVENT...6	000:000	000:000
EVENT...7	000:000	000:000
EVENT...8	000:000	000:000
EVENT...9	000:000	000:000

TOTAL MIXING TIME 002:025

FARREL F80 MIXER CONTROL   DATE 012:012:088
                            TIME 011:017:037

#26 ROLL

COMPOUND NUMBER 002
BATCH NUMBER 003

	TIME MN:SS	TEMP 'F	ENERGY KWH*100	TORQUE (FT-LB)/100	ROTOR SPEED	RAM PRESSURE
EVENT.....1	000:000	185	000	000	035	079
EVENT.....2	001:006	195	185	069	036	079
EVENT.....3	000:000	000	000	000	000	000
EVENT.....4	000:000	000	000	000	000	000
EVENT.....5	000:000	000	000	000	000	000

EVENT.....6	000:000	000	000	000	000	000
EVENT.....7	000:000	000	000	000	000	000
EVENT.....8	000:000	000	000	000	000	000
EVENT.....9	000:000	000	000	000	000	000

STANDARD MIX TIME VALUES
COMPOUND NO :002
BATCH NO: 003

	ON EVENT	ON ACKNOWLEDGEMENT
EVENT...1	000:001	001:017
EVENT...2	002:024	000:000
EVENT...3	000:000	000:000
EVENT...4	000:000	000:000
EVENT...5	000:000	000:000
EVENT...6	000:000	000:000
EVENT...7	000:000	000:000
EVENT...8	000:000	000:000
EVENT...9	000:000	000:000

TOTAL MIXING TIME 002:024

FARREL F80 MIXER CONTROL
DATE 012:012:088
TIME 011:042:007

#27 Roll

COMPOUND NUMBER 002
BATCH NUMBER 002

	TIME MM:SS	TEMP °F°	ENERGY KWH*100	TORQUE (FT-LB)/100	ROTOR SPEED	RAM PRESSURE
EVENT.....1	000:000	178	000	000	035	079
EVENT.....2	000:059	193	185	072	036	079
EVENT.....3	000:000	000	000	000	000	000
EVENT.....4	000:000	000	000	000	000	000
EVENT.....5	000:000	000	000	000	000	000
EVENT.....6	000:000	000	000	000	000	000
EVENT.....7	000:000	000	000	000	000	000
EVENT.....8	000:000	000	000	000	000	000
EVENT.....9	000:000	000	000	000	000	000

STANDARD MIX TIME VALUES
COMPOUND NO :002
BATCH NO: 002

	ON EVENT	ON ACKNOWLEDGEMENT
EVENT...1	000:001	001:015
EVENT...2	002:016	000:000
EVENT...3	000:000	000:000

EVENT...4	000:000	000:000
EVENT...5	000:000	000:000
EVENT...6	000:000	000:000
EVENT...7	000:000	000:000
EVENT...8	000:000	000:000
EVENT...9	000:000	000:000

TOTAL MIXING TIME 002:016

FARREL F80 MIXER CONTROL

DATE 012:012:088
TIME 012:054:016

#28 ROLL

COMPOUND NUMBER 002
BATCH NUMBER 001

	TIME MM:SS	TEMP °F	ENERGY KWH*100	TORQUE (FT-LB)/100	ROTOR SPEED	RAM PRESSURE
EVENT.....1	000:000	176	000	000	034	079
EVENT.....2	000:059	193	165	071	036	079
EVENT.....3	000:000	000	000	000	000	000
EVENT.....4	000:000	000	000	000	000	000
EVENT.....5	000:000	000	000	000	000	000
EVENT.....6	000:000	000	000	000	000	000
EVENT.....7	000:000	000	000	000	000	000
EVENT.....8	000:000	000	000	000	000	000
EVENT.....9	000:000	000	000	000	000	000

STANDARD MIX TIME VALUES
COMPOUND NO :002
BATCH NO: 001

	ON EVENT	ON ACKNOWLEDGEMENT
EVENT...1	000:000	001:0[illegible]8
EVENT...2	002:019	000:000
EVENT...3	000:000	000:000
EVENT...4	000:000	000:000
EVENT...5	000:000	000:000
EVENT...6	000:000	000:000
EVENT...7	000:000	000:000
EVENT...8	000:000	000:000
EVENT...9	000:000	000:000

TOTAL MIXING TIME 002:019

FARREL F80 MIXER CONTROL

DATE 012:012:088
TIME 013:017:058

#29 ROLL

COMPOUND NUMBER 002
BATCH NUMBER 009

	TIME MM:SS	TEMP °F	ENERGY KWH*100	TORQUE (FT-LB)/100	ROTOR SPEED	RAM PRESSURE
EVENT.....1	000:000	168	000	000	035	079
EVENT.....2	001:003	190	135	072	036	079
EVENT.....3	000:000	000	000	000	000	000
EVENT.....4	000:000	000	000	000	000	000
EVENT.....5	000:000	000	000	000	000	000
EVENT.....6	000:000	000	000	000	000	000
EVENT.....7	000:000	000	000	000	000	000
EVENT.....8	000:000	000	000	000	000	000
EVENT.....9	000:000	000	000	000	000	000

STANDARD MIX TIME VALUES
COMPOUND NO :002
BATCH NO: 009

	ON EVENT	ON ACKNOWLEDGEMENT
EVENT...1	000:001	001:020
EVENT...2	002:023	000:000
EVENT...3	000:000	000:000
EVENT...4	000:000	000:000
EVENT...5	000:000	000:000
EVENT...6	000:000	000:000
EVENT...7	000:000	000:000
EVENT...8	000:000	000:000
EVENT...9	000:000	000:000

TOTAL MIXING TIME 002:023

FARREL F80 MIXER CONF[illegible]

DATE 012:012:088
TIME 013:043:02[illegible]

COMPOUND [illegible]
BATCH [illegible]

#30 Roll

	[illegible] MM:SS	[illegible] °F	ENERGY KWH*100	TORQUE (FT-LB)/100	ROTOR SPEED	RAM PRESSURE
[illegible].....1	000:000	169	[illegible]	000	035	079
EVENT.....2	001:007	[illegible]	185	067	036	079
EVENT.....3	[illegible]	000	000	000	000	000
EVENT.....4	000:000	000	000	000	000	000
EVENT.....5	000:000	000	000	000	000	000
EVENT.....6	000:000	000	000	000	000	000
EVENT.....7	000:000	000	000	000	000	000
EVENT.....8	000:000	000	000	000	000	000
EVENT.....9	000:000	000	000	000	000	000

STANDARD MIX TIME VALUES
COMPOUND NO :002
BATCH NO: 008

	ON EVENT	ON ACKNOWLEDGEMENT
EVENT...1	000:000	001:010
EVENT...2	002:019	000:000
EVENT...3	000:000	000:000
EVENT...4	000:000	000:000
EVENT...5	000:000	000:000
EVENT...6	000:000	000:000
EVENT...7	000:000	000:000
EVENT...8	000:000	000:000
EVENT...9	000:000	000:000

TOTAL MIXING TIME 002:019

FARREL F80 MIXER CONTROL

DATE 012:012:088
TIME 014:005:046

COMPOUND NUMBER 002 #31 Roll
BATCH NUMBER 007

	TIME MM:SS	TEMP F	ENERGY KWH*100	TORQUE (FT-LB)/100	ROTOR SPEED	RAM PRESSURE
EVENT.....1	000:000	170	000	000	035	079
EVENT.....2	001:007	189	185	080	036	079
EVENT.....3	000:000	000	000	000	000	000
EVENT.....4	000:000	000	000	000	000	000
EVENT.....5	000:000	000	000	000	000	000
EVENT.....6	000:000	000	000	000	000	000
EVENT.....7	000:000	000	000	000	000	000
EVENT.....8	000:000	000	000	000	000	000
EVENT.....9	000:000	000	000	000	000	000

STANDARD MIX TIME VALUES
COMPOUND NO :002
BATCH NO: 007

	ON EVENT	ON ACKNOWLEDGEMENT
EVENT...1	000:001	000:052
EVENT...2	002:001	000:000
EVENT...3	000:000	000:000
EVENT...4	000:000	000:000
EVENT...5	000:000	000:000
EVENT...6	000:000	000:000
EVENT...7	000:000	000:000
EVENT...8	000:000	000:000
EVENT...9	000:000	000:000

002:001

FARREL F80 MIXER CONTROL

DATE 012:012:088
TIME 014:030:024

COMPOUND NUMBER 002 #32 Roll
BATCH NUMBER 006

	TIME MM:SS	TEMP 'F	ENERGY KWH*100	TORQUE (FT-LB)/100	ROTOR SPEED	RAM PRESSURE
EVENT.....1	000:000	166	000	000	035	079
EVENT.....2	001:011	191	185	070	036	079
EVENT.....3	000:000	000	000	000	000	000
EVENT.....4	000:000	000	000	000	000	000
EVENT.....5	000:000	000	000	000	000	000
EVENT.....6	000:000	000	000	000	000	000
EVENT.....7	000:000	000	000	000	000	000
EVENT.....8	000:000	000	000	000	000	000
EVENT.....9	000:000	000	000	000	000	000

STANDARD MIX TIME VALUES
COMPOUND NO :002
BATCH NO: 006

	ON EVENT	ON ACKNOWLEDGEMENT
EVENT...1	000:001	000:056
EVENT...2	002:009	000:000
EVENT...3	000:000	000:000
EVENT...4	000:000	000:000
EVENT...5	000:000	000:000
EVENT...6	000:000	000:000
EVENT...7	000:000	000:000
EVENT...8	000:000	000:000
EVENT...9	000:000	000:000

TOTAL MIXING TIME 002:009

FARREL F80 MIXER CONTROL

DATE 012:012:088
TIME 014:055:028

COMPOUND NUMBER 002 #33 Roll
BATCH NUMBER 005

	TIME MM:SS	TEMP 'F	ENERGY KWH*100	TORQUE (FT-LB)/100	ROTOR SPEED	RAM PRESSURE
EVENT.....1	000:000	168	000	000	035	079
EVENT.....2	001:011	194	191	072	036	079
EVENT.....3	000:000	000	000	000	000	000
EVENT.....4	000:000	000	000	000	000	000

EVENT.....5	000:000	000	000	000	000	000
EVENT.....6	000:000	000	000	000	000	000
EVENT.....7	000:000	000	000	000	000	000
EVENT.....8	000:000	000	000	000	000	000
EVENT.....9	000:000	000	000	000	000	000

STANDARD MIX TIME VALUES
COMPOUND NO :002
BATCH NO: 005

	ON EVENT	ON ACKNOWLEDGEMENT
EVENT...1	000:000	000:045
EVENT...2	001:057	000:000
EVENT...3	000:000	000:000
EVENT...4	000:000	000:000
EVENT...5	000:000	000:000
EVENT...6	000:000	000:000
EVENT...7	000:000	000:000
EVENT...8	000:000	000:000
EVENT...9	000:000	000:000

TOTAL MIXING TIME 001:057

FARREL F80 MIXER CONTROL

DATE 012:012:088
TIME 015:021:024

#34 SHINGLE

COMPOUND NUMBER 002
BATCH NUMBER 004

	TIME MM:SS	TEMP 'F	ENERGY KWH*100	TORQUE (FT-LB)/100	ROTOR SPEED	RAM PRESSURE
EVENT.....1	000:000	167	000	000	036	079
EVENT.....2	002:013	207	210	036	036	079
EVENT.....3	000:000	000	000	000	000	000
EVENT.....4	000:000	000	000	000	000	000
EVENT.....5	000:000	000	000	000	000	000
EVENT.....6	000:000	000	000	000	000	000
EVENT.....7	000:000	000	000	000	000	000
EVENT.....8	000:000	000	000	000	000	000
EVENT.....9	000:000	000	000	000	000	000

12-9-88

STANDARD MIX TIME VALUES
COMPOUND NO :002
BATCH NO: 004

	ON EVENT	ON ACKNOWLEDGEMENT
EVENT...1	000:001	000:055
EVENT...2	003:0[illegible]7	000:000

EVENT...3	000:000	000:000
EVENT...4	000:000	000:000
EVENT...5	000:000	000:000
EVENT...6	000:000	000:000
EVENT...7	000:000	000:000
EVENT...8	000:000	000:000
EVENT...9	000:000	000:000

TOTAL MIXING TIME 003:007

#35.

FARREL F80 MIXER CONTROL

DATE 012:012:088
TIME 009:011:032

COMPOUND NUMBER 002
BATCH NUMBER 003

	TIME MM:SS	TEMP 'F	ENERGY KWH*100	TORQUE (FT-LB)/100	ROTOR SPEED	RAM PRESSURE
EVENT.....1	000:000	153 205°F	000	000	034	079
EVENT.....2	000:000	000	000	000	000	000
EVENT.....3	000:000	000	000	000	000	000
EVENT.....4	000:000	000	000	000	000	000
EVENT.....5	000:000	000	000	000	000	000
EVENT.....6	000:000	000	000	000	000	000
EVENT.....7	000:000	000	000	000	000	000
EVENT.....8	000:000	000	000	000	000	000
EVENT.....9	000:000	000	000	000	000	000

STANDARD MIX TIME VALUES
COMPOUND NO :002
BATCH NO: 003

	ON EVENT	ON ACKNOWLEDGEMENT
EVENT...1	000:000	000:015
EVENT...2	000:000	000:000.
EVENT...3	000:000	000:000
EVENT...4	000:000	000:000
EVENT...5	000:000	000:000
EVENT...6	000:000	000:000
EVENT...7	000:000	000:000
EVENT...8	000:000	000:000
EVENT...9	000:000	000:000

TOTAL MIXING TIME 007:028

FARREL F80 MIXER CONTROL

DATE 012:012:088
TIME 009:051:054

#36

285°F

COMPOUND NUMBER 002

BATCH NUMBER 002

	TIME MM:SS	TEMP 'F	ENERGY KWH*100	TORQUE (FT-LB)/100	ROTOR SPEED	RAM PRESSURE
EVENT.....1	000:000	188	[illegible]	[illegible]	035	079
EVENT.....2	2:45	[illegible]	[illegible]	[illegible]	000	000
EVENT.....3	[illegible]	[illegible]	[illegible]	000	000	000
EVENT.....4	[illegible]	[illegible]	000	000	000	000
EVENT.....5	[illegible]	000	000	000	000	000
EVENT.....6	000:000	000	000	000	000	000
EVENT.....7	000:000	000	000	000	000	000
EVENT.....8	000:000	000	000	000	000	000
EVENT.....9	000:000	000	000	000	000	000

STANDARD MIX TIME VALUES
COMPOUND NO :002
BATCH NO: 002

	ON EVENT	ON ACKNOWLEDGEMENT
EVENT...1	000:000	000:027
EVENT...2	000:000	000:000
EVENT...3	000:000	000:000
EVENT...4	000:000	000:000
EVENT...5	000:000	000:000
EVENT...6	000:000	000:000
EVENT...7	000:000	000:000
EVENT...8	000:000	000:000
EVENT...9	000:000	000:000

2:17 RuPz
2'45" total

TOTAL MIXING TIME 002:045

FARREL F80 MIXER CONTROL

DATE 012:012:088
TIME 010:018:048

COMPOUND NUMBER 002 #37 Shivg/E
BATCH NUMBER 001

	TIME MM:SS	TEMP 'F	ENERGY KWH*100	TORQUE (FT-LB)/100	ROTOR SPEED	RAM PRESSURE
EVENT.....1	000:000	184	000	000	036	079
EVENT.....2	001:013	185	165	071	036	079
EVENT.....3	000:000	000	000	000	000	000
EVENT.....4	000:000	000	000	000	000	000
EVENT.....5	000:000	000	000	000	000	000
EVENT.....6	000:000	000	000	000	000	000
EVENT.....7	000:000	000	000	000	000	000
EVENT.....8	000:000	000	000	000	000	000
EVENT.....9	000:000	000	000	000	000	000

STANDARD MIX TIME VALUES
COMPOUND NO :002
BATCH NO: 001

	ON EVENT	ON ACKNOWLEDGEMENT
EVENT...1	000:001	000:028
EVENT...2	001:041	000:000
EVENT...3	000:000	000:000
EVENT...4	000:000	000:000
EVENT...5	000:000	000:000
EVENT...6	000:000	000:000
EVENT...7	000:000	000:000
EVENT...8	000:000	000:000
EVENT...9	000:000	000:000

TOTAL MIXING TIME 001:041

FARREL F80 MIXER CONTROL

DATE 012:012:088
TIME 010:046:015

COMPOUND NUMBER 002
BATCH NUMBER 009

38 SHiNGle

	TIME MM:SS	TEMP 'F	ENERGY KWH*100	TORQUE (FT-LB)/100	ROTOR SPEED	RAM PRESSURE
EVENT.....1	000:000	174	000	000	035	079
EVENT.....2	001:012	175	170	068	035	079
EVENT.....3	000:000	000	000	000	000	000
EVENT.....4	000:000	000	000	000	000	000
EVENT.....5	000:000	000	000	000	000	000
EVENT.....6	000:000	000	000	000	000	000
EVENT.....7	000:000	000	000	000	000	000
EVENT.....8	000:000	000	000	000	000	000
EVENT.....9	000:000	000	000	000	000	000

STANDARD MIX TIME VALUES
COMPOUND NO :002
BATCH NO: 009

	ON EVENT	ON ACKNOWLEDGEMENT
EVENT...1	000:000	000:045
EVENT...2	001:058	000:000
EVENT...3	000:000	000:000
EVENT...4	000:000	000:000
EVENT...5	000:000	000:000
EVENT...6	000:000	000:000
EVENT...7	000:000	000:000
EVENT...8	000:000	000:000
EVENT...9	000:000	000:000

TOTAL MIXING TIME 001:058

FARREL F80 MIXER CONTROL

DATE 012:012:088
TIME 011:009:059

#39 SHiNGle

COMPOUND NUMBER 002
BATCH NUMBER 008

	TIME MM:SS	TEMP 'F	ENERGY KWH*100	TORQUE (FT-LB)/100	ROTOR SPEED	RAM PRESSURE
EVENT.....1	000:000	174	000	000	035	079
EVENT.....2	001:034	190	180	050	036	079
EVENT.....3	000:000	000	000	000	000	000
EVENT.....4	000:000	000	000	000	000	000
EVENT.....5	000:000	000	000	000	000	000
EVENT.....6	000:000	000	000	000	000	000
EVENT.....7	000:000	000	000	000	000	000
EVENT.....8	000:000	000	000	000	000	000
EVENT.....9	000:000	000	000	000	000	000

STANDARD MIX TIME VALUES
COMPOUND NO :002
BATCH NO: 008

	ON EVENT	ON ACKNOWLEDGEMENT
EVENT...1	000:001	000:033
EVENT...2	002:008	000:000
EVENT...3	000:000	000:000
EVENT...4	000:000	000:000
EVENT...5	000:000	000:000
EVENT...6	000:000	000:000
EVENT...7	000:000	000:000
EVENT...8	000:000	000:000
EVENT...9	000:000	000:000

TOTAL MIXING TIME 002:008

FARREL F80 MIXER CONTROL

DATE 012:012:088
TIME 011:033:031

#40 SHiNGle

COMPOUND NUMBER 002
BATCH NUMBER 007

	TIME MM:SS	TEMP 'F	ENERGY KWH*100	TORQUE (FT-LB)/100	ROTOR SPEED	RAM PRESSURE
EVENT.....1	000:000	175	000	000	035	079
EVENT.....2	001:026	188	180	058	036	079
EVENT.....3	000:000	000	000	000	000	000

EVENT.....4	000:000	000	000	000	000	000
EVENT.....5	000:000	000	000	000	000	000
EVENT.....6	000:000	000	000	000	000	000
EVENT.....7	000:000	000	000	000	000	000
EVENT.....8	000:000	000	000	000	000	000
EVENT.....9	000:000	000	000	000	000	000

STANDARD MIX TIME VALUES
COMPOUND NO :002
BATCH NO: 007

	ON EVENT	ON ACKNOWLEDGEMENT
EVENT...1	000:000	000:033
EVENT...2	002:000	000:000
EVENT...3	000:000	000:000
EVENT...4	000:000	000:000
EVENT...5	000:000	000:000
EVENT...6	000:000	000:000
EVENT...7	000:000	000:000
EVENT...8	000:000	000:000
EVENT...9	000:000	000:000

TOTAL MIXING TIME 002:000

FARREL F80 MIXER CONTROL #40 [illegible]

DATE 012:012:088
TIME 012:039:016

COMPOUND NUMBER 002
BATCH NUMBER 006

	TIME MM:SS	TEMP F	ENERGY KWH*100	TORQUE (FT-LB)/100	ROTOR SPEED	RAM PRESSURE
EVENT.....1	000:000	168	000	000	035	079
EVENT.....2	001:039	194	180	050	036	079
EVENT.....3	000:000	000	000	000	000	000
EVENT.....4	000:000	000	000	000	000	000
EVENT.....5	000:000	000	000	000	000	000
EVENT.....6	000:000	000	000	000	000	000
EVENT.....7	000:000	000	000	000	000	000
EVENT.....8	000:000	000	000	000	000	000
EVENT.....9	000:000	000	000	000	000	000

STANDARD MIX TIME VALUES
COMPOUND NO :002
BATCH NO: 006

ON EVENT ON ACKNOWLEDGEMENT

EVENT ..1

EVENT...1	[illegible]	[illegible]
EVENT...3	000:000	000:000
EVENT...4	000:000	000:000
EVENT...5	000:000	000:000
EVENT...6	000:000	000:000
EVENT...7	000:000	000:000
EVENT...8	000:000	000:000
EVENT...9	000:000	000:000

TOTAL MIXING TIME 002:015

FARREL F80 MIXER CONTROL — DATE [illegible]:088 — TIME [illegible]:049

#42 SHINGLE

COMPOUND NUMBER [illegible]
BATCH NUMBER [illegible]

	TIME [illegible]	TEMP F	SHEAR [illegible]	TORQUE (FT-LB)/100	ROTOR SPEED	RAM PRESSURE
EVENT.....1	[illegible]	[illegible]	000	000	036	079
EVENT.....2	[illegible]:000	191	180	060	036	079
EVENT.....3	000:000	000	000	000	[illegible]	[illegible]
EVENT.....4	000:000	000	000	000	[illegible]	[illegible]
EVENT.....5	000:000	000	000	[illegible]	000	000
EVENT.....6	000:000	000	[illegible]	[illegible]	000	000
EVENT.....7	000:000	000	[illegible]	000	000	000
EVENT.....8	000:000	[illegible]	000	000	000	000
EVENT.....9	[illegible]	000	000	000	000	000

STANDARD MIX TIME VALUES
COMPOUND NO :002
BATCH NO: 005

	ON EVENT	ON ACKNOWLEDGEMENT
EVENT...1	000:001	000:032
EVENT...2	002:002	000:000
EVENT...3	000:000	000:000
EVENT...4	000:000	000:000
EVENT...5	000:000	000:000
EVENT...6	000:000	000:000
EVENT...7	000:000	000:000
EVENT...8	000:000	000:000
EVENT...9	000:000	000:000

TOTAL MIXING TIME 002:002

FARREL F80 MIXER CONTROL — DATE 012:012:088

#43 SHINGLE

TIME [illegible]:057

COMPOUND NUMBER [illegible]
BATCH NUMBER 004

	TIME MM:SS	TEMP 'F	ENERGY KWH*100	TORQUE (FT-LB)/100	ROTOR SPEED	RAM PRESSURE
EVENT.....1	000:000	170	000	000	036	079
EVENT.....2	001:024	189	180	058	036	079
EVENT.....3	000:000	000	000	000	000	000
EVENT.....4	000:000	000	000	000	000	000
EVENT.....5	000:000	000	000	000	000	000
EVENT.....6	000:000	000	000	000	000	000
EVENT.....7	000:000	000	000	000	000	000
EVENT.....8	000:000	000	000	000	000	000
EVENT.....9	000:000	000	000	000	000	000

STANDARD MIX TIME VALUES
COMPOUND NO :002
BATCH NO: 004

	ON EVENT	ON ACKNOWLEDGEMENT
EVENT...1	000:000	000:027
EVENT...2	001:052	000:000
EVENT...3	000:000	000:000
EVENT...4	000:000	000:000
EVENT...5	000:000	000:000
EVENT...6	000:000	000:000
EVENT...7	000:000	000:000
EVENT...8	000:000	000:000
EVENT...9	000:000	000:000

TOTAL MIXING TIME 001:052

FARREL F80 MIXER CONTROL

DATE 012:012:088
TIME 013:056:034

COMPOUND NUMBER 002 #44 SHINGLE
BATCH NUMBER 003

	TIME MM:SS	TEMP 'F	ENERGY KWH*100	TORQUE (FT-LB)/100	ROTOR SPEED	RAM PRESSURE
EVENT.....1	000:000	167	000	000	035	079
EVENT.....2	001:017	189	180	068	035	079
EVENT.....3	000:000	000	000	000	000	000
EVENT.....4	000:000	000	000	000	000	000
EVENT.....5	000:000	000	000	000	000	000
EVENT.....6	000:000	000	000	000	000	000
EVENT.....7	000:000	000	000	000	000	000
EVENT.....8	000:000	000	000	000	000	000
EVENT.....9	000:000	000	000	000	000	000

STANDARD MIX TIME VALUES
COMPOUND NO :002
BATCH NO: 003

	ON EVENT	ON ACKNOWLEDGEMENT
EVENT...1	000:000	000:026
EVENT...2	001:043	000:000
EVENT...3	000:000	000:000
EVENT...4	000:000	000:000
EVENT...5	000:000	000:000
EVENT...6	000:000	000:000
EVENT...7	000:000	000:000
EVENT...8	000:000	000:000
EVENT...9	000:000	000:000

TOTAL MIXING TIME 001:045

FARREL F80 MIXER CONTROL

DATE 012:012:088
TIME 014:021:023

COMPOUND NUMBER 002
BATCH NUMBER 002

#45 Shingle

	TIME MM:SS	TEMP 'F	ENERGY KWH*100	TORQUE (FT-LB)/100	ROTOR SPEED	RAM PRESSURE
EVENT.....1	000:000	180	000	000	036	079
EVENT.....2	001:018	188	180	067	036	079
EVENT.....3	000:000	000	000	000	000	000
EVENT.....4	000:000	000	000	000	000	000
EVENT.....5	000:000	000	000	000	000	000
EVENT.....6	000:000	000	000	000	000	000
EVENT.....7	000:000	000	000	000	000	000
EVENT.....8	000:000	000	000	000	000	000
EVENT.....9	000:000	000	000	000	000	000

STANDARD MIX TIME VALUES
COMPOUND NO :002
BATCH NO: 002

	ON EVENT	ON ACKNOWLEDGEMENT
EVENT...1	000:001	000:040
EVENT...2	002:000	000:000
EVENT...3	000:000	000:000
EVENT...4	000:000	000:000
EVENT...5	000:000	000:000
EVENT...6	000:000	000:000
EVENT...7	000:000	000:000
EVENT...8	000:000	000:000
EVENT...9	000:000	000:000

TOTAL MIXING TIME 002:000

FARREL F80 MIXER CONTROL

DATE 012:012:088
TIME 014:050:009

COMPOUND NUMBER 002
BATCH NUMBER 001

#46 SHINGLE

	TIME MM:SS	TEMP 'F	ENERGY KWH*100	TORQUE (FT-LB)/100	ROTOR SPEED	RAM PRESSURE
EVENT.....1	000:000	174	000	000	035	079
EVENT.....2	001:016	192	180	067	036	079
EVENT.....3	000:000	000	000	000	000	000
EVENT.....4	000:000	000	000	000	000	000
EVENT.....5	000:000	000	000	000	000	000
EVENT.....6	000:000	000	000	000	000	000
EVENT.....7	000:000	000	000	000	000	000
EVENT.....8	000:000	000	000	000	000	000
EVENT.....9	000:000	000	000	000	000	000

STANDARD MIX TIME VALUES
COMPOUND NO :002
BATCH NO: 001

	ON EVENT	ON ACKNOWLEDGEMENT
EVENT...1	000:001	000:057
EVENT...2	002:014	000:000
EVENT...3	000:000	000:000
EVENT...4	000:000	000:000
EVENT...5	000:000	000:000
EVENT...6	000:000	000:000
EVENT...7	000:000	000:000
EVENT...8	000:000	000:000
EVENT...9	000:000	000:000

TOTAL MIXING TIME 002:014

FARREL F80 MIXER CONTROL

DATE 012:012:088
TIME 015:015:049

#47 SHINGLE

COMPOUND NUMBER 002
BATCH NUMBER 009

	TIME MM:SS	TEMP 'F	ENERGY KWH*100	TORQUE (FT-LB)/100	ROTOR SPEED	RAM PRESSURE
EVENT.....1	000:000	177	000	000	035	079
EVENT.....2	001:010	191	130	[illegible]	035	079

EVENT.....3	000:000	000	000	000	000	000
EVENT.....4	000:000	000	000	000	000	000
EVENT.....5	000:000	000	000	000	000	000
EVENT.....6	000:000	000	000	000	000	000
EVENT.....7	000:000	000	000	000	000	000
EVENT.....8	000:000	000	000	000	000	000
EVENT.....9	000:000	000	000	000	000	000

STANDARD MIX TIME VALUES
COMPOUND NO :002
BATCH NO: 009

	ON EVENT	ON ACKNOWLEDGEMENT
EVENT...1	000:001	000:056
EVENT...2	002:008	000:000
EVENT...3	000:000	000:000
EVENT...4	000:000	000:000
EVENT...5	000:000	000:000
EVENT...6	000:000	000:000
EVENT...7	000:000	000:000
EVENT...8	000:000	000:000
EVENT...9	000:000	000:000

TOTAL MIXING TIME 002:008

Shingle 12/12/88

001:050	098	180	000	000	000

↓

FARREL F80 MIXER CONTROL

DATE 012:012:088
TIME 008:051:004

COMPOUND NUMBER 002
BATCH NUMBER 006

	TIME MM:SS	TEMP °F	ENERGY KWH*100	TORQUE (FT-LB)/100	ROTOR SPEED	RAM PRESSURE
EVENT.....1	000:000	243	000	000	035	079
EVENT.....2	001:053	207	180	037	035	079
EVENT.....3	000:000	000	000	000	000	000
EVENT.....4	000:000	000	000	000	000	000
EVENT.....5	000:000	000	000	000	000	000
EVENT.....6	000:000	000	000	000	000	000
EVENT.....7	000:000	000	000	000	000	000
EVENT.....8	000:000	000	000	000	000	000
EVENT.....9	000:000	000	000	000	000	000

STANDARD MIX TIME VALUES
COMPOUND NO :002
BATCH NO: 006

	ON EVENT	ON ACKNOWLEDGEMENT
EVENT...1	000:000	000:052
EVENT...2	002:047	000:000
EVENT...3	000:000	000:000
EVENT...4	000:000	000:000
EVENT...5	000:000	000:000
EVENT...6	000:000	000:000
EVENT...7	000:000	000:000
EVENT...8	000:000	000:000
EVENT...9	000:000	000:000

59

TOTAL MIXING TIME 002:047

FARREL F80 MIXER CONTROL

DATE 012:012:088
TIME 009:017:046

COMPOUND NUMBER 002
BATCH NUMBER 005

	TIME MM:SS	TEMP °F	ENERGY KWH*100	TORQUE (FT-LB)/100	ROTOR SPEED	RAM PRESSURE
EVENT.....1	000:000	238	000	000	035	079

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
EVENT.....3	000:000	000	000	000	000	000
EVENT.....4	000:000	000	000	000	000	000
EVENT.....5	000:000	000	000	000	000	000
EVENT.....6	000:000	000	000	000	000	000
EVENT.....7	000:000	000	000	000	000	000
EVENT.....8	000:000	000	000	000	000	000
EVENT.....9	000:000	000	000	000	000	000

STANDARD MIX TIME VALUES
COMPOUND NO :002
BATCH NO: 005

	ON EVENT	ON ACKNOWLEDGEMENT
EVENT...1	000:001	001:018
EVENT...2	003:003	000:000
EVENT...3	000:000	000:000
EVENT...4	000:000	000:000
EVENT...5	000:000	000:000
EVENT...6	000:000	000:000
EVENT...7	000:000	000:000
EVENT...8	000:000	000:000
EVENT...9	000:000	000:000

#60 Shingle

TOTAL MIXING TIME 003:003

FARREL F80 MIXER CONTROL

DATE 012:012:088
TIME 009:045:004

COMPOUND NUMBER 002
BATCH NUMBER 004

	TIME MM:SS	TEMP 'F	ENERGY KWH*100	TORQUE (FT-LB)/100	ROTOR SPEED	RAM PRESSURE
EVENT.....1	000:000	225	000	000	035	079
EVENT.....2	001:039	206	180	028	035	079
EVENT.....3	000:000	000	000	000	000	000
EVENT.....4	000:000	000	000	000	000	000
EVENT.....5	000:000	000	000	000	000	000
EVENT.....6	000:000	000	000	000	000	000
EVENT.....7	000:000	000	000	000	000	000
EVENT.....8	000:000	000	000	000	000	000
EVENT.....9	000:000	000	000	000	000	000

STANDARD MIX TIME VALUES
COMPOUND NO :002
BATCH NO: 004

ON EVENT ON ACKNOWLEDGEMENT

EVENT...1	000:001	001:013
EVENT...2	002:053	000:000
EVENT...3	000:000	000:000
EVENT...4	000:000	000:000
EVENT...5	000:000	000:000
EVENT...6	000:000	000:000
EVENT...7	000:000	000:000
EVENT...8	000:000	000:000
EVENT...9	000:000	000:000

#61 Shingle

TOTAL MIXING TIME 002:053

FARREL F80 MIXER CONTROL

DATE 012:012:088
TIME 010:018:059

COMPOUND NUMBER 002
BATCH NUMBER 003

	TIME MM:SS	TEMP °F	ENERGY KWH*100	TORQUE (FT-LB)/100	ROTOR SPEED	RAM PRESSURE
EVENT.....1	000:000	284	000	000	035	079
EVENT.....2	001:052	210	180	035	036	079
EVENT.....3	000:000	000	000	000	000	000
EVENT.....4	000:000	000	000	000	000	000
EVENT.....5	000:000	000	000	000	000	000
EVENT.....6	000:000	000	000	000	000	000
EVENT.....7	000:000	000	000	000	000	000
EVENT.....8	000:000	000	000	000	000	000
EVENT.....9	000:000	000	000	000	000	000

STANDARD MIX TIME VALUES
COMPOUND NO :002
BATCH NO: 003

	ON EVENT	ON ACKNOWLEDGEMENT
EVENT...1	000:001	001:002
EVENT...2	002:056	000:000
EVENT...3	000:000	000:000
EVENT...4	000:000	000:000
EVENT...5	000:000	000:000
EVENT...6	000:000	000:000
EVENT...7	000:000	000:000
EVENT...8	000:000	000:000
EVENT...9	000:000	000:000

#62 Shingle

TOTAL MIXING TIME 002:056

FARREL F80 MIXER CONTROL

DATE 012:012:088

COMPOUND NUMBER 002

BATCH NUMBER 002

	TIME MM:SS	TEMP °F	ENERGY KWH*100	TORQUE (FT-LB)/100	ROTOR SPEED	RAM PRESSURE
EVENT.....1	000:000	242	000	000	035	079
EVENT.....2	001:035	199	180	043	036	079
EVENT.....3	000:000	000	000	000	000	000
EVENT.....4	000:000	000	000	000	000	000
EVENT.....5	000:000	000	000	000	000	000
EVENT.....6	000:000	000	000	000	000	000
EVENT.....7	000:000	000	000	000	000	000
EVENT.....8	000:000	000	000	000	000	000
EVENT.....9	000:000	000	000	000	000	000

STANDARD MIX TIME VALUES
COMPOUND NO :002
BATCH NO: 002

	ON EVENT	ON ACKNOWLEDGEMENT
EVENT...1	000:000	000:046
EVENT...2	002:023	000:000
EVENT...3	000:000	000:000
EVENT...4	000:000	000:000
EVENT...5	000:000	000:000
EVENT...6	000:000	000:000
EVENT...7	000:000	000:000
EVENT...8	000:000	000:000
EVENT...9	000:000	000:000

#63 Shingle

TOTAL MIXING TIME 002:023

FARREL F80 MIXER CONTROL

DATE 012:012:088
TIME 011:031:041

COMPOUND NUMBER 002
BATCH NUMBER 001

	TIME MM:SS	TEMP °F	ENERGY KWH*100	TORQUE (FT-LB)/100	ROTOR SPEED	RAM PRESSURE
EVENT.....1	000:000	228	000	000	035	079
EVENT.....2	001:036	203	180	042	035	079
EVENT.....3	000:000	000	000	000	000	000
EVENT.....4	000:000	000	000	000	000	000
EVENT.....5	000:000	000	000	000	000	000
EVENT.....6	000:000	000	000	000	000	000
EVENT.....7	000:000	000	000	000	000	000
EVENT.....8	000:000	000	000	000	000	000
EVENT.....9	000:000	000	000	000	000	000

#64 shingle

STANDARD MIX TIME VALUES
COMPOUND NO :002
BATCH NO: 001

	ON EVENT	ON ACKNOWLEDGEMENT
EVENT...1	000:001	001:008
EVENT...2	002:046	000:000
EVENT...3	000:000	000:000
EVENT...4	000:000	000:000
EVENT...5	000:000	000:000
EVENT...6	000:000	000:000
EVENT...7	000:000	000:000
EVENT...8	000:000	000:000
EVENT...9	000:000	000:000

TOTAL MIXING TIME 002:046

FARREL FBO MIXER CONTROL

DATE 01[illegible]:012:058
TIME 0[illegible]2:040:054

COMPOUND NUMBER 002
BATCH NUMBER 009

	TIME MM:SS	TEMP F	ENERGY KWH*100	TORQUE (FT-LB)/100	ROTOR SPEED	RAM PRESSURE
EVENT.....1	000:000	194	000	000	035	079
EVENT.....2	001:029	201	180	045	035	079
EVENT.....3	000:000	000	000	000	000	000
EVENT.....4	000:000	000	000	000	000	000
EVENT.....5	000:000	000	000	000	000	000
EVENT.....6	000:000	000	000	000	000	000
EVENT.....7	000:000	000	000	000	[illegible]	[illegible]
EVENT.....8	000:000	000	000	000	[illegible]	[illegible]
EVENT.....9	000:000	000	000	[illegible]	000	000

#65 shingle

STANDARD MIX TIME VALUES
COMPOUND NO :002
BATCH NO: 009

	ON EVENT	ON ACKNOWLEDGEMENT
EVENT...1	[illegible]	
EVENT...2	[illegible]	000:000
EVENT...3	[illegible]	000:000
EVENT...4	[illegible]	000:000
EVENT...5	[illegible]	000:000
EVENT...6	000:000	000:000
EVENT...7	000:000	000:000
EVENT...8	[illegible]	[illegible]

[illegible]
EVENT...9 000:000 000:000

TOTAL MIXING TIME 002:039

FARREL F80 MIXER CONTROL

DATE 012:012:088
TIME 013:009:029

COMPOUND NUMBER 002
BATCH NUMBER 008

	TIME MM:SS	TEMP 'F	ENERGY KWH*100	TORQUE (FT-LB)/100	ROTOR SPEED	RAM PRESSURE
EVENT.....1	000:000	283	000	000	035	079
EVENT.....2	001:046	208	160	039	035	079
EVENT.....3	000:000	000	000	000	000	000
EVENT.....4	000:000	000	000	000	000	000
EVENT.....5	000:000	000	000	000	000	000
EVENT.....6	000:000	000	000	000	000	000
EVENT.....7	000:000	000	000	000	000	000
EVENT.....8	000:000	000	000	000	000	000
EVENT.....9	000:000	000	000	000	000	000

STANDARD MIX TIME VALUES
COMPOUND NO :002
BATCH NO: 008

	ON EVENT	ON ACKNOWLEDGEMENT
EVENT...1	000:000	000:044
EVENT...2	002:032	000:000
EVENT...3	000:000	000:000
EVENT...4	000:000	000:000
EVENT...5	000:000	000:000
EVENT...6	000:000	000:000
EVENT...7	000:000	000:000
EVENT...8	000:000	000:000
EVENT...9	000:000	000:000

#66 Shingle

TOTAL MIXING TIME 002:032

FARREL F80 MIXER CONTROL

DATE 012:012:088
TIME 013:055:005

COMPOUND NUMBER 002
BATCH NUMBER 007

	TIME MM:SS	TEMP 'F	ENERGY KWH*100	TORQUE (FT-LB)/100	ROTOR SPEED	RAM PRESSURE

EVENT.....1	000:000	228	000	000	034	079
EVENT.....2	001:038	202	180	042	036	079
EVENT.....3	000:000	000	000	000	000	000
EVENT.....4	000:000	000	000	000	000	000
EVENT.....5	000:000	000	000	000	000	000
EVENT.....6	000:000	000	000	000	000	000
EVENT.....7	000:000	000	000	000	000	000
EVENT.....8	000:000	000	000	000	000	000
EVENT.....9	000:000	000	000	000	000	000

STANDARD MIX TIME VALUES
COMPOUND NO :002
BATCH NO: 007

	ON EVENT	ON ACKNOWLEDGEMENT
EVENT...1	000:000	001:002
EVENT...2	002:042	000:000
EVENT...3	000:000	000:000
EVENT...4	000:000	000:000
EVENT...5	000:000	000:000
EVENT...6	000:000	000:000
EVENT...7	000:000	000:000
EVENT...8	000:000	000:000
EVENT...9	000:000	000:000

#67 Shingle

TOTAL MIXING TIME 002:042

FARREL F80 MIXER CONTROL

DATE 012:012:088
TIME 014:025:034

COMPOUND NUMBER 002
BATCH NUMBER 006

	TIME MM:SS	TEMP °F	ENERGY KWH*100	TORQUE (FT-LB)/100	ROTOR SPEED	RAM PRESSURE
EVENT.....1	000:000	282	000	000	035	079
EVENT.....2	001:057	205	180	035	036	079
EVENT.....3	000:000	000	000	000	000	000
EVENT.....4	000:000	000	000	000	000	000
EVENT.....5	000:000	000	000	000	000	000
EVENT.....6	000:000	000	000	000	000	000
EVENT.....7	000:000	000	000	000	000	000
EVENT.....8	000:000	000	000	000	000	000
EVENT.....9	000:000	000	000	000	000	000

STANDARD MIX TIME VALUES
COMPOUND NO :002
BATCH NO: 006

ON EVENT ON ACKNOWLEDGEMENT

EVENT...1	000:000	001:002
EVENT...2	003:001	000:000
EVENT...3	000:000	000:000
EVENT...4	000:000	000:000
EVENT...5	000:000	000:000
EVENT...6	000:000	000:000
EVENT...7	000:000	000:000
EVENT...8	000:000	000:000
EVENT...9	000:000	000:000

68 Shingle

TOTAL MIXING TIME 003:001

FARREL F80 MIXER CONTROL

DATE 012:012:088
TIME 014:054:036

COMPOUND NUMBER 002
BATCH NUMBER 005

	TIME MM:SS	TEMP °F	ENERGY KWH*100	TORQUE (FT-LB)/100	ROTOR SPEED	RAM PRESSURE
EVENT.....1	000:000	261	000	000	035	079
EVENT.....2	001:057	208	180	034	036	079
EVENT.....3	000:000	000	000	000	000	000
EVENT.....4	000:000	000	000	000	000	000
EVENT.....5	000:000	000	000	000	000	000
EVENT.....6	000:000	000	000	000	000	000
EVENT.....7	000:000	000	000	000	000	000
EVENT.....8	000:000	000	000	000	000	000
EVENT.....9	000:000	000	000	000	000	000

STANDARD MIX TIME VALUES
COMPOUND NO :002
BATCH NO: 005

	ON EVENT	ON ACKNOWLEDGEMENT
EVENT...1	000:001	000:045
EVENT...2	002:043	000:000
EVENT...3	000:000	000:000
EVENT...4	000:000	000:000
EVENT...5	000:000	000:000
EVENT...6	000:000	000:000
EVENT...7	000:000	000:000
EVENT...8	000:000	000:000
EVENT...9	000:000	000:000

TOTAL MIXING TIME 002:043

TABLE A-2

FARREL CORPORATION

25 Main Street
Ansonia, Connecticut 06401-1601
Phone: (203) 734-3331
TWX: 710-451-1649
Telex: 96-3496

FARREL

PROCESS LABORATORY

SHEET NO.

DATE 1

F-1638d 6/4/86

DATA SHEET FOR
F80 AND BR BANBURY MIXERS
Exhibit I

CLIENT Bird Inc.

COMPOUND INGREDIENTS

Typical BANBURY* operating character

A = rolls of roofing stock

BATCH NO.	TIME MIN.	LOADING OR OPERATION SEQUENCE	RAM AIR P.S.I.	ROTOR R.P.M.	TEMP. °F DOOR FRAME TC.	TEMP. °F WT. TC.	TEMP. °F PYROM.	PEAK H.P.	Amps	TOTAL CYCLE	MIXING TIME	Lbs.	LBS. PER HR.	BANBURY TEMP. CONDITIONS ROTORS	SIDES	DOOR TOP	REMARKS
	0	Load A	40	35										210	210	210	Rolls
	1'18	Ram down															
	2'52	Disch.			199	-	200	60	1.75	2'52"	1'28"	200	-				Product stuck to the door at disch. and had to be scraped after every batch. A slide door machine is required.

Note: Cycle time varied from 2'30" to 3'15" depending on feed form

TABLE A-3

ı No. 160D

ARREL CORPORATION

Main Street
sonia, Connecticut 06401-1601
one: (203) 734-3331
X: 710-451-1649
ex: 96-3498

FARREL

PROCESS LABORATORY

Sheet No. 2

Date

DATA SHEET FOR

22" x 60" MILL

Data is approximate

IENT Bird

Typical Operating Data

atch No.	Material	Wt. Lbs.	Feet Per Min. Front Roll	Feet Per Min. Back Roll	Temp. °F Front Roll	Temp. °F Back Roll	Gap Set X10^{-3}		Separating Forces Lbs.	Stock Temp. °F	Mill Pass Time Min.	KW P(2)	Pass	P2-P1	KW-HR/LB	Remarks
#6	Prewarmed	200	125	125	220	230	2.5-4	15	90,000	220	4'50"	52	1	24	.010	No load=28 KW
	Roofing mat'l							16	97,000	220	4'30	56	2	28	.010	
								16	"	"	"	55	3	27	.010	
								18	110,000	"	"	55	4	27	.010	
								19	115,000	"	"	54	5	26	.010	
								20	123,000	"	"	54	6	26	.010	
								21	130,000	"	"	54	7	26	.010	
											31'80" Min.				.070	Total
#10	Prewarmed	"	"	"	210	"	4	5	30,000	212	3'35	44	1	16	.005	
	Roofing Mat'l							6	35,000	216	2'50	52	2	24	.006	
								4	27,000	216	4'31	52.8	3	24.8	.009	
								3	17,000	216	5'10	"	4	"	.011	
											16'1" Min.				.031	Total
#58	Prewarmed	"	"	"	222	240	3-4	9	55,000	226	1'40"	54	1	26	.007	
								2	10,000	236	4'18	54	2	26	.009	
	(typical produ)							2	10,000	227	5'38	56.8	3	28.8	.014	
											11.6 Min.				.030	Total

APPENDIX B

PROCESSED WASTE DATA

RECYCLE FIBERGLASS ROOFING SCRAP PROCESSED ON 22" DIA. BY 60" MILL AT FARREL CORPORATION, ANSONIA, CT.

TABLE B-1 FIBERGLASS FINGERS/CUTOUTS

	Ign. US Sieve Series,	% Ret.	Ign. % Solids	Soft. Point, F	Brookfield	Viscosity, cps
Batch 1	30	45.3	80	--	@350F	--
Gap 0.045	50	9.3			@400F	--
Passes 8	70	3.1			@450F	--
250 lbs	100	2.1				
	200	8.2				
	325	5.2				
	Pan	26.8				
Batch 1A	30	26.1	--	--	@350F	--
Gap 0.015	50	8	(Spilled)		@400F	--
Passes 1	70	3.4			@450F	--
250 lbs	100	3.4				
	200	14.8				
	325	8				
	Pan	36.3				
Batch 1B	30	1.1	74.7	--	@350F	--
Gap 0.015	50	16.9			@400F	--
Passes 2	70	6.7			@450F	--
250 lbs	100	3.4				
	200	20.2				
	325	15.7				
	Pan	36				
Batch 1C	30	8.7	75.9	--	@350F	--
Gap 0.015	50	23.2			@400F	--
Passes 3	70	4.3			@450F	--
250 lbs	100	5.8				
	200	15.9				
	325	4.3				
	Pan	37.8				
Batch 1D	30	4.2	76	--	@350F	--
Gap 0.015	50	20			@400F	--
Passes 4	70	7.4			@450F	--
250 lbs	100	3.2				
	200	13.7				
	325	7.4				
	Pan	44.1				

TABLE B-1 CONTINUED

	Ign. US Sieve Series, % Ret.		Ign. % Solids	Soft. Point, F	Brookfield	Viscosity, cps
Batch 1E	30	1.8	76.4	--	@350F	--
Gap 0.015	50	17.5			@400F	--
Passes 5	70	5.3			@450F	--
250 lbs	100	5.3				
	200	19.3				
	325	8.8				
	Pan	42				
Batch 1F	30	14.3	80	--	@350F	--
Gap 0.015	50	20.4			@400F	--
Passes 6	70	6.1			@450F	--
250 lbs	100	5.1				
	200	16.3				
	325	8.2				
	Pan	29.6				
Batch 1G	30	2.2	77.2	--	@350F	--
Gap 0.015	50	14.6			@400F	--
Passes 7	70	7.9			@450F	--
250 lbs	100	5.6				
	200	18				
	325	5.6				
	Pan	46.1				
Batch 2A	30	26.3	75.6	--	@350F	--
Gap.008-.010	50	9.9			@400F	--
Passes 1	70	4.4			@450F	--
200 lbs	100	3.3				
	200	12.1				
	325	6.6				
	Pan	37.4				
Batch 2B	30	6.8	76.1	--	@350F	--
Gap.008-.010	50	17.5			@400F	--
Passes 2	70	5.4			@450F	--
200 lbs	100	2.7				
	200	12.2				
	325	13.5				
	Pan	41.9				

TABLE B-1 CONTINUED

	Ign. US Sieve Series, % Ret.		Ign. % Solids	Soft. Point, F	Brookfield	Viscosity, cps
Batch 2C	30	3.8	76.8	--	@350F	--
Gap.008-.010	50	11.5			@400F	--
Passes 3	70	5.8			@450F	--
200 lbs	100	3.8				
	200	11.5				
	325	7.7				
	Pan	55.9				
Batch 2D	30	4.5	76.7	--	@350F	--
Gap.008-.010	50	15.7			@400F	--
Passes 4	70	5.6			@450F	--
200 lbs	100	5.6				
	200	12.4				
	325	10.1				
	Pan	46.1				
Batch 2E	30	1.4	76.9	--	@350F	--
Gap.008-.010	50	12.5			@400F	--
Passes 5	70	5.5			@450F	--
200 lbs	100	4.2				
	200	13.9				
	325	9.7				
	Pan	52.8				
Batch 3A	30	23.5	73.7	--	@350F	--
Gap.004-.005	50	2.9			@400F	--
Passes 1	70	5.9			@450F	--
200 lbs	100	2.9				
(Rolls touch-	200	13.2				
-ing on ends)	325	7.4				
	Pan	44.2				
Batch 3B	30	2.2	78.3	--	@350F	--
Gap.004-.005	50	20			@400F	--
Passes 2	70	6.7			@450F	--
200 lbs	100	4.4				
(Rolls touch-	200	13.3				
-ing on ends)	325	6.7				
	Pan	46.7				

TABLE B-1 CONTINUED

	Ign. US Sieve Series, % Ret.		Ign. % Solids	Soft. Point, F	Brookfield	Viscosity, cps
Batch 3C	30	0	75	--	@350F	--
Gap.004-.005	50	15.5			@400F	--
Passes 3	70	8.2			@450F	--
200 lbs	100	8.2				
(Rolls touch-	200	17.5				
-ing on ends)	325	9.4				
	Pan	41.2				
Batch 3D	30	1	76	--	@350F	--
Gap.004-.005	50	1			@400F	--
Passes 4	70	28.1			@450F	--
200 lbs	100	7.3				
(Rolls touch-	200	18.8				
-ing on ends)	325	10.4				
	Pan	33.4				
Batch 3E	30	0	74	--	@350F	--
Gap.004-.005	50	11.4			@400F	--
Passes 5	70	11.4			@450F	--
200 lbs	100	8.2				
(Rolls touch-	200	22.7				
-ing on ends)	325	8.2				
	Pan	38.1				
Batch 3F	30	0	75	--	@350F	--
Gap.004-.005	50	6.9			@400F	--
Passes 6	70	9.7			@450F	--
200 lbs	100	6.9				
(Rolls touch-	200	22.2				
-ing on ends)	325	8.5				
	Pan	45.8				
Batch 3G	30	0	74	--	@350F	--
Gap.004-.005	50	4.1			@400F	--
Passes 7	70	9.3			@450F	--
200 lbs	100	9.3				
(Rolls touch-	200	27.9				
-ing on ends)	325	8.2				
	Pan	41.2				

TABLE B-1 CONTINUED

	Ign. US Sieve Series, % Ret.		Ign. % Solids	Soft. Point, F	Brookfield	Viscosity, cps
Batch 4A	30	5.1	74	--	@350F	--
Gap.002-.004	50	16.7			@400F	--
Passes 1	70	5.1			@450F	--
200 lbs	100	5.1				
(Rolls tight	200	11.5				
together)	325	9				
	Pan	47.5				
Batch 4B	30	0	74.2	--	@350F	--
Gap.002-.004	50	2.5			@400F	--
Passes 2	70	6.3			@450F	--
200 lbs	100	7.6				
(Rolls tight	200	15.2				
together)	325	8.9				
	Pan	59.5				
(FIRST BATCH SAVED TOWARDS WIND SEAL 80 RECYCLE TRIAL)						
Batch 4C	30	0	75.1	297	@350F	Off Scale
Gap.002-.004	50	0			@400F	286, 438
Pases 3	70	2.6			@450F	81, 488
200 lbs	100	3.9				
(Rolls tight	200	22.1				
together)	325	7.8				
	Pan	63.6				
Batch 4D	30	0	76	--	@350F	--
Gap.002-.004	50	0			@400F	--
Passes 4	70	2.9			@450F	--
200 lbs	100	6.2				
(Rolls tight	200	29.1				
together)	325	7.3				
	Pan	54.5				
Batch 4E	30	0	76	--	@350F	--
Gap.002-.004	50	0			@400F	--
Passes 5	70	1.7			@450F	--
200 lbs	100	3.4				
(Rolls tight	200	22				
together)	325	8.5				
	Pan	64.4				

TABLE B-1 CONTINUED

	Ign. US Sieve Series	% Ret.	Ign. % Solids	Soft. Point, F	Brookfield	Viscosity, cps
Batch 4F	30	0	76.2	--	@350F	--
Gap.002-.004	50	1.9			@400F	--
Passes 6	70	0			@450F	--
200 lbs	100	3.7				
(Rolls tight	200	29.6				
together)	325	7.4				
	Pan	57.4				
Batch 4G	30	0	76.4	--	@350F	--
Gap.002-.004	50	0			@400F	--
Passes 7	70	1			@450F	--
200 lbs	100	4				
(Rolls tight	200	34.3				
together)	325	10.1				
	Pan	50.6				
Batch 5	30	0	78.9	--	@350F	--
Gap.002-.004	50	0			@400F	--
Passes 7	70	0			@450F	--
200 lbs	100	5.1				
(Rolls tight	200	32.2				
together)	325	6.8				
	Pan	55.9				
Batch 6	30	0	76.5	350	@350F	Off Scale
Gap.002-.004	50	0			@400F	Off Scale
Passes 7	70	2.9			@450F	Off Scale,0ver
200 lbs	100	7.1				500, 000
(Rolls tight	200	32.8				
together)	325	4.3				
	Pan	52.9				

FIBERGLASS SHINGLES

TABLE B-2

	Ign. US Sieve Series, % Ret.		Ign. % Solids	Soft. Point, F	Brookfield	Viscosity, cps
Batch 7	30	0	72.3	--	@350F	--
Gap.002-.004	50	0			@400F	--
Passes 5	70	2			@450F	--
200 lbs	100	8.1				
(Rolls tight	200	33.3				
together)	325	9.1				
	Pan	47.5				
Batch 8	30	0	74.9	--	@350F	--
Gap.002-.004	50	3.6			@400F	--
Passes 3	70	10.7			@450F	--
200 lbs	100	9.5				
(Rolls tight	200	22.6				
together)	325	6				
	Pan	47.6				
Batch 9	30	0	72.7	320	@350F	Off Scale
Gap.002-.004	50	0			@400F	Off Scale
Passes 3	70	1			@450F	475, 000
200 lbs	100	4				
(Rolls tight	200	37.4				
together)	325	6.1				
	Pan	51.5				
Batch 10	30	0	76.2	--	@350F	--
Gap.002-.005	50	0			@400F	--
Passes 4	70	0			@450F	--
200 lbs	100	3.2				
(Rolls tight	200	30.2				
together)	325	9.5				
	Pan	57.1				
Batch 11	30	0	76	323	@350F	Off Scale
Gap.002-.005	50	0			@400F	301, 375
Passes 3	70	1.2			@450F	121, 783
200 lbs	100	9.8				
(Rolls tight	200	30.5				
together)	325	12.2				
	Pan	46.3				

TABLE B-2 CONTINUED

	Ign. US Sieve Series, % Ret.		Ign. % Solids	Soft. Point, F	Brookfield	Viscosity, cps
Batch 12	30	0	76.8	--	@350F	--
Gap.002-.005	50	0			@400F	--
Passes 3	70	3.2			@450F	--
200 lbs	100	10.5				
(Rolls tight	200	28.4				
together)	325	13.7				
	Pan	44.2				
Batch 13	30	0	80.7	--	@350F	--
Gap.002-.005	50	0			@400F	--
Passes 3	70	6.5			@450F	--
200 lbs	100	13				
(Rolls tight	200	24.7				
together)	325	9				
	Pan	46.8				
Batch 14	30	0	76.2	--	@350F	--
Gap.002-.005	50	0			@400F	--
Passes 3	70	1			@450F	--
200 lbs	100	5				
(Rolls tight	200	36.4				
together)	325	10.1				
	Pan	47.5				
Batch 15	30	0	76.1	--	@350F	--
Gap.002-.005	50	0			@400F	--
Passes 3	70	2			@450F	--
200 lbs	100	10				
(Rolls tight	200	29				
together)	325	12				
	Pan	47				
Batch 16	30	0	76.5	--	@350F	--
Gap.002-.005	50	0			@400F	--
Passes 3	70	1			@450F	--
200 lbs	100	11				
(Rolls tight	200	32				
together)	325	12				
	Pan	44				

TABLE B-2 CONTINUED

	Ign. US Sieve Series,	% Ret.	Ign. % Solids	Soft. Point, F	Brookfield	Viscosity, cps
Batch 17	30	0	74.9	--	@350F	--
Gap.002-.005	50	0			@400F	--
Passes 3	70	1			@450F	--
200 lbs	100	6				
(Rolls tight	200	36				
together)	325	10				
	Pan	47				
Batch 18	30	0	76.6	--	@350F	--
Gap.002-.005	50	0			@400F	--
Passes 3	70	2			@450F	--
200 lbs	100	10				
(Roll tight	200	34				
together)	325	8				
	Pan	46				
Batch 19	30	0	75.6	--	@350F	--
Gap.002-.005	50	0			@400F	--
Passes 3	70	1			@450F	--
200 lbs	100	10				
(Rolls tight	200	35				
together)	325	10				
	Pan	44				
Batch 20	30	0	74.4	--	@350F	--
Gap.002-.005	50	0			@400F	--
Passes 3	70	0			@450F	--
200 lbs	100	4				
(Rolls tight	200	32				
together)	325	11				
	Pan	53				
Batch 21	30	0	75.8	--	@350F	--
Gap.002-.005	50	0			@400F	--
Passes 3	70	0			@450F	--
200 lbs	100	7				
(Rolls tight	200	31				
together)	325	10				
	Pan	52				

TABLE B-2 CONTINUED

	Ign. US Sieve Series,	% Ret.	Ign. % Solids	Soft. Point, F	Brookfield	Viscosity, cps
Batch 22	30	0	79.4	--	@350F	-
Gap.004-.005	50	0			@400F	--
Passes 3	70	0			@450F	--
200 lbs	100	6				
(Rolls tight	200	29				
together)	325	9				
	Pan	56				
Batch 23	30	0	--	--	@350F	--
Gap.004-.005	50	0	(Spilled)		@400F	--
Passes 3	70	0			@450F	--
200 lbs	100	3.1				
(Rolls tight	200	26.2				
together)	325	9.2				
	Pan	61.5				
Batch 34	30	0	76.1	310	@350F	Off Scale
Gap.005-.006	50	0			@400F	383, 000
Passes 3	70	4			@450F	241, 250
200 lbs	100	9				
(Rolls tight	200	26				
together)	325	11				
	Pan	50				
Batch 35		NO GOOD, TO HOT				
Batch 36	30	0	75.6	--	@350F	--
Gap.004-.005	50	0			@400F	--
Passes 3	70	2.1			@450F	--
200 lbs	100	7.1				
(Rolls tight	200	31.6				
together)	325	8.2				
	Pan	51				
Batch 37	30	0	76.2	--	@350F	--
Gap.004-.005	50	0			@400F	--
Passes 3	70	2.3			@450F	--
200 lbs	100	6.8				
(Rolls tight	200	28.4				
together)	325	11.4				
	Pan	51.1				

TABLE B-2 CONTINUED

	Ign. US Sieve Series, % Ret.		Ign. % Solids	Soft. Point, F	Brookfield Viscosity, cps	
Batch 38	30	0	--	--	@350F	--
Gap.004-.005	50	0	(Spilled)		@400F	--
Passes 3	70	0			@450F	--
200 lbs	100	6.3				
(Rolls tight	200	22.9				
together)	325	12.5				
	Pan	58.3				
Batch 39	30	0	76.7	--	@350F	--
Gap.004-.005	50	0			@400F	--
Passes 3	70	0			@450F	--
200 lbs	100	4.5				
(Rolls tight	200	20				
together)	325	2.2				
	Pan	73.3				
Batch 40	30	0	--	--	@350F	--
Gap.004-.005	50	0	(Spilled)		@400F	--
Passes 3	70	2.5			@450F	--
200 lbs	100	5				
(Rolls tight	200	15				
together)	325	12.5				
	Pan	65				
Batch 41	30	0	79.2	324	@350F	Off Scale
Gap.004-.005	50	0			@400F	438, 000
Passes 3	70	3.8			@450F	266, 500
200 lbs	100	5.7				
(Rolls tight	200	18.8				
together)	325	3.8				
	Pan	67.9				
Batch 42	30	0	75.6	--	@350F	--
Gap.004-.005	50	0			@400F	--
Passes 3	70	2			@450F	--
200 lbs	100	8.1				
(Rolls tight	200	24.2				
together)	325	9.1				
	Pan	56.6				

TABLE B-2 CONTINUED

	Ign. US Sieve Series	% Ret.	Ign. % Solids	Soft. Point, F	Brookfield	Viscosity, cps
Batch 43	30	0	74.1	--	@350F	--
Gap.004-.005	50	0			@400F	--
Passes 3	70	2			@450F	--
200 lbs	100	4				
(Rolls tight	200	25.3				
together)	325	7.1				
	Pan	61.6				
Batch 44	30	0	74.2	--	@350F	--
Gap.004-.005	50	0			@400F	--
Passes 3	70	1			@450F	--
200 lbs	100	6.9				
(Rolls tight	200	29.7				
together)	325	5.9				
	Pan	56.5				
Batch 45	30	0	76	--	@350F	--
Gap.004-.005	50	0			@400F	--
Passes 3	70	3			@450F	--
200 lbs	100	10.9				
(Rolls tight	200	29.7				
together)	325	5.9				
	Pan	50.5				
Batch 46	30	0	75.1	--	@350F	--
Gap.004-.005	50	0			@400F	--
Passes 3	70	3			@450F	--
200 lbs	100	10				
(Rolls tight	200	29				
together)	325	4				
	Pan	54				
Batch 47	30	0	77.2	--	@350F	--
Gap.004-.005	50	0			@400F	--
Passes 3	70	5			@450F	--
200 lbs	100	11				
(Rolls tight	200	27				
together)	325	3				
	Pan	54				

TABLE B-2 CONTINUED

	Ign. US Sieve Series, % Ret.		Ign. % Solids	Soft. Point, F	Brookfield Viscosity, cps	
Batch 48	30	0	75.9	--	@350F	--
Gap.003-.005	50	0			@400F	--
Passes 3	70	2			@450F	--
200 lbs	100	12				
(Rolls tight	200	32				
together)	325	7				
	Pan	47				
Batch 49	30	0	74.2	--	@350F	--
Gap.003-.004	50	0			@400F	--
Passes 3	70	0			@450F	--
200 lbs	100	4				
(Rolls tight	200	37				
together)	325	8				
	Pan	51				
Batch 50	30	0	75.1	306	@350F	Off Scale
Gap.003-.004	50	0			@400F	217, 313
Passes 3	70	1			@450F	89, 294
200 lbs	100	7				
(Rolls tight	200	35				
together)	325	38				
	Pan	19				
Batch 51	30	0	73.7	--	@350F	--
Gap.003-.004	50	0			@400F	--
Passes 3	70	0			@450F	--
200 lbs	100	4.1				
(Rolls tight	200	38.4				
together)	325	34.3				
	Pan	23.2				
Batch 52	30	0	76.8	--	@350F	--
Gap.003-.004	50	0			@400F	--
Passes 3	70	1.9			@450F	--
200 lbs	100	3.8				
(Rolls tight	200	32.1				
together)	325	32.1				
	Pan	30.1				

TABLE B-2 CONTINUED

	Ign. US Sieve Series, % Ret.		Ign. % Solids	Soft. Point, F	Brookfield	Viscosity, cps
Batch 53	30	0	76.6	--	@350F	--
Gap.003-.004	50	0			@400F	--
Passes 3	70	0			@450F	--
200 lbs	100	3.4				
(Rolls tight	200	27.6				
together)	325	43.1				
	Pan	25.9				
Batch 55	30	0	75	--	@350F	--
Gap.003-.004	50	0			@400F	--
Passes 3	70	0			@450F	--
200 lbs	100	11.2				
(Rolls tight	200	34.6				
together)	325	27.6				
	Pan	26.6				
Batch 56	30	0	75.2	- -	@350F	--
Gap.003- 004	50	0			@400F	--
Passes 3	70	0			@450F	--
200 lbs	100	7.1				
(Rolls tight	200	37.8				
together)	325	26.5				
	Pan	28.6				
Batch 57	30	0	76	--	@350F	--
Gap.003-.004	50	0			@400F	--
Passes 3	70	2			@450F	--
200 lbs	100	16.2				
(Rolls tight	200	34.3				
together)	325	25.3				
	Pan	22.2				
Batch 58	30	0	73.3	--	@350F	--
Gap.003-.004	50	0			@400F	--
Passes 3	70	0			@450F	--
200 lbs	100	2				
(Rolls tight	200	36				
together)	325	29				
	Pan	33				

TABLE B-2 CONTINUED

	Ign. US Sieve	Series, % Ret.	Ign. % Solids	Soft. Point, F	Brookfield	Viscosity, cps
Batch 59	30	0	75.9	--	@350F	--
Gap.003-.004	50	0			@400F	--
Passes 3	70	0			@450F	--
200 lbs	100	7.9				
(Rolls tight	200	32.9				
together)	325	40.8				
	Pan	18.4				
Batch 60	30	0	75	--	@350F	--
Gap.003-.004	50	0			@400F	--
Passes 3	70	0			@450F	--
200 lbs	100	4.3				
(Rolls tight	200	32.6				
together)	325	41.3				
	Pan	21.8				
Batch 61	30	0	72	--	@350F	--
Gap.003-.004	50	0			@400F	--
Passes 3	70	0.1			@450F	--
200 lbs	100	3.3				
(Rolls tight	200	25.9				
together)	325	19.6				
	Pan	51.1				
Batch 62	30	0	72.1	--	@350F	--
Gap.003-.004	50	0			@400F	--
Passes 3	70	0.4			@450F	--
200 lbs	100	5.2				
(Rolls tight	200	26.9				
together)	325	19.5				
	Pan	48				
Batch 63	30	0	71.4	--	@350F	--
Gap.003-.004	50	0			@400F	--
Passes 3	70	0.5			@450F	--
200 lbs	100	4.9				
(Rolls tight	200	26.4				
together)	325	13.1				
	Pan	55.1				

TABLE B-2 CONTINUED

	Ign US Sieve Series, % Ret.		Ign. % Solids	Soft. Point, F	Brookfield	Viscosity, cps
Batch 64	30	0	71.9	--	@350F	--
Gap.003-.004	50	0.1			@400F	--
Passes 3	70	0.4			@450F	--
200 lbs	100	3.8				
(Rolls tight	200	24.4				
together)	325	14.4				
	Pan	56.9				
Batch 65	30	0	73	--	@350F	--
Gap.003-.004	50	0			@400F	--
Passes 3	70	0.4			@450F	--
200 lbs	100	3.4				
(Rolls tight	200	23.3				
together)	325	13.7				
	Pan	59.2				
Batch 66	30	0	71.6	--	@350F	--
Gap.003-.004	50	0			@400F	--
Passes 3	70	0.2			@450F	--
200 lbs	100	4.1				
(Rolls tight	200	26.4				
together)	325	14.4				
	Pan	54.9				
Batch 67	30	0	73.7	--	@350F	--
Gap.003-.004	50	0			@400F	--
Passes 3	70	0.9			@450F	--
200 lbs	100	8.2				
(Rolls tight	200	25.2				
together)	325	12.8				
	Pan	52.9				
Batch 68	30	0	71.8	--	@350F	--
Gap.003-.004	50	0			@400F	--
Passes 3	70	0.3			@450F	--
200 lbs	100	3.9				
(Rolls tight	200	30.5				
together)	325	10.4				
	Pan	54.9				

TABLE B-2 CONTINUED

	Ign. US Sieve Series, % Ret.		Ign. % Solids	Soft. Point, F	Brookfield	Viscosity, cps
Batch 69	30	0	72	--	@350F	--
Gap.003-.004	50	0			@400F	--
Passes 3	70	0.6			@450F	--
200 lbs	100	6.7				
(Rolls tight	200	30.7				
together)	325	15.2				
	Pan	46.8				

GLASS MSR ROLLS

TABLE B-3

	Ign. US Sieve Series	% Ret.	Ign. % Solids	Soft. Point, F	Brookfield	Viscosity, cps
Batch 24	30	0	72.7	--	@350F	--
Gap.005-.006	50	0			@400F	--
Passes 3	70	2			@450F	--
200 lbs	100	7				
(Rolls tight	200	31				
together)	325	16				
	Pan	44				
Batch 25	30	0	71.4	--	@350F	--
Gap.005-.006	50	0			@400F	--
Passes 3	70	0			@450F	--
200 lbs	100	3				
(Rolls tight	200	29				
together)	325	10				
	Pan	58				
Batch 26	30	0	74.7	--	@350F	--
Gap.005-.006	50	0			@400F	--
Passes 3	70	1			@450F	--
200 lbs	100	8.7				
(Rolls tight	200	26.1				
together)	325	10.9				
	Pan	53.3				
Batch 27	30	0	74.4	--	@350F	--
Gap.005-.006	50	0			@400F	--
Passes 3	70	1			@450F	--
200 lbs	100	8.1				
(Rolls tight	200	28.3				
together)	325	13.1				
	Pan	49.5				
Batch 28	30	0	76.1	293	@350F	Off Scale
Gap.005-.006	50	0			@400F	238, 625
Passes 3	70	4.9			@450F	76, 381
200 lbs	100	11				
(Rolls tight	200	23.2				
together)	325	13.4				
	Pan	47.5				

TABLE B-3 CONTINUED

	Ign. US Sieve Series, % Ret.		Ign. % Solids	Soft. Point, F	Brookfield	Viscosity, cps
Batch 29	30	0	75.6	--	@350F	--
Gap.005-.006	50	0			@400F	--
Passes 3	70	1.9			@450F	--
200 lbs	100	5.7				
(Rolls tight	200	30.2				
together)	325	7.5				
	Pan	54.7				
Batch 30	30	0	--	--	@350F	--
Gap.005-.006	50	0	(Spilled)		@400F	--
Passes 3	70	1.6			@450F	--
200 lbs	100	6.5				
(Rolls tight	200	29				
together)	325	16.1				
	Pan	46.8				
Batch 31	30	0	74.4	292	@350F	Off Scale
Gap.005-.006	50	0			@400F	204, 000
Passes 3	70	2			@450F	79, 400
200 lbs	100	10				
(Rolls tight	200	29				
together)	325	12				
	Pan	47				
Batch 32	30	0	73.6	--	@350F	--
Gap.005-.006	50	0			@400F	--
Passes 3	70	1			@450F	--
200 lbs	100	7				
(Rolls tight	200	28				
together)	325	7				
	Pan	57				
Batch 33	30	0	74.3	--	@350F	--
Gap.005-.006	50	0			@400F	--
Passes 3	70	4			@450F	--
200 lbs	100	10				
(Rolls tight	200	30				
together)	325	12				
	Pan	44				

MIXTURE OF SHINGLES, ROLLS AND CUTOUTS

TABLE B-4

	Ign. US Sieve	Series, % Ret.	Ign. % Solids	Soft. Point, F	Brookfield	Viscosity, cps
Batch 54	30	0	75	312	@350F	Off Scale
Gap.003-.004	50	0			@400F	258, 938
Passes 3	70	0			@450F	161, 767
200 lbs	100	10.1				
(Rolls tight	200	34.4				
together)	325	32.3				
	Pan	23.2				

APPENDIX C

SHINGLE PRODUCTION DESCRIPTION AND DATA

EXPERIMENTAL PRODUCTION DESCRIPTION

The amount of processed waste was estimated to be enough to run approximately 250 squares at each of the three planned percentages of 5%, 10%, and 20%. It was decided to leave filled coating in the filled coating vertical mixer and add the amount of waste necessary to bring the mixtures to the planned percentages. The following calculations show the necessary amount of waste to be added to (1) convert virgin filled coating to a mixture of 5% waste, (2) convert mixture of 5% waste and filled coating to a 10% mixture and (3) convert mixture of 10% waste and filled coating to a 20% mixture.

Description of Pumping Ratios And Methods Used To Meter Roofing Waste Mixtures

"Loss on Ignition" tests done using the processed roofing waste from Farrel Corp. showed that the waste averaged 75% filler, 25% raw asphalt. This mixture was to be added to normal filled coating asphalt at 5%, 10% and 20% ratios. This 75% filled coating was too viscous to pump at normal operating temperatures (approx. 420°F). Raw asphalt was therefore added to the 75% roofing waste mix which was being melted in a 1200 gallon waste run tank used to hold the mix during this test. The raw asphalt was to be added in an amount which would dilute the 75% filled roofing waste and make it equivalent to normal filled coating. The waste mixture was blended to 61-63% filler to conserve waste because there was a limited amount (approx. 11,000 lbs.) to work with for achieving the targeted quantity (200-250 sq.) of shingles at the 5%, 10%, and 20% waste levels. The following calculation was used to arrive at a new percentage of diluted roofing waste mix to add which would give 5%, 10% or 20% actual waste ratio.

Calculating on a 100 lb. batch basis:

Bird 64% filled coating consists of: (64 lbs. filler + 36 lbs. raw asphalt)	75% filled roofing waste consists of: (75 lbs. solids + 25lbs. raw asphalt)

Since the goal was to add roofing waste to Bird filled coating at a 5% rate, then:

[(64 lbs. filler)(.95) + (36 lbs. asphalt)(.95)]+
[(75 lbs. solids)(.05) + (25 lbs. asphalt (.05)]= 100 lbs.

[60.8 lbs. filler + 34.2 lbs. asphalt] +
[3.75 lbs. solids + 1.25 lbs. asphalt] = 100 lbs.

From this calculation, a 5% mixture of filled coating and roofing waste would have 3.75 lbs. of roofing waste filler and 60.8 lbs. of virgin filler. In order to eliminate the dilution effect of the asphalt added to the waste in the tank, one would have to add a larger percentage of roofing waste mix to get a true 5% mixture of solids. This percentage would be:

$$\frac{3.75 \text{ lbs.}}{60.8 \text{ lbs.}} \times 100 = 6.17\% \text{ or approx. } 6.2\%$$

The filler content in the diluted waste was measured to be 60.9% and the filler content in the waste averaged 75.1%. The ratio of waste in the diluted waste in the tank was, therefore, 60.9/75.1 = .811. The 5% goal of waste would be met by 5/.811 = 6.2%, confirming the above calculation.

The actual percent of diluted waste to achieve waste concentrations of 5%, 10% and 20% were calculated to be 6.2%, 12.4% and 24.8%. These percentages can be seen on a chart "Pump Speeds For D.O.E. Scrap Recycling Test" shown as Table C-1. This table shows the rates of filled coating supplied to the roofing machine and the respective pump speeds to achieve them. The normal filled coating is produced by combining the filler dust from an automated weigh feeder system with raw coating asphalt fed into a mixer by an asphalt metering pump whose speed is controlled by the output rate of the automated weigh feeder. The reference signal which the weigh feeder supplied to this asphalt pump was also used as a reference signal through a 10 turn potentiometer to control the waste pump speed. The waste pump was feeding into the same mixer at the 6.2%, 12.4% and 24.8% ratios as set by the potentiometer. The following calculations will show how the pump speeds shown in Table C-1 were determined. It should be noted that the weigh feeder master throughput settings shown on Table C-1 are set on controls at the weigh feeder control station and that the feed rate is constantly being corrected by the weigh feeder unit to achieve the desired throughput selected. This is why Table C-1 lists throughput from 79,000 lb/hr. to 84,000 lb/hr. The table could be used at any given instant by following the asphalt pump tachometer readout at the control station and comparing it to the waste pump tachometer readout to verify if the waste mixture percentages are as desired. Some constants used in the calculations were:

Asphalt Metering Pump
- 0.56 gal/rev. (from manufacturer's pump curves)
- 7.41 lbs/gal. (raw coating @ 420°F from Bird lab data)
- Sprocket ratio = 1.0286
- Reducer ratio = 11.4

Waste Pump
- 0.138 gal/rev. (from manufacturer's pump curves)
- 12.03 lbs/gal. (61% filled coating @ 450°F from Bird lab data)
- Sprocket ratio = 2.0
- Reducer ratio = 5.1

The following calculations illustrate how the first line of Table C-1 was derived for a throughput of 84,000 lbs/hr. filled coating and metering of 6.2% waste mix.

(84,000 lbs/hr.) x (64% targeted filler in coating) = 53,760 lb/hr. filler
(84,000 lbs/hr. total) - (53,760 lb/hr. filler) = 30,240 lb/hr. asphalt

To achieve 30,240 lb/hr. asphalt the asphalt metering pump r.p.m. would be:

$$\left(\frac{30240\ \text{lb.asphalt}}{\text{Hr.}}\right)\text{x}\left(\frac{\text{Hr.}}{60\ \text{min.}}\right)\text{x}\left(\frac{\text{Gal}}{7.41\ \text{lb}}\right)\text{x}\left(\frac{\text{Rev.}}{0.56\ \text{gal.}}\right) = 121.5\ \text{rpm}$$

The motor speed to achieve this was:

(121.5 rpm) x (1.0286 sprocket ratio) x (11.4 reducer ratio) = 1424.2 rpm

TABLE C-1 PUMP SPEEDS FOR D.O.E. SCRAP RECYCLING TEST

(All figures below based on 64% filler)

Weigh Feeder Master Thruput Setting	Amount Filler @ 64%	Amount Asphalt Added	Asphalt Metering Pump R.P.M.	Asphalt Pump-Motor R.P.M.	% Waste Added	Total Thruput	Waste Pump R.P.M.	Waste Pump Motor R.P.M.
84,000 lb/hr.	53,760 lb/hr.	30,240 lb/hr.	121.5	1424.2	6.2%	89,208 lb/hr.	52.3	533.7
84,000	53,760	30,240	121.5	1424.2	12.4%	94,416	104.6	1067.5
84,000	53,760	30,240	121.5	1424.2	24.8%	104,832	209.3	2135.0
83,000	53,120	29,880	120.0	1407.3	6.2%	88,146	51.7	527.4
83,000	53,120	29,880	120.0	1407.3	12.4%	93,292	103.3	1053.9
83,000	53,120	29,880	120.0	1407.3	24.8%	103,584	206.6	2107.8
82,000	52,480	29,520	118.6	1390.3	6.2%	87,084	51.0	520.6
82,000	52,480	29,520	118.6	1390.3	12.4%	92,168	102.1	1041.2
82,000	52,480	29,520	118.6	1390.3	24.8%	102,336	204.2	2082.4
81,000	51,840	29,160	117.1	1373.3	6.2%	86,022	50.4	514.3
81,000	51,840	29,160	117.1	1373.3	12.4%	91,044	100.8	1028.5
81,000	51,840	29,160	117.1	1373.3	24.8%	101,088	201.7	2057.0
80,000	51,200	28,800	115.7	1356.4	6.2%	84,960	49.8	507.9
80,000	51,200	28,800	115.7	1356.4	12.4%	89,920	99.6	1015.8
80,000	51,200	28,800	115.7	1356.4	24.8%	99,840	199.2	2031.6
79,000	50,560	28,440	114.2	1339.4	6.2%	83,898	49.2	501.6
79,000	50,560	28,440	114.2	1339.4	12.4%	88,796	98.3	1003.1
79,000	50,560	28,440	114.2	1339.4	24.8%	98,592	196.7	2006.2

The reference signal which determined this motor speed was also the reference signal used through the potentiometer setting to run the waste pump motor.

Since 6.2% waste mixture was to be added to the previously calculated filled coating:

(84,000 lbs/hr filled coating throughput) + (6.2% waste mixture)(84,000 lbs/hr) = 89,208 lb/hr total throughput

To achieve the added amount of waste mixture, the waste pump rpm was calculated:

$$(89{,}208 \text{ lb/hr} - 84{,}000 \text{ lb/hr}) \times \left(\frac{\text{Hr.}}{60 \text{ min}}\right) \times \left(\frac{\text{Gal.}}{12.03 \text{ lb}}\right) \times \left(\frac{\text{Rev.}}{0.138}\right) = 52.3 \text{ rpm}$$

The motor speed for this waste pump speed was:

(52.3 rpm)x(2.0 sprocket ratio)x(5.1 reducer ratio) = 533.7 rpm

This shows how the asphalt metering pump and waste pump rpm's were arrived at, as shown on Table C-1. Prior to running the actual waste test, the waste pump was set in synchronization with the asphalt metering pump during a normal roofing run, with the waste pump being run without any material. This was achieved by varying the previously mentioned 10 turn micrometer adjustable potentiometer. Experimental settings for the potentiometer were arrived at in this manner and following the information in Table C-1. These were:

6.2% waste added - potentiometer setting = 311
12.4% waste added - potentiometer setting = 628
24.8% waste added - potentiometer setting = 1000

During the running of the actual test, a team member was stationed at the weigh feeder control panel where he monitored the asphalt metering pump speed, waste pump speed, and weigh feeder instantaneous throughput and compared these figures to Table C-1. Again, since throughput is constantly being corrected by the automated feeder, the readings could be verified at any instant when the throughput corresponded with one listed on the chart. When this occurred it was found that the waste pump rpm did not differ by more than 0.2 rpm from the listed figure. This would translate to a maximum error ranging from 0.4% during the 6.2% diluted waste test to 0.1% during the 24.8% diluted waste test.

As a check to verify the amount of waste added to convert the remaining filled coating or mixture in the filled coating vertical mixer to the next trial percentage, the waste run tank and the filled coating vertical mixer were calibrated to record levels and respective quantities before and after pumping. Both of these tanks are identical in size and construction. (see Table C-2)

A single revolution counter was installed on the waste metering pump to record the revolutions of the pump. The pump has a displacement of 0.138 gallons per revolution which made it possible to calculate the amount of waste pumped to the filled coating mixture.

Prior to the start of mixing waste with virgin filled coating, the waste supply line was charged from the waste run tank to the filled coating vertical mixer. This supply line (160+ feet) was installed with a slight pitch away from the filled coating vertical mixer towards the waste pump, so as to hold its prime and not drain into the filled coating vertical mixer.

TABLE C-2 CALIBRATION OF 1200 GAL. MIXER

In. From Top	Gal.	In. From Top	Gal.	In. From Top	Gal.
0	1239	29	731.91	58	231.95
1	1221.45	30	714.67	59	214.71
2	1203.90	31	697.43	60	197.47
3	1186.35	32	680.19	61	180.23
4	1168.80	33	662.95	62	162.99
5	1151.25	34	645.71	63	145.75
6	1133.70	35	628.47	64	128.51
7	1116.15	36	611.23	65	111.27
8	1098.60	37	593.99	66	94.03
9	1081.05	38	576.75	67	
10	1063.50	39	559.51	68	
11	1045.95	40	542.27	69	
12	1028.40	41	525.03	70	
13	1010.85	42	507.79	71	
14	993.30	43	490.55	72	Volume
15	975.75	44	473.31	73	of
16	958.20	45	456.07	74	Dished
17	940.65	46	438.83	75	Head
18	923.10	47	421.59	76	
19	905.55	48	404.35	77	
20	888.00	49	387.11	78	
21	870.45	50	369.87	79	
22	852.90	51	352.63	80	0
23	835.35	52	335.39		
24	818.11	53	318.15		
25	800.87	54	300.91		
26	783.63	55	283.67		
27	766.39	56	266.43		
28	749.15	57	249.19		

Calculations To Convert Virgin Filled Coating In Filled Coating Vertical Mixer To 5% Mix Of Waste

The liquid level in the filled coating vertical mixer was measured at 60 inches down from the top. This is equivalent to 197.47 gallons (from Table C-2). Knowing that 6.2 gallons of waste mixture per 100 gallons of virgin filled coating must be added, the following amounts were needed to arrive at the proper mix.

$$\frac{197.47 \text{ gals.}}{100 \text{ gals.}} = 1.97$$

(1.97) (6.2 gallons) = 12.21 gallons to be added

$$\frac{12.21 \text{ gals.}}{17.55 \text{ gals./in.}} = .695 \text{ in.}$$

$$\frac{12.21 \text{ gallons}}{.138 \text{ gals/rev}} = 88.47 \text{ revolutions}$$

The level of the waste run tank was recorded as 19" down from the top after charging the supply line. The waste metering pump was run until 88 revolutions were reached. The pump was stopped at this count and the level of the waste vertical mixer recorded at 19-3/4" down from the top. The difference of 3/4" from before and after pumping is equivalent to

(.75 in.) (17.55 gals/in.) = 13.16 gallons pumped.

The calculated amount of waste that was needed to convert virgin filled coating to a 5% waste mixture was 12.21 gallons, the actual measured amount was 13.16. The difference is within the expected measuring accuracy.

The filled coating vertical mixer was measured after the pumping of waste and found to be 59 1/4" down from the top. This difference of 3/4" gained was approximately equal to the amount removed from the waste run tank.

After the above was completed, the waste metering pump was set to automatically follow the filled coating mixing system and the shingle machine was re-started.

The pump revolution totalizer was reset to zero at the start of the 5% batches.

The following data were taken during the 5% waste run.

5% Waste Run

Batch #	Pump Totalizer Start	Pump Totalizer Finish	Displ. Gallons	Level Start	Level Finish	Transf. Gallons
1	0	314	43.33	19.75	22.25	43.87
2	314	551	32.70	22.25	24	30.71
3	551	893	47.20	24	26.75	47.41
4	893	1044	20.84	26.75	28	21.55
				Total Gals.		143.54
				Total Lbs.		1726.80

The total pounds of waste used in the production was calculated from the diluted waste as 81.1% of 1727 = 1401.

Note: A batch consisted of the volume of material consumed from the tank between the high and low signal levels. The filled coating mixing system and the waste metering pump started when the low level was reached. They both ran until the high level in the filled coating vertical mixer was reached, and then shut down.

Sample Calculations

$$(551 \text{ revs} - 314 \text{ revs})\ (.138 \text{ gal/rev}) = 32.70$$

$$(24 \text{ in} - 22.25 \text{ in})\ (17.55 \text{ gal/in}) = 30.71 \text{ gals.}$$

Note that from 0-24" down from the top, the volume is 17.55 gal/in.; from 25" down to 66" down, the volume is 17.24 gals/in. The difference is due to the area occupied by the agitator paddles.

The shingle machine was run until the needed quantity of shingles for the 5% waste trial had been produced. It was at this time that the shingle machine was stopped and the 10% trial set up was begun.

Calculations To Convert 5% Mixture Of Waste and Filled Coating To A 10% Mixture

The filled coating vertical mixer was measured at 42" down from the top; this is equivalent to the 507.79 gallons from Table C-2. As previously calculated, 7.1 gallons per 100 gallons were added to convert a 5% mix to 10%.

$$\frac{507.79 \text{ gal.}}{100 \text{ gal.}} = 5.07$$

$$5.07 \times 7.1 \text{ gal.} = 35.99 \text{ gallons to be added}$$

$$\frac{35.99 \text{ gal.}}{17.55 \text{ gal/in.}} = 2.08 \text{ in.}$$

$$\frac{35.99 \text{ gal.}}{.138 \text{ gal/rev.}} = 260.79 \text{ rev.}$$

The pump totalizer was reset and then the pump was run until the totalizer reached 234 revolutions. The waste tank level went from 28" down from the top to 30" down from the top. This is equivalent to

$$(2 \text{ in.})\,(17.24 \text{ gal/in.}) = 34.48 \text{ gal.}$$

The filled coating vertical mixer had a change of 42" down from the top to 39 3/4" down from the top, or 2 1/4". This confirmed that the amount added was within range to convert a 5% mix to a 10% mix.

The waste metering pump was then set to follow the filled coating mixing system. The following data was taken during the 10% waste run.

10% Waste Run

Batch #	Pump Totalizer Start	Pump Totalizer Finish	Displ. Gallons	Level Start	Level Finish	Transf. Gallons
1	234	626	54.09	30	33	51.72
2	626	1207	80.18	33	37.75	81.89
3	1207	1795	81.14	37.75	42.25	77.58
4	1795	1928	18.35	42.25	43.25	17.24
				Total Gals.		228.43
				Total Lbs.		2748.01

The total pounds of waste used was 0.812 x 2748=2229.

Sample Calculations

$$(626 \text{ revs} - 234 \text{ revs.})(.138 \text{ gal/rev.}) = 54.09 \text{ gals.}$$

$$(33.0 \text{ in} - 30.0 \text{ in})\,(17.24 \text{ gal/in}) = 51.72 \text{ gals.}$$

The shingle machine was run until the needed quantity of shingles for the 10% waste trial had been produced. It was at this time that the shingle machine was stopped and the 20% trial set up was started.

Calculations To Convert 10% Mixture Of Waste And Filled Coating To A 20% Mixture

The filled coating vertical mixer was measured at 48" down from the top . This is equivalent to 404.35 gallons from Table C-2. As previously calculated, 16.6 gallons per 100 gallons were added to convert a 10% mix to 20%.

$$\frac{404.35 \text{ gals.}}{100 \text{ gals.}} = 4.04/100$$

$$(4.04)/100\,(16.6) \text{ gal.} = 67.06 \text{ gal.}$$

$$\frac{67.06 \text{ gal.}}{17.42 \text{ gal/in.}} = 3.84 \text{ in.}$$

$$\frac{67.06 \text{ gals}}{.138 \text{ gals/rev.}} = 485.97 \text{ rev.}$$

The pump totalizer was reset and the pump was run until the level in the filled coating vertical mixer went from 48" down from the top to 43.75" down from the top. The waste run tank level went from 43.25" down from the top to 47.25" down from the top. The pump totalizer went to 431 revolutions. The amount of waste for these three readings is:

Filled coating vertical mixer level change
(48 in - 43.75 in) (17.24 gals/in) = 73.27 gals.

Waste tank level change
(47.25 in - 43.25 in) (17.24 gals/in) = 68.96 gals.

Pump displacement
(431 rev) (.138 gal/rev) = 59.47 gals.

After completing the change from a 10% mix to 20% mix, the waste pump was set to automatically follow the filled coating system. The following data were taken during the 20% waste run.

20% Waste Run

Batch #	Pump Totalizer Start	Pump Totalizer Finish	Displ. Gallons	Level Start	Level Finish	Transf. Gallons
1	431	1722	178.16	47.25	56.5	159.47
2	1722	2678	131.92	56.5	63	112.06
3	2678	3805	155.53	63	80 (empty)	145.75
				Total Gals.		417.28
				Total Lbs.		5020.00

The total pounds of waste used was 0.811 x 5020=4071.

Sample Calculations

(1722 rev - 431 rev) (.138 gals/rev) = 178.16 gals.

(56.5" - 47.25") (17.24) = 159.47 gals.

When the waste run tank was down to 80" or empty, the filled coating system was stopped so as not to put any virgin filled coating into our 20% mix. The filled coating system was not started again until production of the desired quantity of shingles containing 20% waste had been verified.

Verification

1. The amount of waste pumped determined by the number of pump revolutions, times the pump displacement and the amount determined by the difference in levels, times the volume per inch, for all 3 runs were well within expected accuracy.

2. The pump r.p.m.'s were watched and recorded to verify that the waste pump was following the filled coating mixer system. See Table C-1.

3. The filler content of the coating asphalt containing waste in each trial was within the range calculated for each target mixture of waste and virgin coating.

Energy Consumption

The motor loadings of the waste metering pump, the waste run tank agitator and the raw coating transfer pump were recorded. The waste tank agitator motor is a 20 h.p., 1750 r.p.m., 575 V, 3 ph. The amperage of the motor was recorded on an Amprobe Recorder at a steady 10.5 amps during the trial. These readings were also checked against a hand held ammeter and found to be the same.

$$\text{Kilowatts} = \frac{I \times E \times 1.73}{1000}$$

$$= \frac{(10.5)\,(575)\,(1.73)}{1000}$$

$$= 10.44$$

The waste metering pump motor is a 5 h.p., 1800 r.p.m., Direct Current (D.C.) motor with a 500 volt armature.

$$\text{Kilowatts} = \frac{I \times E}{1000}$$

For the 5% trial the motor amperage averaged 2.85 amps.

$$\text{Kilowatts} = \frac{2.85 \times 500}{1000}$$

$$\text{Kilowatts} = 1.43$$

For the 10% trial the D.C. motor amperage was recorded at an average of 3.50 amps.

$$\text{Kilowatts} = \frac{3.50 \times 500}{1000} = 1.75$$

For the 20% trial the D.C. motor amperage was recorded and the average found to be 4.20 amps.

$$\text{Kilowatts} = \frac{4.20 \times 500}{1000} = 2.1$$

The raw coating transfer pump motor is a 5 h.p., 1750 r.p.m., 575 V, 3 ph. Instantaneous readings taken during its short time of operation were 3.72 amps.

$$\text{Kilowatts} = \frac{(3.72)\ (575\ (1.73)}{1000} = 3.70$$

It can be concluded that the electrical power used in running this process has some fixed and some variable components:

1. The agitator motor and raw coating pump will run constantly for the duration of a given production schedule.

2. The waste mixture pump, however, varies somewhat with the % of waste in the mixture and will operate only when actually pumping waste to the roofing machine's filled coating system.

The following table summarizes the electrical consumption data for the waste mixing and pumping during the shingle production trial run.

	Waste Percentage		
Motor	5%	10%	20%
Agitator	10.44 KW	10.44 KW	10.44 KW
Raw Coating Transfer Pump	3.70	3.70	3.70
Waste Metering Pump	1.43	1.75	2.10
Total KW/Batch	15.57	15.89	16.24
KW/ton Waste	17.0	11.0	6.2

Energy can be calculated from the above data and the running time to produce each batch.

	Waste Percentage		
	5%	10%	20%
Running Time, Hr			
Agitator*	9.19	14.6	26.7
Transfer Pump*	0.011	0.018	0.033
Metering Pump	0.347	0.277	0.252
KWH			
Agitator	95.9	152.4	278.7
Transfer Pump	0.04	0.07	0.12
Metering Pump	0.50	0.48	0.53
KWH/Batch	96.44	152.95	279.35
Pounds Waste/Batch	1401	2229	4071
KWH/Ton	137.7	137.2	137.2

*Allocated based on pounds of waste.

This additional energy was consumed to produce 690 squares of standard Bird shingles which included 9495 lbs. of waste mixture, or 7701 lbs. of pure reprocessed factory waste.

The agitator motor was "on" during much of the two day melting and dilution of the waste and also during the one day of calibration and set up. This was not typical of a commercial operation with no set up time and the higher enthalpy of freshly processed waste.

Heat Load Calculation to Melt Roofing Scrap and Maintain Temperature of Mix

From the previous discussion, 7701 lbs of reprocessed factory scrap were used during this test. At 75.1% average filler content as determined by "loss on ignition" testing, this scrap would contain 5783.5 lbs filler and 1917.5 lbs asphalt. In addition, 1794 lbs raw asphalt (9495 lbs mixture - 7701 lbs scrap) were added to get a pumpable mixture. These figures will be used along with appropriate specific heats (Cp) for each material to determine Btu input to both melt and maintain temperature of the mixture during the test. Assumptions made for purposes of calculation were:

1. Roofing scrap initial temperature was equal to 40°F temperature of warehouse where melting was conducted, since it had been stored there for several days.

2. Initial temperature of steel in hot oil jacketed melt tank and jacketed double wall asphalt piping was also 40°F, since it was located in the same warehouse.

3. Initial temperature of raw asphalt added to mix was 440°F, since this asphalt is maintained in the plant's existing coating asphalt tanks and would be drawn off existing recirculating asphalt loop.

4. Final temperature of mix was maintained at 450°F during testing.

5. Specific heats of materials were:

   Trap rock filler @ 400°F - Cp = 0.189 Btu/lb - ° F

   Raw coating asphalt @ 450°F - Cp = 0.55 Btu/lb - ° F

   Low carbon steel - Cp = 0.12 Btu/lb - ° F

6. Heat load necessary to maintain temperature of mixture would consist only of heat loss through insulation of piping and melt tank.

Calculations follow.

Heat Load to Raise Temperature of Filler in Scrap

$Q1 = (M)(Cp)(\Delta t)$

Where Q = Heat load in Btu
M = Mass in lbs
Cp = Specific heat in Btu/lb - ° F
Δt = Temperature change in° F

$Q1 = (5783.5\ \text{lb})(0.189\ \text{Btu/lb} - °\text{F})(450°\text{F} - 40°\text{F})$

$Q1 = 448{,}163\ \text{Btu}$

Heat Load to Raise Temperature of Asphalt in Scrap

$Q2 = (M)\ (Cp)\ (\Delta t)$

$Q2 = (1917.5\ lb)\ (0.55\ Btu/lb - {}^\circ F)\ (450^\circ F - 440^\circ F)$

$Q2 = 432{,}396\ Btu$

Heat Load to Raise Temperature of Raw Asphalt Added

$Q3 = (M)\ (Cp)\ (\Delta t)$

$Q3 = (1794\ lb)\ (0.55\ Btu/lb - {}^\circ F)\ (450^\circ F - 440^\circ F)$

$Q3 = 9{,}867\ Btu$

Heat Load to Raise Temperature of Steel Tank & Asphalt Piping

The melt tank was fabricated of 1/4" steel plate and had an inside diameter of 72 inches and inside height of 80 inches. The outer jacket of tank (an outer covering around a 2 inch annular space containing hot oil) was 76 inches in diameter and had an outside height of 82 inches. Computing the surface areas of the steel contained in this tank gives:

Surface area of inside tank	$= 154\ ft^2$
Surface area of outside jacket	$= 167.3\ ft^2$
Area of annular sealing ring at top	$= 3.2\ ft^2$

From manufacturers data - 1/4" steel plate = $10.21\ lb/ft^2$

Therefore:

$Q4 = (M)\ (Cp)\ (\Delta t)$

$$Q4 = [(154\ ft^2 + 167.3\ ft^2 + 3.2\ ft^2)\ (10.21\ lb/ft^2)]\ (0.12\ Btu/lb\ {}^\circ F)\ (450^\circ F - 40^\circ F)$$

$Q4 = 163{,}007\ Btu$ <u>one time heat load</u>

Similarly, the asphalt piping was hot oil jacketed and consisted of 165 ft of 3" schedule 40 steel pipe which was contained within 165 ft of 4" schedule 40 steel pipe jacket.

From manufacturers data - 4" sch. 40 pipe = 10.79 lb/ft
3" sch. 40 pipe = 7.58 lb/ft

$Q5 = (M)\ (Cp)\ (\Delta t)$

$$Q5 = [(7.58\ lb/ft + 10.79\ lb/ft)\ (165\ ft)]\ (0.12\ Btu/lb\text{-}{}^\circ F)\ (450^\circ F - 40^\circ F)$$

$Q5 = 149{,}128\ Btu$ <u>one time heat load</u>

Heat Load to Maintain Temperature of Mixture

Mixture was melted starting at 1:00 pm on Friday, December 16, 1988, and mixture was held at 450°F temperature through completion of test run on Tuesday, December 20, 1988. This would give a figure of 96 hours during which mixture temperature was maintained.

The melt tank was insulated with 2" thick calcium silicate insulation with an aluminum protective covering.

From tables published by Johns Manville Insulation, heat loss for this insulation system would be 58 Btu/ft^2/hr.

$$Q6 = \left(58\ \frac{\text{Btu/ft}^2}{\text{hr}}\right)(154\ \text{ft}^2 + 167.3\ \text{ft}^2 + 3.2\ \text{ft}^2)(96\ \text{hr})$$

$$Q6 = 1{,}806{,}816\ \text{Btu's Total or } 18{,}821\ \text{Btu/hr}$$

The jacketed asphalt pipe was insulated with 2" fiberglass insulation with a paper covering. From tables published by Johns Manville Insulation, heat loss for this insulation system would be 102 Btu/ft/hr.

$$Q7 = \left(102\ \frac{\text{Btu/ft}}{\text{hr}}\right)(165\ \text{ft})(96\ \text{hr})$$

$$Q7 = 1{,}615{,}680\ \text{Btu's Total or } 16{,}830\ \text{Btu/hr}$$

This piping heat loss would be reduced by more than 60% on a full scale system due to a combination of the shorter piping runs and higher insulation values that would be utilized on a commercial scale system.

Total Heat Energy Usage During Testing

$$Q\ \text{Total} = Q1 + Q2 + Q3 + Q4 + Q5 + Q6 + Q7$$

$$Q\ \text{Total} = 448{,}163\ \text{Btu} + 432{,}396\ \text{Btu} + 9{,}867\ \text{Btu} + 163{,}007\ \text{Btu} + 149{,}128\ \text{Btu} + 1{,}806{,}816\ \text{Btu} + 1{,}615{,}680\ \text{Btu}$$

$$Q\ \text{Total} = 4{,}625{,}057\ \text{Btu}$$

In summary, it can be said that approximately 94 Btu's/lb [(448+432+10M Btu's) /9495 lbs] were used in this trial run to melt the processed scrap and raise it to the operating temperature, and line losses of approximately 36000 Btu's/hr occurred in the storage and piping system.

On a full scale commercial factory waste processing system, there would be a reduced melting load since the reprocessing machinery would deliver the processed scrap to the filled coating system at 200° F ±20° F.

Some additional heat energy is added via frictional heat and the temperature control system of the Banbury^R/Roll Mill equipment (see estimate below). Also, the additional storage tank and piping required to complete this system will require heat input through hot oil or steam jacketing, and there will be some net energy increase as a result of these "line losses".

The following chart summarizes the heat energy requirements of a full scale commercial installation:

Operation/Source	Btu's/Lb	Btu's/Hr @ 6600 tons/yr	Btu's/Hr @ 11000 tons/yr	Btu's/Hr @ 15400 tons/yr
1. Banbury[R]/Roll Mill Reprocessing Btu's	4.5 (est)	20000 (est)	33200 (est)	45500 (est)
2. Reprocessed Scrap Melting Btu's	55	145000	242000	339000
3. Storage & Piping Heat Input (Btu's)	6	25500	25500	25000
Total Heat Energy	65.5	190500	300700	410000

The melting energy may be ignored for calculating national energy savings because the waste is replacing virgin raw materials, which must also be heated up to the factory process temperature. The net heat energy, 10.5 Btu/lb, can be added to the previously reported electrical energy to arrive at a total process energy use of 245 Btu/lb.

TABLE C-3

RECYCLED FIBERGLASS ROOFING WASTE OF 0%, 5%, 10%, AND 20%
IN THE FILLED ASPHALT COATING MANUFACTURED INTO
WIND SEAL 80 SHINGLES

BIRD INSPECTOR'S DATA OF WOOD BLENDE, WIND SEAL 80 SHINGLES ON
12 /19/89 AND 12/20/89

		Std. Product 0% Experiment (12/19/88)	Waste 5% Experiment (12/20/88)	Waste 10% Experiment (12/20/88)	Waste 20% Experiment (12/20/88)	Comments
IDENTITY		0 Experiment	5 Experiment	10 Experiment	20 Experiment	
PRODUCT WEIGHT, lbs/ sq.	Average	219	220	218	218	Within Normal Mfg. Variance
PRODUCTION QUANTITY, sqs.		200	210	209	271	
EMBEDDING EXPOSED, g.	Average	0.5	0.8	0.5	0.7	No Significant Change
LENGTH, 36", in.	Lane 1	0	0			No Variation
	Lane 2	0	0	- 1/16	0	
	Lane 3			- 1/16	0	
	Lane 4					
	Lane 5					
WIDTH, 12", in.	Lane 1	0	0	0	0	No Variation
	Lane 2	0	0			
	Lane 3	0	0			
	Lane 4	0	0			
	Lane 5	0	0	0	0	
PERCENT FILLER, %, On Line Tests	Average	63.4	62.5	62	62.6	

TABLE C-4

RECYCLED FIBERGLASS ROOFING WASTE OF 0%, 5%, 10%, AND 20% IN THE FILLED ASPHALT COATING MANUFACTURED INTO WIND SEAL 80 SHINGLES

AUDIT OF WOOD BLENDE, WIND SEAL 80 SHINGLES, ONE MONTH AFTER PRODUCTION

		Std. Product 0% Experiment (12/19/88)	Waste 5% Experiment (12/20/88)	Waste 10% Experiment (12/20/88)	Waste 20% Experiment (12/20/88)	Comments
IDENTITY		0 Experiment	5 Experiment	10 Experiment	20 Experiment	
EMBEDDING EXPOSED, g.	Average	0.4	0.7	0.8	0.8	No Significant Change
40F Mandrel Bend, (1.5" Dia. Mandrel)	Lane 1	54 6 Sl. Cracks 1 Mod. Cracks 3 Ser. Cracks	52 6 Sl. Cracks 2 Mod. Cracks 2 Ser. Cracks	48 7 Sl. Cracks 2 Mod. Cracks 1 Ser. Cracks	48 7 Sl. Cracks 2 Mod. Cracks 1 Ser. Cracks	The Smaller Number Means More Flexible
	Lane 3	46 8 Sl. Cracks 1 Mod. Cracks 1 Ser. Cracks	58 4 Sl. Cracks 3 Mod. Cracks 3 Ser. Cracks	48 7 Sl. Cracks 2 Mod. Cracks 1 Ser. Cracks	52 6 Sl. Cracks 2 Mod. Cracks 2 Ser. Cracks	
	Lane 5	52 5 Sl. Cracks 4 Mod. Cracks 1 Ser. Cracks	56 5 Sl. Cracks 2 Mod. Cracks 3 Ser. Cracks	50 6 Sl. Cracks 3 Mod. Cracks 1 Ser. Cracks	50 7 Sl. Cracks 1 Mod. Cracks 2 Ser. Cracks	
	Average	52 6 Sl. Cracks 2 Mod. Cracks 2 Ser. Cracks	56 5 Sl. Cracks 2 Mod. Cracks 3 Ser. Cracks	48 7 Sl. Cracks 2 Mod. Cracks 1 Ser. Cracks	50 7 Sl. Cracks 1 Mod. Cracks 2 Ser. Cracks	No Significant Change

TABLE C-5

RECYCLED FIBERGLASS ROOFING WASTE OF 0%, 5%, 10%, AND 20% IN THE FILLED ASPHALT COATING MANUFACTURED INTO WIND SEAL 80 SHINGLES

ASPHALT COATING PROPERTIES OF 12/19/88 AND 12/20/88

	Unfilled Coating Asphalt	Melt & Mix Tank Waste & Asphalt Ctg.	Std. Product 0% Experiment (12/19/88)	Waste 5% Experiment (12/20/88)	Waste 10% Experiment (12/20/88)	Waste 20% Experiment (12/20/88)
IDENTITY			0 Experiment	5 Experiment	10 Experiment	20 Experiment
SOFT'G. PT. F	213 - 214	261	236	235	237	240
PEN. @ 77 F	18.5-19.5					
PERCENT FILLER, % (Ctg. Samples, Post Production Audit)		60.9	63.1	61.5	61.4	62.8
BROOKFIELD VISCOSITY, cps						
@350F		69, 642	18, 784	17, 692	17, 622	21, 722
@400F		9, 932	4, 184	4, 207	3,' 959	4, 454
@425F		4, 488	2, 815	2, 405	3, 054	3, 984
@450F		2, 389	2, 152	2, 490	2, 751	2, 815
TEMP. IN MELT & MIX TANK, F		440-470	- -	440-450	440-450	470
WASTE AMOUNT IN MELT & MIX TANK, lbs		10, 000				
ASPHALT CTG. IN MELT & MIX TANK, F		2, 379				
CAL PERCENT FILLER IN MELT & MIX TANK, F		60.6				
% SOLIDS IN RECYCLED WASTE, %		Approx. 75				

TABLE C-6

RECYCLED FIBERGLASS ROOFING WASTE OF 0%, 5%, 10%, AND 20% IN THE FILLED ASPHALT COATING MANUFACTURED INTO WIND SEAL 80 SHINGLES

		ROOFING MACHINE CONDITIONS OF 12/19/88 AND 12/20/88			
		Std. Product 0% Experiment (12/19/88)	Waste 5% Experiment (12/20/88)	Waste 10% Experiment (12/20/88)	Waste 20% Experiment (12/20/88)
IDENTITY		0 Experiment	5 Experiment	10 Experiment	20 Experiment
MACHINE SPEED, fpm		430-450	286-403	318-406	258-418
1st SET OF SQUEEZE ROLL, psi	Front	Normal	No Change	No Change	No Change
	Back	Normal	No Change	No Change	No Change
2nd SET OF SQUEEZE ROLLS, psi	Front	Normal	No Change	No Change	No Change
	Back	Normal	No Change	No Change	No Change
TEMP. IN MELT & MIX TANK, F			440-450	440-450	470
TEMP. OF COATING IN BASKET, F		410	425-430 (15F-20F Higher)	425 (Same as 5% Waste Run)	435-440 (25F-30F Higher)
TEMP. OF VERTICAL MIXER, F		430	460 (30F Higher)	460 (30F Higher)	485 (45F Higher)
WATER SPRAYS SETINGS		Normal	No Change	No Change	No Change
PRODUCT WEIGHT & BACK COATING		Standard	No Change	No Change	No Change

APPENDIX D

SHINGLE TESTING DATA

TABLE D-1: SHINGLE TESTING DATA

SAMPLE	% WASTE	TEMPERATURE	TEAR STRENGTH MD	TEAR STRENGTH CD
1	0	30	928	1248
2	0	30	1056	1280
3	0	30	1120	1216
4	0	30	1248	1344
5	0	30	1088	1152
6	0	30	1120	1280
7	0	30	992	1440
8	0	30	1056	1408
9	0	30	1312	1216
10	0	30	1120	1216
11	5	30	1024	1088
12	5	30	992	1184
13	5	30	1120	1344
14	5	30	1056	1216
15	5	30	1120	1088
16	5	30	1280	960
17	5	30	1248	1280
18	5	30	1056	1312
19	5	30	1024	1344
20	5	30	1184	1216
21	10	30	832	992
22	10	30	1344	1152
23	10	30	1120	992
24	10	30	928	1216
25	10	30	1152	1376
26	10	30	1376	1280
27	10	30	928	1376
28	10	30	1376	1440
29	10	30	928	1120
30	10	30	960	1280
31	20	30	1088	1408
32	20	30	1184	1408
33	20	30	1056	1120
34	20	30	1152	1344
35	20	30	1248	1248
36	20	30	1152	1248
37	20	30	1056	1472
38	20	30	1088	1056
39	20	30	1152	1312
40	20	30	1248	1248
41	0	70	1056	1248
42	0	70	1120	1568
43	0	70	1088	1376
44	0	70	1152	1696
45	0	70	1152	1408
46	0	70	1312	1280

SAMPLE	% WASTE	TEMPERATURE	TEAR STRENGTH MD	TEAR STRENGTH CD
47	0	70	1280	960
48	0	70	1344	1344
49	0	70	1280	1312
50	0	70	1216	1600
51	5	70	1280	1216
52	5	70	1120	1344
53	5	70	1280	1280
54	5	70	1024	1248
55	5	70	1440	1216
56	5	70	1120	1376
57	5	70	1440	1312
58	5	70	1280	1472
59	5	70	1216	1632
60	5	70	1248	1248
61	10	70	1120	1088
62	10	70	992	1536
63	10	70	1024	1120
64	10	70	1120	1120
65	10	70	1056	1664
66	10	70	1152	1280
67	10	70	1088	1600
68	10	70	1536	1248
69	10	70	1440	1184
70	10	70	1056	1184
71	20	70	1312	1152
72	20	70	1312	992
73	20	70	1152	1216
74	20	70	1280	1376
75	20	70	960	1280
76	20	70	1536	1120
77	20	70	1120	1376
78	20	70	1248	1248
79	20	70	1120	1632
80	20	70	1152	1152

SAMPLE	TENSILE LOAD MD	TENSILE LOAD CD	% STRAIN MD	% STRAIN CD	NAIL PULL	NAIL PULL,1 LANE
1	80.000	78.6667	1.40	1.71	.	.
2	100.000	84.3333	2.08	1.89	.	.
3	88.333	70.6667	1.89	1.40	.	.
4	98.000	77.0000	1.89	1.65	.	.
5	90.000	74.6667	1.95	1.71	.	.
6	99.333	71.3333	2.01	1.65	.	.
7	98.000	85.3333	1.83	1.89	.	.
8	97.000	82.6667	1.89	1.83	.	.
9	100.333	83.0000	2.01	1.95	.	.
10	81.000	68.0000	1.65	1.47	.	.
11	87.667	61.0000	1.71	1.37	.	.
12	88.000	74.3333	1.89	1.71	.	.
13	104.667	70.0000	2.08	1.71	.	.
14	90.667	63.0000	1.74	1.50	.	.
15	100.667	73.6667	2.14	1.80	.	.
16	98.333	56.0000	2.04	1.25	.	.
17	88.333	62.6667	1.83	1.47	.	.
18	92.000	60.0000	1.74	1.34	.	.
19	90.333	68.0000	1.80	1.62	.	.
20	94.333	66.0000	1.86	1.83	.	.
21	96.667	73.6667	2.14	1.89	.	.
22	103.667	66.6667	2.26	1.71	.	.
23	101.000	64.0000	2.26	1.59	.	.
24	71.667	64.0000	1.62	1.59	.	.
25	87.667	74.0000	1.92	1.98	.	.
26	84.667	81.6667	1.92	2.04	.	.
27	90.333	71.3333	2.08	1.65	.	.
28	104.667	71.6667	2.08	1.62	.	.
29	86.000	77.3333	1.80	1.83	.	.
30	98.000	77.3333	2.17	1.92	.	.
31	87.333	63.3333	1.89	1.59	.	.
32	89.000	74.6667	2.01	1.83	.	.
33	69.667	74.0000	1.50	1.92	.	.
34	107.333	71.6667	2.11	1.59	.	.
35	107.667	64.6667	2.14	1.47	.	.
36	91.667	59.3333	2.04	1.56	.	.
37	109.000	70.0000	2.29	1.65	.	.
38	96.000	64.3333	2.01	1.28	.	.
39	99.333	64.0000	2.04	1.86	.	.
40	81.000	69.0000	1.71	1.62	.	.
41	69.333	54.3333	2.32	2.32	6.9	8.1
42	69.000	53.3333	2.75	2.44	5.9	5.1
43	70.667	59.0000	2.56	2.38	6.0	4.8
44	62.667	54.3333	2.20	2.20	6.8	5.6
45	78.667	48.3333	2.32	2.08	7.1	5.0
46	69.333	57.6667	2.32	2.44	6.5	4.0
47	62.3333	48.0000	2.26	2.08	7.9	7.1
48	65.6667	57.3333	2.44	2.38	6.9	5.6
49	68.0000	57.6667	2.50	2.44	7.0	6.2
50	68.6667	49.6667	2.75	2.26	6.3	7.0
51	76.6667	56.6667	2.20	2.62	6.1	5.6
52	73.0000	51.3333	2.50	2.20	9.8	6.7

SAMPLE	TENSILE LOAD MD	TENSILE LOAD CD	% STRAIN MD	% STRAIN CD	NAIL PULL	NAIL PULL,1 LANE
53	73.0000	55.6667	2.14	1.95	6.9	3.9
54	72.3333	54.3333	2.32	1.95	6.5	4.2
55	72.0000	59.0000	2.20	2.62	7.5	6.5
56	69.0000	46.6667	2.56	1.89	7.7	5.4
57	77.3333	45.3333	2.38	1.89	7.5	6.7
58	.	40.6667	.	1.77	7.3	5.6
59	66.3333	56.6667	2.26	3.05	10.0	3.6
60	73.0000	55.3333	2.50	2.26	5.8	3.6
61	42.6667	48.3333	1.28	2.20	6.2	8.2
62	58.6667	58.6667	2.38	2.50	6.6	5.3
63	72.3333	60.0000	2.50	2.50	9.8	7.0
64	49.0000	60.3333	1.71	2.20	8.2	5.5
65	68.0000	61.6667	2.14	2.44	5.7	4.6
66	74.6667	61.6667	2.62	2.50	6.7	7.4
67	68.3333	55.6667	2.50	2.38	7.3	6.9
68	66.6667	65.0000	2.44	2.44	8.9	6.1
69	66.0000	62.6667	2.56	2.69	8.1	6.2
70	71.0000	61.3333	2.81	2.44	7.9	6.7
71	58.0000	54.6667	1.89	2.01	5.8	8.3
72	77.3333	63.3333	2.38	2.62	5.8	6.7
73	59.3333	62.0000	2.14	2.44	6.9	6.4
74	75.6667	67.3333	2.32	2.62	4.6	6.2
75	53.0000	60.3333	1.95	2.44	4.4	5.3
76	63.3333	55.3333	2.38	2.08	5.1	5.5
77	59.3333	54.0000	1.89	2.08	5.9	9.3
78	68.3333	57.6667	2.20	2.62	.	7.3
79	68.6667	49.0000	2.20	2.44	5.0	6.7
80	71.6667	48.0000	2.32	2.08	3.1	6.5

TABLE D-2: WIND RESISTANCE OF SHINGLES

Observations at 70-75F

	0% Waste	5% Waste	10% Waste	20% Waste
22 mph	----------------------no activity----------------------			
28 mph	----------------------no activity----------------------			
33 mph	-------------------shingle tab lifted-------------------			

Observations at 30-35F

22 mph	no activity	no activity	no activity	sl. fluttering
28 mph	no activity	sl. fluttering	no activity	sl. fluttering
33 mph	-------------------shingle tab lifted-------------------			
44 mph	1 in lift	1 in lift	1 1/2 in lift	2 1/2 in lift
57 mph	2 in lift	2 in lift	3 in lift	3 1/2 in lift
66 mph	3 1/4 in lift	1 in tear	4 1/2 in lift	5 in lift
75 mph	2 nails pulled through	1 nail pulled through	three tears up to 4 in	1 nail pulled through

TABLE D-3 FIRE RESISTANCE OF SHINGLES

	Percent Waste in Asphalt			
	0%	5%	10%	20%
Spread of Flame				
1	5 ft	5 ft 10 in	5 ft 4 in	5 ft
2	4 ft 3 in	5 ft 10 in	5 ft 6 in	5 ft 8 in
3	4 ft 6 in	.	.	.
Burning Brand, Class A	---------------------no failures------------------------			

TABLE D-4 DIMENSIONAL STABILITY

	Percent Waste in Asphalt											
	0			5			10			20		
	a	b	c	a	b	c	a	b	c	a	b	c
Weight, gr												
0days	462.0	479.0	445.5	473.5	474.0	490.5	476.5	476.5	469.5	495.5	491.5	477.0
1	467.5	487.5	453.5	480.5	483.5	498.5	483.5	483.0	475.0	494.0	499.5	484.5
2	468.0	487.5	453.5	481.5	481.5	499.5	483.0	484.5	476.0	503.5	500.5	487.0
3	470.0	488.5	454.5	484.5	485.5	501.5	486.5	486.0	476.5	506.0	502.0	488.5
4	467.5	490.5	456.5	484.0	484.0	501.5	486.5	486.0	476.5	505.5	500.5	487.5
5	469.0	489.5	454.5	484.0	484.5	501.5	486.5	486.0	480.5	507.5	503.5	488.5
14	473.5	491.5	458.0	486.5	487.5	503.0	489.0	489.5	484.5	509.5	504.5	490.5
21	473.5	492.5	459.5	489.0	488.5	504.5	490.5	490.5	481.0	512.0	506.5	494.0
28	475.0	494.5	461.0	489.5	488.5	505.0	491.5	490.5	482.5	512.5	506.5	494.0
56	478.5	497.5	464.5	491.5	492.5	510.5	495.5	495.5	487.0	516.5	511.5	496.5
Length, in												
0 days						ALL						
1												
2						SAMPLES						
3												
4						MEASURED						
5												
14						32.0 INCHES						
21												
28						AT ALL TIMES						
56												
% Water Absorbed												
0 days	0	0	0	0	0	0	0	0	0	0	0	0
1	1.2	1.7	2.0	1.5	2.0	1.6	1.5	1.4	1.2	(0.3)	1.6	1.8
2	1.3	1.7	2.0	1.7	1.6	1.8	1.4	1.7	1.4	1.6	1.8	2.1
3	1.7	1.9	2.2	2.3	2.4	2.2	2.1	2.0	1.5	2.1	2.1	2.4
4	1.2	2.3	2.7	2.2	2.1	2.2	2.1	2.0	1.5	2.0	1.8	2.2
5	1.5	2.1	2.2	2.3	2.2	2.2	2.1	2.0	2.3	2.4	2.4	2.4
14	2.5	2.5	3.0	2.7	2.8	2.5	2.6	2.7	3.2	2.8	2.6	2.8
21	2.5	2.7	3.4	3.3	3.1	2.9	2.9	2.9	2.4	3.3	3.1	3.6
28	2.8	3.1	3.7	3.4	3.1	3.0	3.1	2.9	2.8	3.4	3.1	3.6
56	3.6	3.8	4.3	3.8	3.9	4.1	4.0	4.0	3.7	4.2	4.1	4.1

TABLE D-5: HANDLEABILITY OF SHINGLES

at 70 - 75 F

Observer 1	No distinguishable difference between lots.
Observer 2	No distinguishable difference between lots.
Observer 3	No distinguishable difference between lots.

at 30 - 35 F

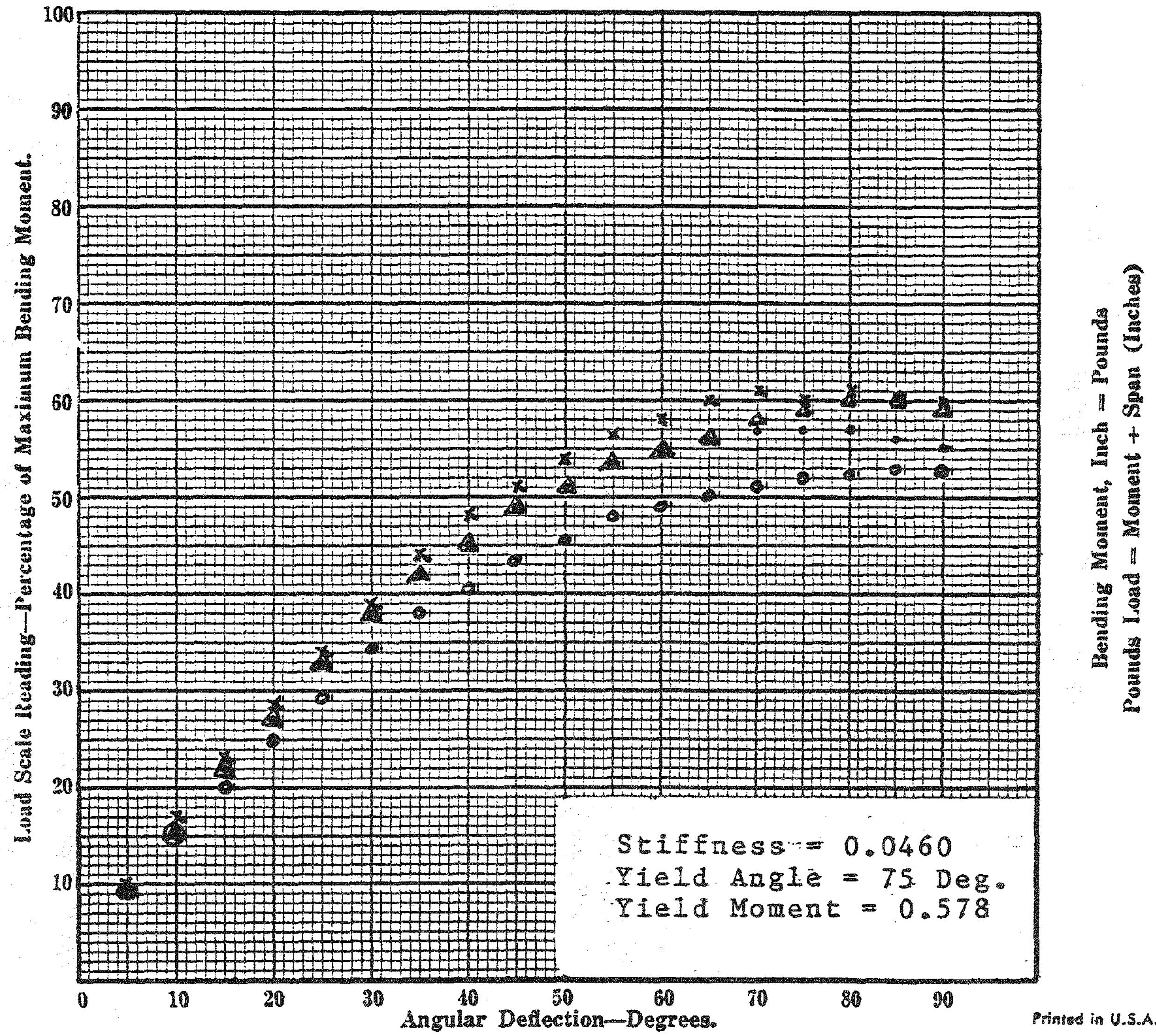
Observer 1	0%	Fair to good.
	5%	Fair, some damage.
	10%	Fair to good.
	20%	Fair to poor.
Observer 2	0%	Fair, moderate damage, worst of lot.
	5%	Fair to good, moderate damage.
	10%	Good, slight damage, best of lot.
	20%	Fair to good, moderate damage.
Observer 3	0%	OK, somewhat more flexible than others.
	5%	Can be applied with care, slightly damage prone.
	10%	Same as 5%.
	20%	Same as 5%.

STIFFNESS TEST RECORD

TINIUS OLSEN TOUR-MARSHAL TESTER (1.25in.lb.)6in.lb CAPACITY

Specimen Control 0% waste. CD dir. 72 deg. F

For DOE/ID/12795 Date 2-9-89



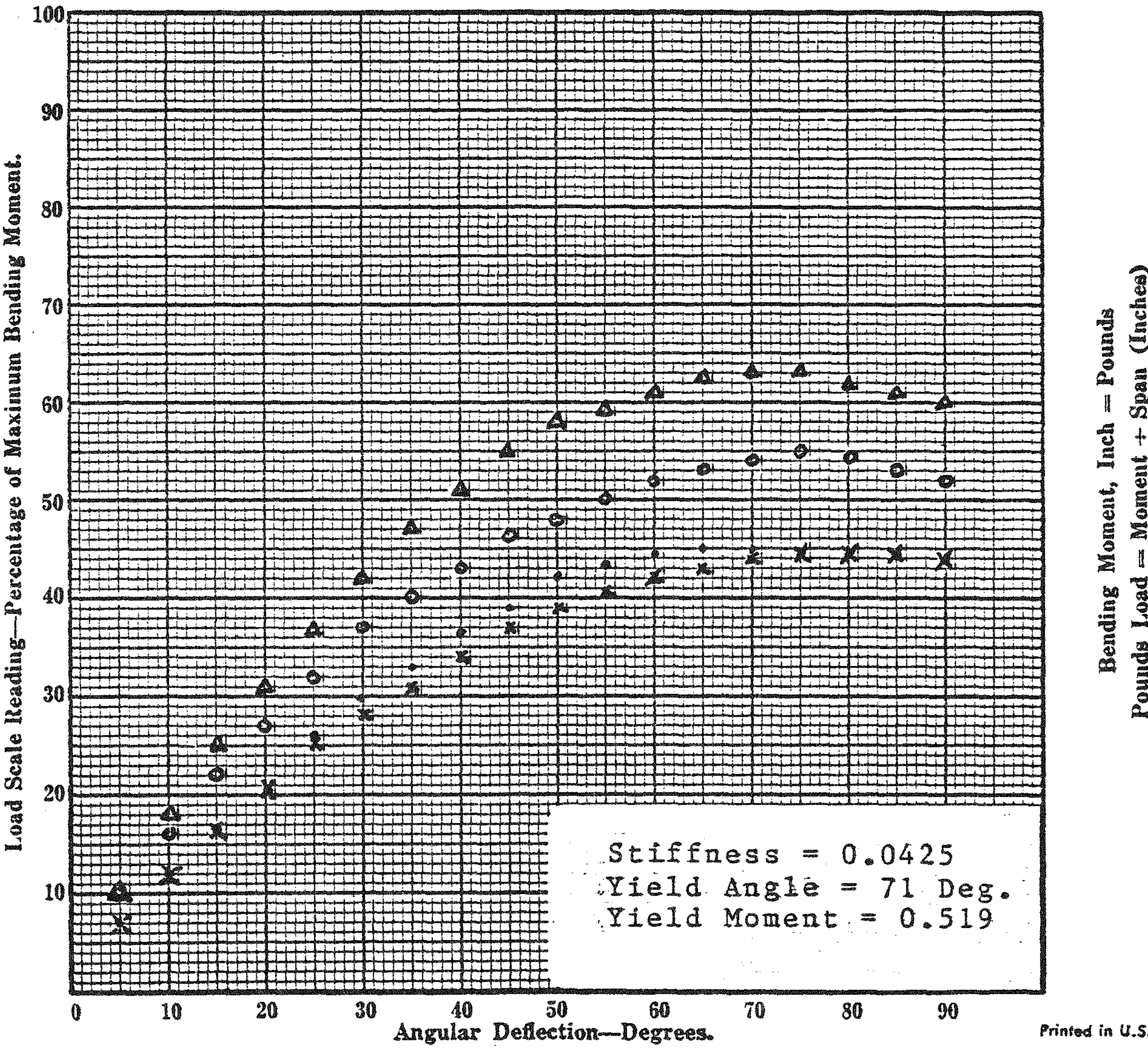
Printed in U.S.A.

STIFFNESS TEST RECORD

TINIUS OLSEN TOUR-MARSHAL TESTER (1.25in.lb.) 6in.lb CAPACITY

Specimen 5% waste CD dir. 72 deg. F

For DOE/ID/12795 Date 2-9-89



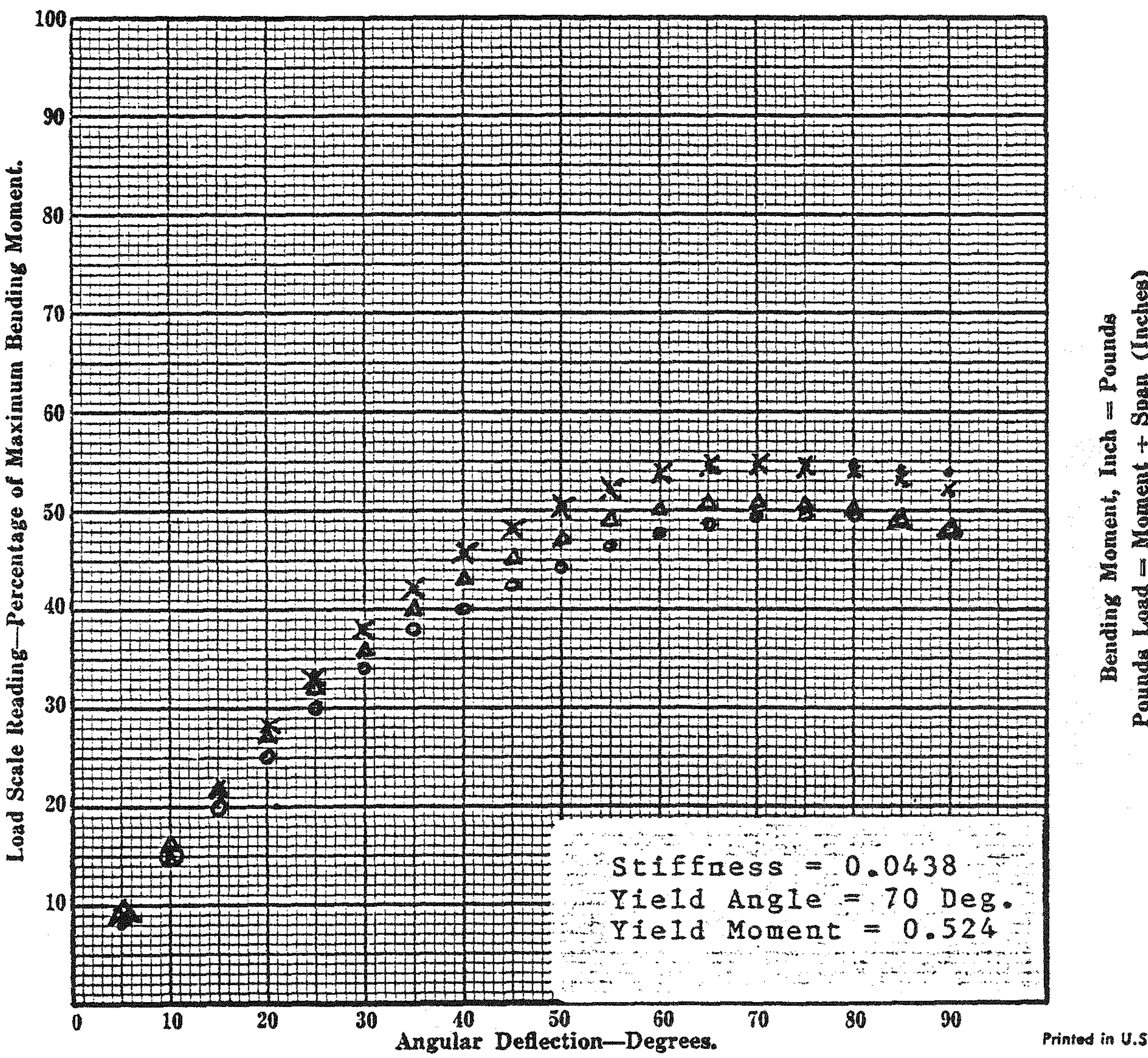
Printed in U.S.A.

STIFFNESS TEST RECORD

TINIUS OLSEN TOUR-MARSHAL TESTER (1.25in.lb.) 6in.lb CAPACITY

Specimen 10% waste CD dir. 72 deg. F

For DOE/ID/12795 Date 2-9-89



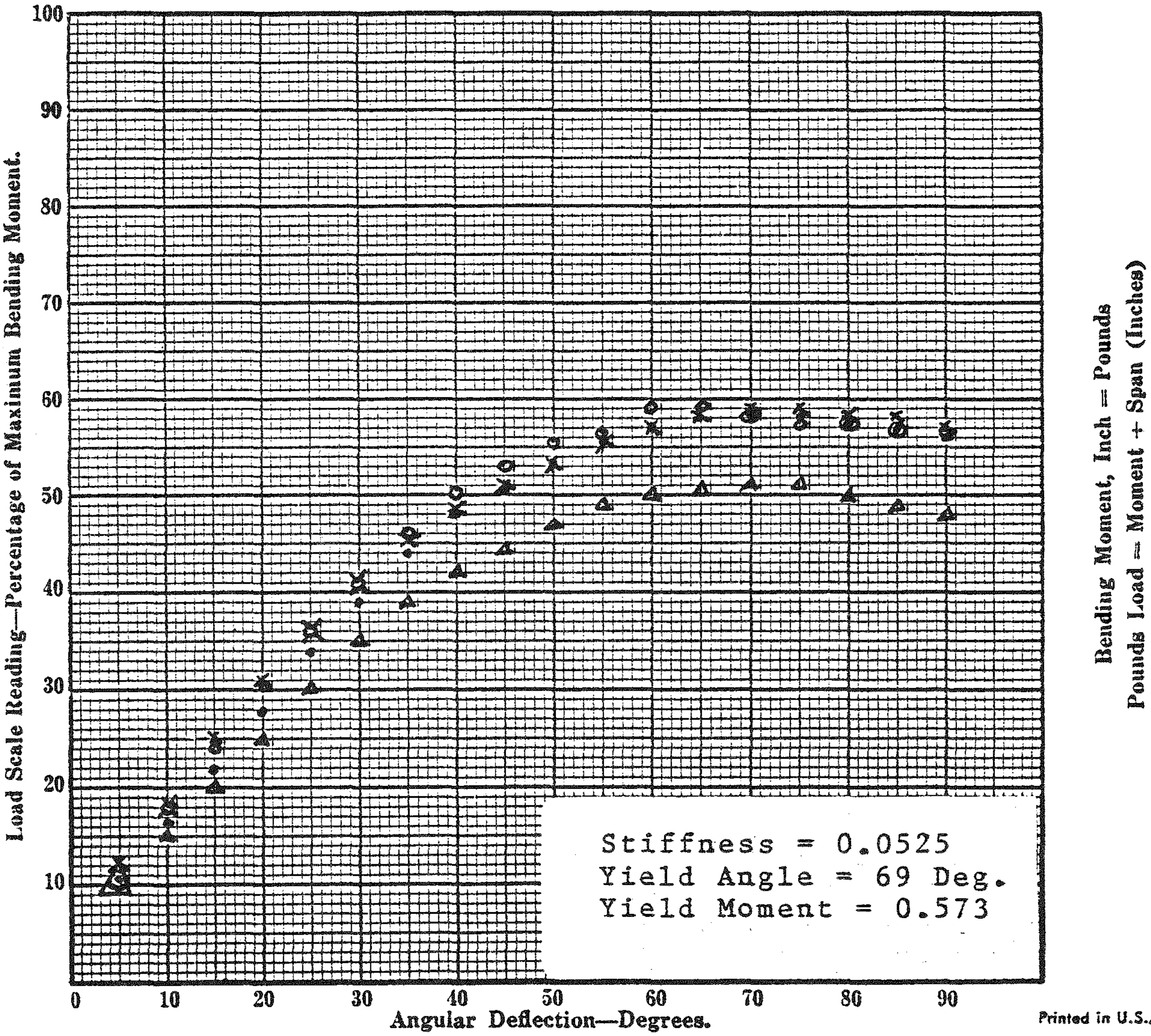
Printed in U.S.A.

STIFFNESS TEST RECORD

TINIUS OLSEN TOUR-MARSHAL TESTER (1.25in.lb.) 6in.lb CAPACITY

Specimen 20% waste CD dir. 72 deg. F

For DOE/ID/12795 Date 2-9-89



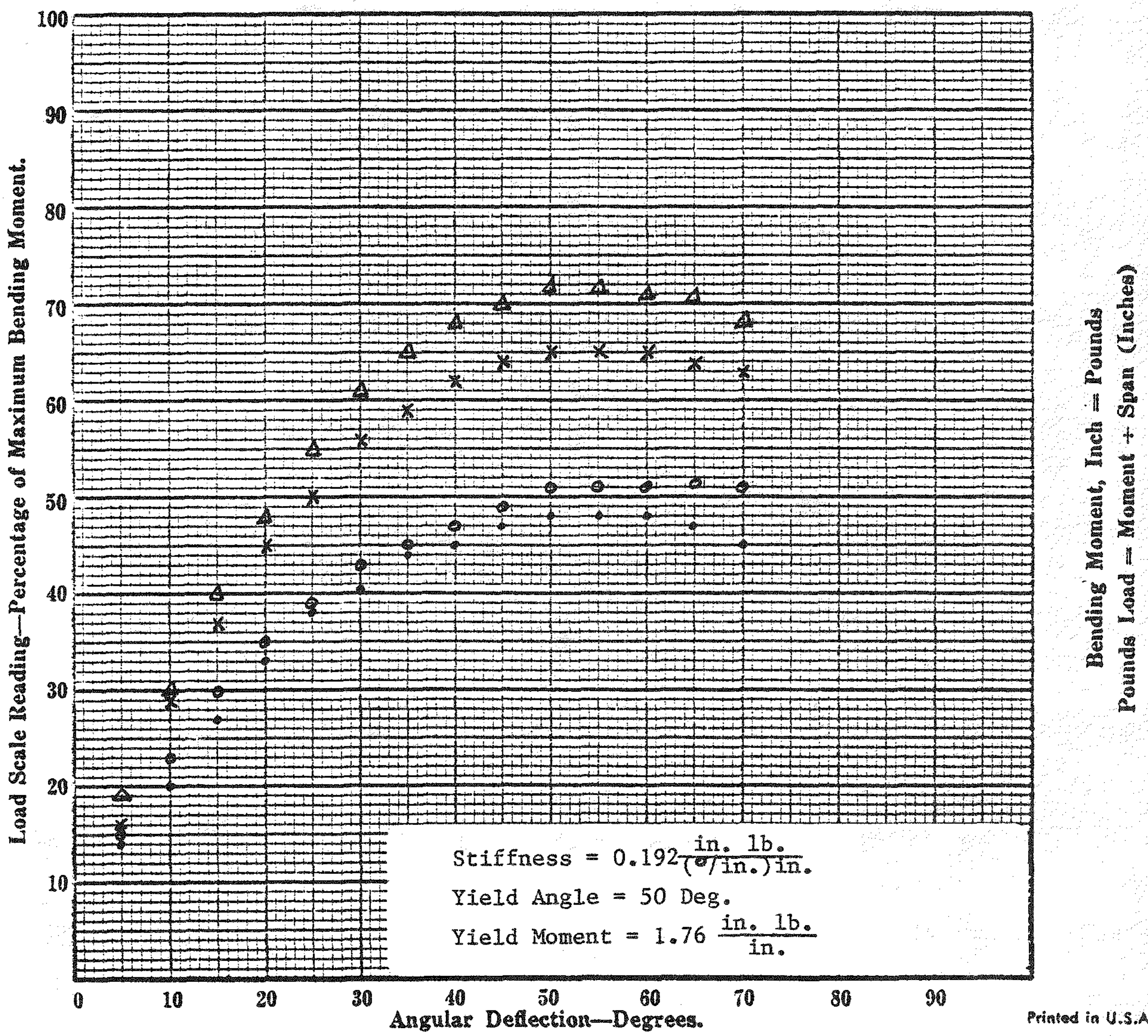
Printed in U.S.A.

STIFFNESS TEST RECORD

TINIUS OLSEN TOUR-MARSHAL TESTER (3.0 in. lb.) 6 in. lb. CAPACITY

Specimen Control 0% Waste CD Dir. 30/35 Deg. F

For DOE/ID/12795 Date 3-16-89



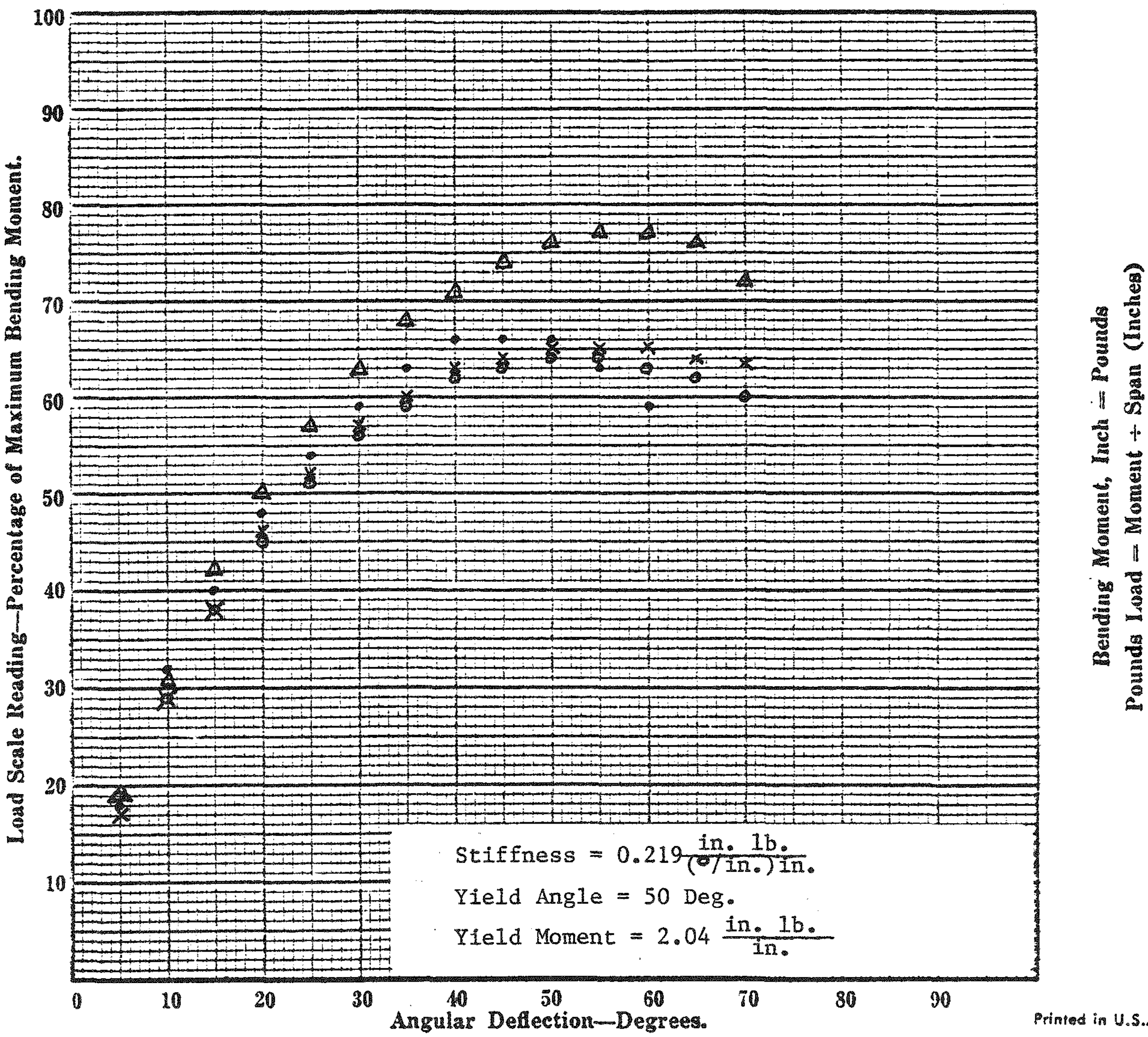
Printed in U.S.A.

STIFFNESS TEST RECORD

TINIUS OLSEN TOUR-MARSHAL TESTER (3.0 in. lb.) 6 in. lb. CAPACITY

Specimen 5% Waste CD Dir. 30/35 Deg. F

For DOE/ID/12795 Date 3-16-89



Stiffness = 0.219 $\frac{\text{in. lb.}}{(°/\text{in.})\text{in.}}$

Yield Angle = 50 Deg.

Yield Moment = 2.04 $\frac{\text{in. lb.}}{\text{in.}}$

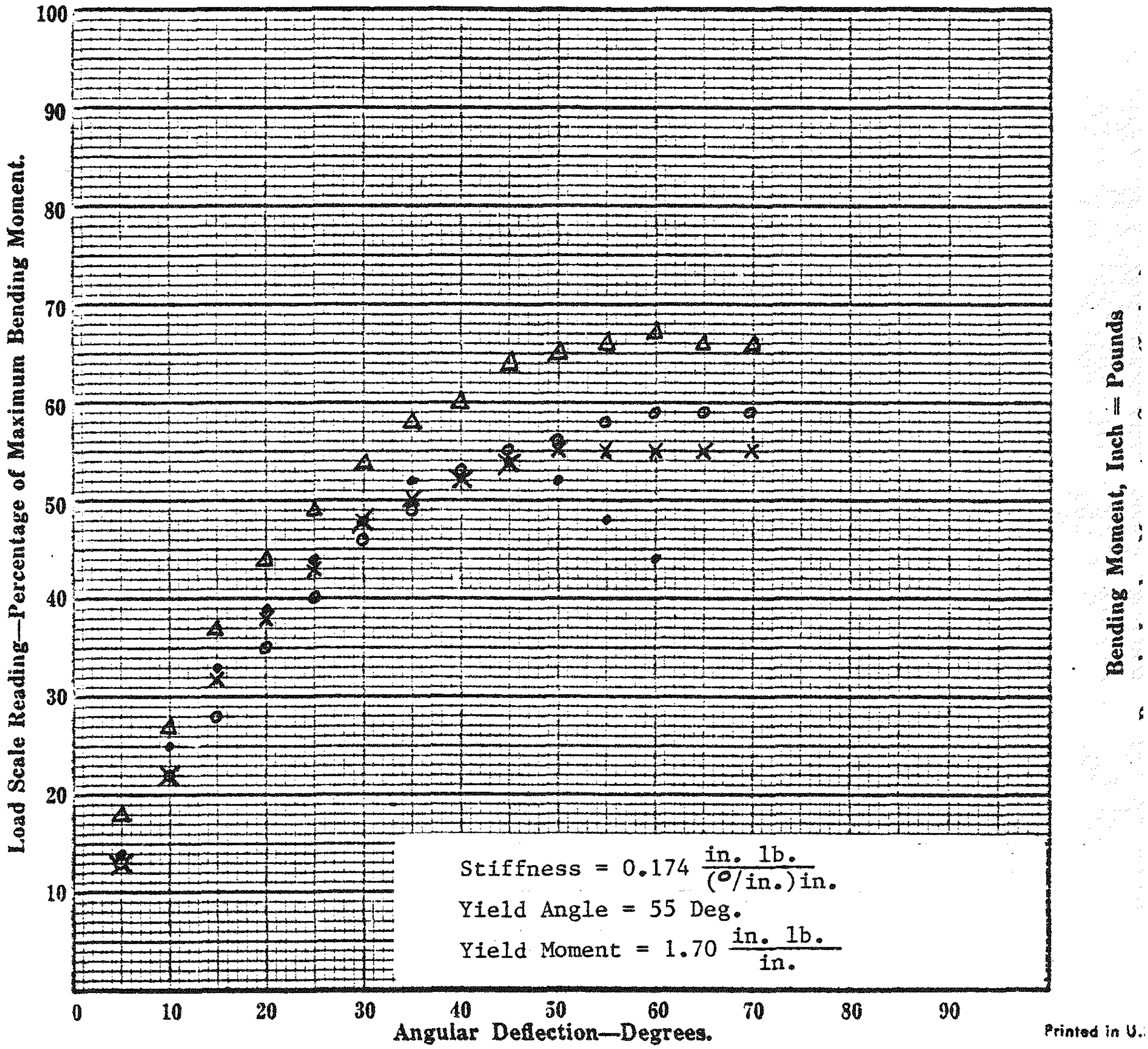
Printed in U.S.A.

STIFFNESS TEST RECORD

TINIUS OLSEN TOUR-MARSHAL TESTER (3.0 in. lb.) 6 in. lb. CAPACITY

Specimen 10% Waste CD Dir. 30/35 Deg. F

For DOE/ID/12795 Date 3-16-89



Stiffness = 0.174 $\frac{\text{in. lb.}}{(^{\circ}/\text{in.})\text{in.}}$

Yield Angle = 55 Deg.

Yield Moment = 1.70 $\frac{\text{in. lb.}}{\text{in.}}$

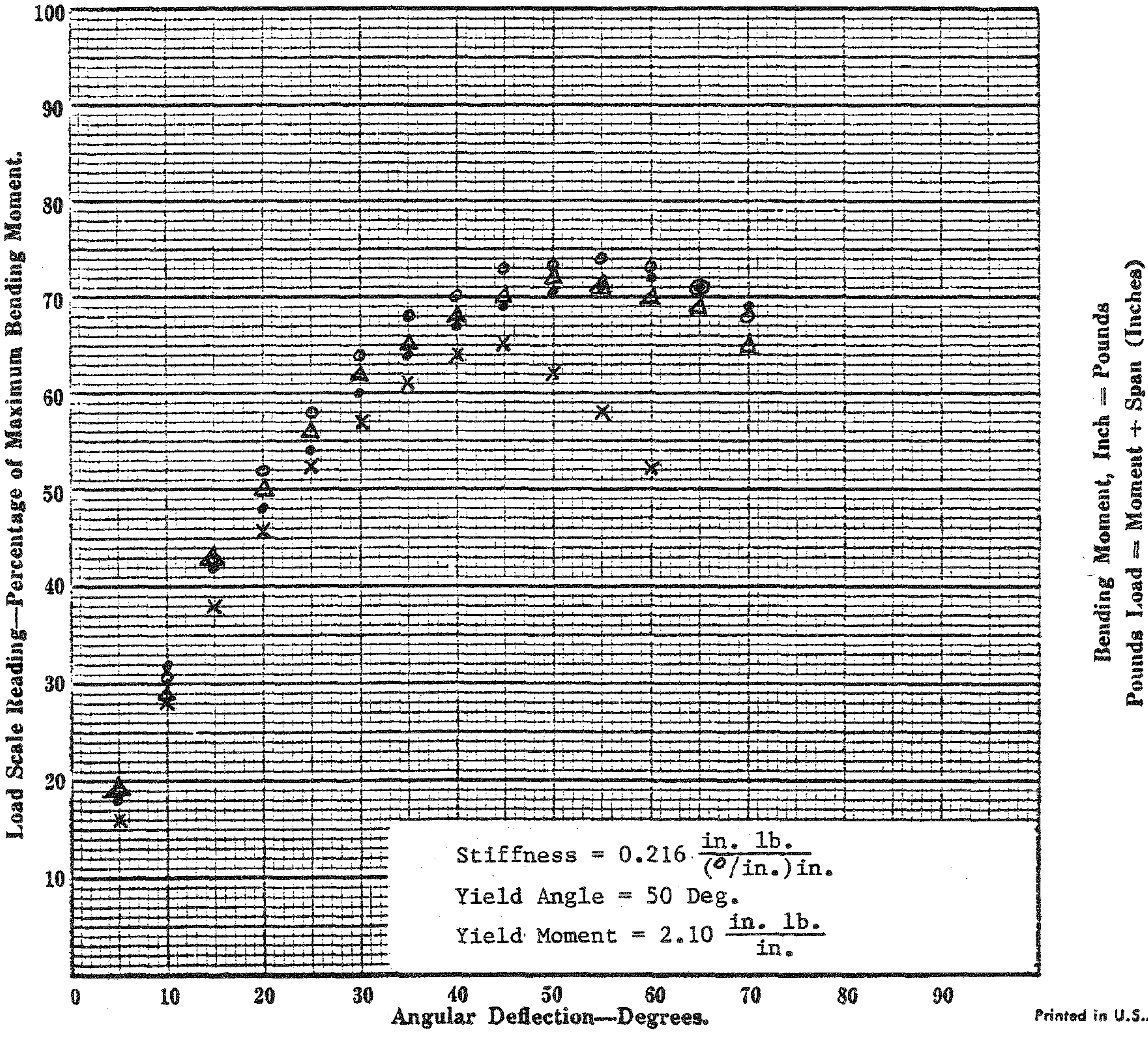
Printed in U.

STIFFNESS TEST RECORD

TINIUS OLSEN TOUR-MARSHAL TESTER (3.0 in. lb.) 6 in. lb. CAPACITY

Specimen 20% Waste CD Dir. 30/35 Deg. F

For DOE/ID/12795 Date 3-16-89



Printed in U.S.A.

TABLE D-6: ACCELERATED WEATHERING TESTS RESULTS

	Number of Exposure Cycles to	
	10% of Surface Cracked	25% of Surface Cracked
Unfilled Coating Asphalt	122	136
Normal Filled Coating Asphalt	113	126
5% Waste in Coating Asphalt	116	126
10% Waste in Coating Asphalt	118	129
20% Waste in Coating Asphalt	113	126

ANALYSIS OF VARIANCE ON SHINGLE DATA

TEMPERATURE = 30

GENERAL LINEAR MODELS PROCEDURE

CLASS LEVEL INFORMATION

CLASS	LEVELS	VALUES
WASTE	4	0 5 10 20

NUMBER OF OBSERVATIONS BY GROUP = 80

ANALYSIS OF VARIANCE ON SHINGLE DATA

TEMPERATURE = 30

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: TEAR_MD TEAR STRENGTH MD

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE
MODEL	3	25958.40000000	8652.80000000
ERROR	76	1282662.40000000	16877.13684211
CORRECTED TOTAL	79	1308620.80000000	

MODEL F = 0.51 PR > F = 0.6748

R-SQUARE	C.V.	ROOT MSE	TEAR_MD MEAN
0.019836	11.6743	129.91203502	1112.80000000

SOURCE	DF	TYPE I SS	F VALUE	PR > F
WASTE	3	25958.40000000	0.51	0.6748

SOURCE	DF	TYPE III SS	F VALUE	PR > F
WASTE	3	25958.40000000	0.51	0.6748

ANALYSIS OF VARIANCE ON SHINGLE DATA

TEMPERATURE = 30

GENERAL LINEAR MODELS PROCEDURE

STUDENT-NEWMAN-KEULS TEST FOR VARIABLE: TEAR_MD

NOTE: THIS TEST CONTROLS THE TYPE I EXPERIMENTWISE ERROR RATE UNDER THE COMPLETE NULL HYPOTHESIS BUT NOT UNDER PARTIAL NULL HYPOTHESES

ALPHA = .01 DF = 76 MSE = 16877.1

NUMBER OF MEANS	2	3	4
CRITICAL RANGE	108.542	123.382	132.264

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

SNK GROUPING	MEAN	N	WASTE
A	1142.40	20	20
A			
A	1110.40	20	5
A			
A	1104.00	20	0
A			
A	1094.40	20	10

ANALYSIS OF VARIANCE ON SHINGLE DATA

TEMPERATURE = 70

GENERAL LINEAR MODELS PROCEDURE

CLASS LEVEL INFORMATION

CLASS	LEVELS	VALUES
WASTE	4	0 5 10 20

NUMBER OF OBSERVATIONS IN BY GROUP = 80

ANALYSIS OF VARIANCE ON SHINGLE DATA

TEMPERATURE = 70

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: TEAR_MD TEAR STRENGTH MD

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE
MODEL	3	79616.00000000	26538.66666667
ERROR	76	1531699.20000000	20153.93684211
CORRECTED TOTAL	79	1611315.20000000	

MODEL F = 1.32 PR > F = 0.2751

R-SQUARE	C.V.	ROOT MSE	TEAR_MD MEAN
0.049411	11.7754	141.96456192	1205.60000000

SOURCE	DF	TYPE I SS	F VALUE	PR > F
WASTE	3	79616.00000000	1.32	0.2751

SOURCE	DF	TYPE III SS	F VALUE	PR > F
WASTE	3	79616.00000000	1.32	0.2751

ANALYSIS OF VARIANCE ON SHINGLE DATA

TEMPERATURE = 70

GENERAL LINEAR MODELS PROCEDURE

STUDENT-NEWMAN-KEULS TEST FOR VARIABLE: TEAR_MD

NOTE: THIS TEST CONTROLS THE TYPE I EXPERIMENTWISE ERROR RATE UNDER THE COMPLETE NULL HYPOTHESIS BUT NOT UNDER PARTIAL NULL HYPOTHESES

ALPHA=.01 DF=76 MSE=20153.9

NUMBER OF MEANS	2	3	4
CRITICAL RANGE	118.612	134.828	144.535

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

SNK GROUPING	MEAN	N	WASTE
A	1244.80	20	5
A			
A	1219.20	20	20
A			
A	1200.00	20	0
A			
A	1158.40	20	10

ANALYSIS OF VARIANCE ON SHINGLE DATA

TEMPERATURE = 30

GENERAL LINEAR MODELS PROCEDURE

CLASS LEVEL INFORMATION

CLASS	LEVELS	VALUES
WASTE	4	0 5 10 20

NUMBER OF OBSERVATIONS IN BY GROUP = 80

ANALYSIS OF VARIANCE ON SHINGLE DATA

TEMPERATURE = 30

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: TEAR_CD TEAR STRENGTH CD

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE
MODEL	3	103219.20000000	34406.40000000
ERROR	76	1191116.80000000	15672.58947368
CORRECTED TOTAL	79	1294336.00000000	

MODEL F =	2.20		PR > F = 0.0955

R-SQUARE	C.V.	ROOT MSE	TEAR_CD MEAN
0.079747	10.0313	125.19021317	1248.00000000

SOURCE	DF	TYPE I SS	F VALUE	PR > F
WASTE	3	103219.20000000	2.20	0.0955

SOURCE	DF	TYPE III SS	F VALUE	PR > F
WASTE	3	103219.20000000	2.20	0.0955

ANALYSIS OF VARIANCE ON SHINGLE DATA

TEMPERATURE = 30

GENERAL LINEAR MODELS PROCEDURE

STUDENT-NEWMAN-KEULS TEST FOR VARIABLE: TEAR_CD

NOTE: THIS TEST CONTROLS THE TYPE I EXPERIMENTWISE ERROR RATE UNDER THE COMPLETE NULL HYPOTHESIS BUT NOT UNDER PARTIAL NULL HYPOTHESES

ALPHA = .01 DF = 76 MSE = 15672.6

NUMBER OF MEANS	2	3	4
CRITICAL RANGE	104.597	118.897	127.457

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

SNK GROUPING	MEAN	N	WASTE
A	1286.40	20	20
A			
A	1280.00	20	0
A			
A	1222.40	20	10
A			
A	1203.20	20	5

ANALYSIS OF VARIANCE ON SHINGLE DATA

TEMPERATURE = 70

GENERAL LINEAR MODELS PROCEDURE

CLASS LEVEL INFORMATION

CLASS	LEVELS	VALUES
WASTE	4	0 5 10 20

NUMBER OF OBSERVATIONS IN BY GROUP = 80

ANALYSIS OF VARIANCE ON SHINGLE DATA

TEMPERATURE = 70

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: TEAR_CD TEAR STRENGTH CD

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE
MODEL	3	166041.60000000	55347.20000000
ERROR	76	2499993.60000000	32894.65263158
CORRECTED TOTAL	79	2666035.20000000	

MODEL F = 1.68 PR > F = 0.1778

R-SQUARE	C.V.	ROOT MSE	TEAR_CD MEAN
0.062280	13.7651	181.36883037	1317.60000000

SOURCE	DF	TYPE I SS	F VALUE	PR > F
WASTE	3	166041.60000000	1.68	0.1778

SOURCE	DF	TYPE III SS	F VALUE	PR > F
WASTE	3	166041.60000000	1.68	0.1778

ANALYSIS OF VARIANCE ON SHINGLE DATA

TEMPERATURE = 70

GENERAL LINEAR MODELS PROCEDURE

STUDENT-NEWMAN-KEULS TEST FOR VARIABLE: TEAR_CD

NOTE: THIS TEST CONTROLS THE TYPE I EXPERIMENTWISE ERROR RATE UNDER THE COMPLETE NULL HYPOTHESIS BUT NOT UNDER PARTIAL NULL HYPOTHESES

ALPHA = .01 DF = 76 MSE = 32894.7

NUMBER OF MEANS	2	3	4
CRITICAL RANGE	151.534	172.252	184.653

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

SNK GROUPING	MEAN	N	WASTE
A	1379.20	20	0
A			
A	1334.40	20	5
A			
A	1302.40	20	10
A			
A	1254.40	20	20

ANALYSIS OF VARIANCE ON SHINGLE DATA

TEMPERATURE = 30

GENERAL LINEAR MODELS PROCEDURE

CLASS LEVEL INFORMATION

CLASS	LEVELS	VALUES
WASTE	4	0 5 10 20

NUMBER OF OBSERVATIONS IN BY GROUP = 80

ANALYSIS OF VARIANCE ON SHINGLE DATA

TEMPERATURE = 30

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: TEN_MD TENSILE LOAD MD

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE
MODEL	3	20.66666667	6.88888889
ERROR	76	6558.97777778	86.30233918
CORRECTED TOTAL	79	6579.64444444	

MODEL F =	0.08		PR > F = 0.9708

R-SQUARE	C.V.	ROOT MSE	TEN_MD MEAN
0.003141	9.9641	9.28990523	93.23333333

SOURCE	DF	TYPE I SS	F VALUE	PR > F
WASTE	3	20.66666667	0.08	0.9708

SOURCE	DF	TYPE III SS	F VALUE	PR > F
WASTE	3	20.66666667	0.08	0.9708

ANALYSIS OF VARIANCE ON SHINGLE DATA

TEMPERATURE = 30

GENERAL LINEAR MODELS PROCEDURE

STUDENT-NEWMAN-KEULS TEST FOR VARIABLE: TEN_MD

NOTE: THIS TEST CONTROLS THE TYPE I EXPERIMENTWISE ERROR RATE UNDER THE COMPLETE NULL HYPOTHESIS BUT NOT UNDER PARTIAL NULL HYPOTHESES

ALPHA = .01 DF = 76 MSE = 86.3023

NUMBER OF MEANS	2	3	4
CRITICAL RANGE	7.76174	8.82293	9.4581

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

SNK GROUPING	MEAN	N	WASTE
A	93.800	20	20
A			
A	93.500	20	5
A			
A	93.200	20	0
A			
A	92.433	20	10

ANALYSIS OF VARIANCE ON SHINGLE DATA

TEMPERATURE = 70

GENERAL LINEAR MODELS PROCEDURE

CLASS LEVEL INFORMATION

CLASS	LEVELS	VALUES
WASTE	4	0 5 10 20

NUMBER OF OBSERVATIONS IN BY GROUP = 80

NOTE: ALL DEPENDENT VARIABLES ARE CONSISTENT WITH RESPECT TO THE PRESENCE OR ABSENCE OF MISSING VALUES. HOWEVER, ONLY 78 OBSERVATIONS CAN BE USED IN THIS ANALYSIS.

ANALYSIS OF VARIANCE ON SHINGLE DATA

TEMPERATURE = 70

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: TEN_MD TENSILE LOAD MD

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE
MODEL	3	836.57796771	78.85932257
ERROR	74	3721.40493827	50.28925592
CORRECTED TOTAL	77	4557.98290598	

MODEL F =	5.55		PR > F = 0.0017

R-SQUARE	C.V.	ROOT MSE	TEN_MD MEAN
0.183541	10.5199	7.09149180	67.41025641

SOURCE	DF	TYPE I SS	F VALUE	PR > F
WASTE	3	836.57796771	5.55	0.0017

SOURCE	DF	TYPE III SS	F VALUE	PR > F
WASTE	3	836.57796771	5.55	0.0017

ANALYSIS OF VARIANCE ON SHINGLE DATA

TEMPERATURE = 70

GENERAL LINEAR MODELS PROCEDURE

STUDENT-NEWMAN-KEULS TEST FOR VARIABLE: TEN_MD

NOTE: THIS TEST CONTROLS THE TYPE I EXPERIMENTWISE ERROR RATE UNDER THE COMPLETE NULL HYPOTHESIS BUT NOT UNDER PARTIAL NULL HYPOTHESES

ALPHA = .01 DF = 74 MSE = 50.2893

WARNING: CELL SIZES ARE NOT EQUAL.
HARMONIC MEAN OF CELL SIZES = 19.4595

NUMBER OF MEANS	2	3	4
CRITICAL RANGE	6.01068	6.83351	7.32613

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

SNK GROUPING		MEAN	N	WASTE
	A	72.519	18	5
	A			
B	A	68.433	20	0
B				
B		65.467	20	20
B				
B		63.733	20	10

ANALYSIS OF VARIANCE ON SHINGLE DATA

TEMPERATURE = 30

GENERAL LINEAR MODELS PROCEDURE

CLASS LEVEL INFORMATION

CLASS	LEVELS	VALUES
WASTE	4	0 5 10 20

NUMBER OF OBSERVATIONS IN BY GROUP = 80

ANALYSIS OF VARIANCE ON SHINGLE DATA

TEMPERATURE = 30

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: TEN_CD TENSILE LOAD CD

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE
MODEL	3	1626.55000000	542.18333333
ERROR	76	2487.44444444	32.72953216
CORRECTED TOTAL	79	4113.99444444	

MODEL F =	16.57		PR > F = 0.0001

R-SQUARE	C.V.	ROOT MSE	TEN_CD MEAN
0.395370	8.0662	5.72097301	70.92500000

SOURCE	DF	TYPE I SS	F VALUE	PR > F
WASTE	3	1626.55000000	16.57	0.0001

SOURCE	DF	TYPE III SS	F VALUE	PR > F
WASTE	3	1626.55000000	16.57	0.0001

ANALYSIS OF VARIANCE ON SHINGLE DATA

TEMPERATURE = 30

GENERAL LINEAR MODELS PROCEDURE

STUDENT-NEWMAN-KEULS TEST FOR VARIABLE: TEN_CD

NOTE: THIS TEST CONTROLS THE TYPE I EXPERIMENTWISE ERROR RATE UNDER THE COMPLETE NULL HYPOTHESIS BUT NOT UNDER PARTIAL NULL HYPOTHESES

ALPHA = .01 DF = 76 MSE = 32.7295

NUMBER OF MEANS	2	3	4
CRITICAL RANGE	4.77989	5.4334	5.82455

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

SNK GROUPING		MEAN	N	WASTE
	A	77.567	20	0
	B	72.167	20	10
	B			
C	B	68.500	20	20
C				
C		65.467	20	5

ANALYSIS OF VARIANCE ON SHINGLE DATA

TEMPERATURE = 70

GENERAL LINEAR MODELS PROCEDURE

CLASS LEVEL INFORMATION

CLASS	LEVELS	VALUES
WASTE	4	0 5 10 20

NUMBER OF OBSERVATIONS IN BY GROUP = 80

ANALYSIS OF VARIANCE ON SHINGLE DATA

TEMPERATURE = 70

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: TEN_CD TENSILE LOAD CD

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE
MODEL	3	646.68333333	215.56111111
ERROR	76	2028.06666667	26.68508772
CORRECTED TOTAL	79	2674.75000000	
MODEL F =	8.08		PR > F = 0.0001

R-SQUARE	C.V.	ROOT MSE	TEN_CD MEAN
0.241773	9.2729	5.16576110	55.70833333

SOURCE	DF	TYPE I SS	F VALUE	PR > F
WASTE	3	646.68333333	8.08	0.0001

SOURCE	DF	TYPE III SS	F VALUE	PR > F
WASTE	3	646.68333333	8.08	0.0001

ANALYSIS OF VARIANCE ON SHINGLE DATA

TEMPERATURE = 70

GENERAL LINEAR MODELS PROCEDURE

STUDENT-NEWMAN-KEULS TEST FOR VARIABLE: TEN_CD

NOTE: THIS TEST CONTROLS THE TYPE I EXPERIMENTWISE ERROR RATE UNDER THE COMPLETE NULL HYPOTHESIS BUT NOT UNDER PARTIAL NULL HYPOTHESES

ALPHA = .01 DF = 76 MSE = 26.6851

NUMBER OF MEANS	2	3	4
CRITICAL RANGE	4.31601	4.9061	5.25929

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

SNK GROUPING		MEAN	N	WASTE
	A	59.533	20	10
	A			
B	A	57.167	20	20
B				
B	C	53.967	20	0
	C			
	C	52.167	20	5

ANALYSIS OF VARIANCE ON SHINGLE DATA

TEMPERATURE = 30

GENERAL LINEAR MODELS PROCEDURE

CLASS LEVEL INFORMATION

CLASS	LEVELS	VALUES
WASTE	4	0 5 10 20

NUMBER OF OBSERVATIONS IN BY GROUP = 80

ANALYSIS OF VARIANCE ON SHINGLE DATA

TEMPERATURE = 30

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: STR_MD % STRAIN MD

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE
MODEL	3	0.35898000	0.11966000
ERROR	76	2.83500000	0.03730263
CORRECTED TOTAL	79	3.19398000	

MODEL F =	3.21		R > F = 0.0277

R-SQUARE	C.V.	ROOT MSE	STR_MD MEAN
0.112393	9.9788	0.19313889	1.93550000

SOURCE	DF	TYPE I SS	F VALUE	PR > F
WASTE	3	0.35898000	3.21	0.0277

SOURCE	DF	TYPE III SS	F VALUE	PR > F
WASTE	3	0.35898000	3.21	0.0277

ANALYSIS OF VARIANCE ON SHINGLE DATA

TEMPERATURE = 30

GENERAL LINEAR MODELS PROCEDURE

STUDENT-NEWMAN-KEULS TEST FOR VARIABLE: STR_MD

NOTE: THIS TEST CONTROLS THE TYPE I EXPERIMENTWISE ERROR RATE UNDER THE COMPLETE NULL HYPOTHESIS BUT NOT UNDER PARTIAL NULL HYPOTHESES

ALPHA = .01 DF = 76 MSE = .0373026

NUMBER OF MEANS	2	3	4
CRITICAL RANGE	0.161368	0.18343	0.196636

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

SNK GROUPING	MEAN	N	WASTE
A	2.02500	20	10
A			
A	1.97400	20	20
A			
A	1.88300	20	5
A			
A	1.86000	20	0

ANALYSIS OF VARIANCE ON SHINGLE DATA

TEMPERATURE = 70

GENERAL LINEAR MODELS PROCEDURE

CLASS LEVEL INFORMATION

CLASS	LEVELS	VALUES
WASTE	4	0 5 10 20

NUMBER OF OBSERVATIONS IN BY GROUP = 80

NOTE: ALL DEPENDENT VARIABLES ARE CONSISTENT WITH RESPECT TO THE PRESENCE OR ABSENCE OF MISSING VALUES. HOWEVER, ONLY 78 OBSERVATIONS CAN BE USED IN THIS ANALYSIS.

ANALYSIS OF VARIANCE ON SHINGLE DATA

TEMPERATURE = 70

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: STR_MD % STRAIN MD

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE
MODEL	3	0.77878000	0.25959333
ERROR	74	5.64282000	0.07625432
CORRECTED TOTAL	77	6.42160000	

MODEL F =	3.40		PR > F = 0.0220

R-SQUARE	C.V.	ROOT MSE	STR_MD MEAN
0.121275	11.9542	0.27614186	2.31000000

SOURCE	DF	TYPE I SS	F VALUE	PR > F
WASTE	3	0.77878000	3.40	0.0220

SOURCE	DF	TYPE III SS	F VALUE	PR > F
WASTE	3	0.77878000	3.40	0.0220

ANALYSIS OF VARIANCE ON SHINGLE DATA

TEMPERATURE = 70

GENERAL LINEAR MODELS PROCEDURE

STUDENT-NEWMAN-KEULS TEST FOR VARIABLE: STR_MD

NOTE: THIS TEST CONTROLS THE TYPE I EXPERIMENTWISE ERROR RATE UNDER THE COMPLETE NULL HYPOTHESIS BUT NOT UNDER PARTIAL NULL HYPOTHESES

ALPHA = .01 DF = 74 MSE = .0762543

WARNING: CELL SIZES ARE NOT EQUAL.
HARMONIC MEAN OF CELL SIZES = 19.4595

NUMBER OF MEANS	2	3	4
CRITICAL RANGE	0.234055	0.266096	0.285278

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

SNK GROUPING	MEAN	N	WASTE
A	2.44200	20	0
A			
A	2.34000	18	5
A			
A	2.29400	20	10
A			
A	2.16700	20	20

ANALYSIS OF VARIANCE ON SHINGLE DATA

TEMPERATURE = 30

GENERAL LINEAR MODELS PROCEDURE

CLASS LEVEL INFORMATION

CLASS	LEVELS	VALUES
WASTE	4	0 5 10 20

NUMBER OF OBSERVATIONS IN BY GROUP = 80

ANALYSIS OF VARIANCE ON SHINGLE DATA

TEMPERATURE = 30

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: STR_CD % STRAIN CD

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE
MODEL	3	0.55418000	0.18472667
ERROR	76	2.52684000	0.03324789
CORRECTED TOTAL	79	3.08102000	
MODEL F =	5.56		PR > F = 0.0017

R-SQUARE	C.V.	ROOT MSE	STR_CD MEAN
0.179869	10.8957	0.18234005	1.67350000

SOURCE	DF	TYPE I SS	F VALUE	PR > F
WASTE	3	0.55418000	5.56	0.0017

SOURCE	DF	TYPE III SS	F VALUE	PR > F
WASTE	3	0.55418000	5.56	0.0017

ANALYSIS OF VARIANCE ON SHINGLE DATA

TEMPERATURE = 30

GENERAL LINEAR MODELS PROCEDURE

STUDENT-NEWMAN-KEULS TEST FOR VARIABLE: STR_CD

NOTE: THIS TEST CONTROLS THE TYPE I EXPERIMENTWISE ERROR RATE UNDER THE COMPLETE NULL HYPOTHESIS BUT NOT UNDER PARTIAL NULL HYPOTHESES

ALPHA = .01 DF = 76 MSE = .0332479

NUMBER OF MEANS	2	3	4
CRITICAL RANGE	0.152346	0.173174	0.185641

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

SNK GROUPING		MEAN	N	WASTE
	A	1.78200	20	10
	A			
B	A	1.71500	20	0
B	A			
B	A	1.63700	20	20
B				
B		1.56000	20	5

ANALYSIS OF VARIANCE ON SHINGLE DATA

TEMPERATURE = 70

GENERAL LINEAR MODELS PROCEDURE

CLASS LEVEL INFORMATION

CLASS	LEVELS	VALUES
WASTE	4	0 5 10 20

NUMBER OF OBSERVATIONS IN BY GROUP = 80

ANALYSIS OF VARIANCE ON SHINGLE DATA

TEMPERATURE = 70

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: STR_CD % STRAIN CD

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE
MODEL	3	0.45370000	0.15123333
ERROR	76	5.05012000	0.06644895
CORRECTED TOTAL	79	5.50382000	
MODEL F =	2.28		PR > F = 0.0865

R-SQUARE	C.V.	ROOT MSE	STR_CD MEAN
0.082434	11.0943	0.25777693	2.32350000

SOURCE	DF	TYPE I SS	F VALUE	PR > F
WASTE	3	0.45370000	2.28	0.0865

SOURCE	DF	TYPE III SS	F VALUE	PR > F
WASTE	3	0.45370000	2.28	0.0865

ANALYSIS OF VARIANCE ON SHINGLE DATA

TEMPERATURE = 70

GENERAL LINEAR MODELS PROCEDURE

STUDENT-NEWMAN-KEULS TEST FOR VARIABLE: STR_CD

NOTE: HIS TEST CONTROLS THE TYPE I EXPERIMENTWISE ERROR RATE UNDER THE COMPLETE NULL HYPOTHESIS BUT NOT UNDER PARTIAL NULL HYPOTHESES

ALPHA = .01 DF = 76 MSE = .0664489

NUMBER OF MEANS	2	3	4
CRITICAL RANGE	0.215373	0.244819	0.262444

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

SNK GROUPING	MEAN	N	WASTE
A	2.42900	20	10
A			
A	2.34300	20	20
A			
A	2.30200	20	0
A			
A	2.22000	20	5

ANALYSIS OF VARIANCE ON SHINGLE DATA

TEMPERATURE = 70

GENERAL LINEAR MODELS PROCEDURE

CLASS LEVEL INFORMATION

CLASS	LEVELS	VALUES
WASTE	4	0 5 10 20

NUMBER OF OBSERVATIONS IN BY GROUP = 80

NOTE: ALL DEPENDENT VARIABLES ARE CONSISTENT WITH RESPECT TO THE PRESENCE OR ABSENCE OF MISSING VALUES. HOWEVER, ONLY 79 OBSERVATIONS CAN BE USED IN THIS ANALYSIS.

ANALYSIS OF VARIANCE ON SHINGLE DATA

TEMPERATURE = 70

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: NAILPULL

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE
MODEL	3	7.22370886	2.40790295
ERROR	75	138.43300000	1.84577333
CORRECTED TOTAL	78	145.65670886	

MODEL F =	1.30		PR > F = 0.2793

R-SQUARE	C.V.	ROOT MSE	NAILPULL MEAN
0.049594	21.0531	1.35859241	6.45316456

SOURCE	DF	TYPE I SS	F VALUE	PR > F
WASTE	3	7.22370886	1.30	0.2793

SOURCE	DF	TYPE III SS	F VALUE	PR > F
WASTE	3	7.22370886	1.30	0.2793

ANALYSIS OF VARIANCE ON SHINGLE DATA

TEMPERATURE = 70

GENERAL LINEAR MODELS PROCEDURE

STUDENT-NEWMAN-KEULS TEST FOR VARIABLE: NAILPULL

NOTE: THIS TEST CONTROLS THE TYPE I EXPERIMENTWISE ERROR RATE UNDER THE COMPLETE NULL HYPOTHESIS BUT NOT UNDER PARTIAL NULL HYPOTHESES

ALPHA = .01 DF = 75 MSE = 1.84577

WARNING: CELL SIZES ARE NOT EQUAL.
HARMONIC MEAN OF CELL SIZES = 19.7403

NUMBER OF MEANS	2	3	4
CRITICAL RANGE	1.14294	1.29928	1.39288

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

SNK GROUPING	MEAN	N	WASTE
A	6.9650	20	10
A			
A	6.3450	20	5
A			
A	6.2900	20	0
A			
A	6.2000	19	20

CHI-SQUARE TEST OF INDEPENDENCE

TABLE OF WASTE BY COND

WASTE(% WASTE) COND(CONDITION)

FREQUENCY EXPECTED CELL CHI 2	SLIGHT CRACKS	MOD. CRACKS	SEVERE CRACKS	TOTAL
0%	19 18.5 .013514	6 6.3 .01	5 5.3 .011905	30
5%	15 18.5 .662162	7 6.3 .09	8 5.3 1.44048	30
10%	20 18.5 .121622	7 6.3 .09	3 5.3 .964286	30
20%	20 18.5 .121622	5 6.3 .25	5 5.3 .011905	30
TOTAL	74	25	21	120

STATISTICS FOR TABLE OF WASTE BY CONDITION

STATISTIC	DF	VALUE	PROB
CHI-SQUARE	6	3.787	0.705
LIKELIHOOD RATIO CHI-SQUARE	6	3.817	0.701
MANTEL-HAENSZEL CHI-SQUARE	1	0.431	0.512
PHI		0.178	
CONTINGENCY COEFFICIENT		0.175	
CRAMER'S V		0.126	

SAMPLE SIZE = 120

ANALYSIS OF VARIANCE ON SHINGLE DATA

ANALYSIS OF VARIANCE PROCEDURE

CLASS LEVEL INFORMATION

CLASS	LEVELS	VALUES
WASTE	4	0% 10% 20% 5%

NUMBER OF OBSERVATIONS IN DATA SET = 144

ANALYSIS OF VARIANCE ON SHINGLE DATA

ANALYSIS OF VARIANCE PROCEDURE

DEPENDENT VARIABLE: COND CONDITION FACTOR

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE
MODEL	3	6.30555556	2.10185185
ERROR	140	560.33333333	4.00238095
CORRECTED TOTAL	143	566.63888889	

MODEL F = 0.53 PR > F = 0.6657

R-SQUARE	C.V.	ROOT MSE	COND MEAN
0.011128	39.2487	2.00059515	5.09722222

SOURCE	DF	ANOVA SS	F VALUE	PR > F
WASTE	3	6.30555556	0.53	0.6657

ANALYSIS OF VARIANCE ON SHINGLE DATA

ANALYSIS OF VARIANCE PROCEDURE

STUDENT-NEWMAN-KEULS TEST FOR VARIABLE: COND

NOTE: THIS TEST CONTROLS THE TYPE I EXPERIMENTWISE ERROR RATE UNDER THE COMPLETE NULL HYPOTHESIS BUT NOT UNDER PARTIAL NULL HYPOTHESES

ALPHA = .01 DF = 140 MSE = 4.00238

NUMBER OF MEANS	2	3	4
CRITICAL RANGE	1.2314	1.39656	1.49494

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

SNK GROUPING	MEAN	N	WASTE
A	5.4444	36	5%
A			
A	5.0556	36	0%
A			
A	5.0000	36	20%
A			
A	4.8889	36	10%

ANAYSIS OF VARIANCE ON SHINGLE DATA

GENERAL LINEAR MODELS PROCEDURE

CLASS LEVEL INFORMATION

CLASS	LEVELS	VALUES
WASTE	4	0 5 10 20

NUMBER OF OBSERVATIONS IN DATA SET = 108

NOTE: ALL DEPENDENT VARIABLES ARE CONSISTENT WITH RESPECT TO THE PRESENCE OR ABSENCE OF MISSING VALUES. HOWEVER, ONLY 96 OBSERVATIONS CAN BE USED IN THIS ANALYSIS.

ANAYSIS OF VARIANCE ON SHINGLE DATA

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: WATER % WATER ABSORBED

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE
MODEL	7	32.38524557	4.62646365
ERROR	88	8.14808777	0.09259191
CORRECTED TOTAL	95	40.53333333	

MODEL F = 49.97 PR > F = 0.0001

R-SQUARE	C.V.	ROOT MSE	WATER MEAN
0.798978	13.2781	0.30428918	2.29166667

SOURCE	DF	TYPE III SS	F VALUE	PR > F
LOG10 (DAY)	1	31.08833371	335.76	0.0001
WASTE	3	0.37249293	1.34	0.2663
LOG10 (DAY) *WASTE	3	0.38857853	1.40	0.2485

ANAYSIS OF VARIANCE ON SHINGLE DATA

GENERAL LINEAR MODELS PROCEDURE

LEAST SQUARES MEANS

WASTE	WATER LSMEAN	PROB > |T| H0: LSMEAN(I)=LSMEAN(J) I/J	1	2	3	4
0	2.24583333	1	.	0.1326	0.2995	0.1104
5	2.37916667	2	0.1326	.	0.0121	0.9246
10	2.15416667	3	0.2995	0.0121	.	0.0094
20	2.38750000	4	0.1104	0.9246	0.0094	.

NOTE: TO ENSURE OVERALL PROTECTION LEVEL, ONLY PROBABILITIES ASSOCIATED WITH PRE-PLANNED COMPARISONS SHOULD BE USED.

ANAYSIS OF VARIANCE ON SHINGLE DATA

GENERAL LINEAR MODELS PROCEDURE

CLASS LEVEL INFORMATION

CLASS	LEVELS	VALUES
WASTE	4	0 5 10 20

NUMBER OF OBSERVATIONS IN DATA SET = 108

NOTE: ALL DEPENDENT VARIABLES ARE CONSISTENT WITH RESPECT TO THE PRESENCE OR ABSENCE OF MISSING VALUES. HOWEVER, ONLY 96 OBSERVATIONS CAN BE USED IN THIS ANALYSIS.

ANAYSIS OF VARIANCE ON SHINGLE DATA

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: WATER % WATER ABSORBED

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE
MODEL	4	31.99666704	7.99916676
ERROR	91	8.53666629	0.09380952
CORRECTED TOTAL	95	40.53333333	

MODEL F = 85.27 PR > F = 0.0001

R-SQUARE	C.V.	ROOT MSE	WATER MEAN
0.789391	13.3651	0.30628340	2.29166667

SOURCE	DF	TYPE I SS	F VALUE	PR > F
LDAY	1	31.08833371	331.40	0.0001
WASTE	3	0.90833333	3.23	0.0261

SOURCE	DF	TYPE III SS	F VALUE	PR > F
LDAY	1	31.08833371	331.40	0.0001
WASTE	3	0.90833333	3.23	0.0261

ANAYSIS OF VARIANCE ON SHINGLE DATA

GENERAL LINEAR MODELS PROCEDURE

LEAST SQUARES MEANS

WASTE	WATER LSMEAN	PROB > |T| H0: LSMEAN(I)=LSMEAN(J) I/J	1	2	3	4
0	2.24583333	1	.	0.1350	0.3026	0.1126
5	2.37916667	2	0.1350	.	0.0126	0.9251
10	2.15416667	3	0.3026	0.0126	.	0.0098
20	2.38750000	4	0.1126	0.9251	0.0098	.

NOTE: TO ENSURE OVERALL PROTECTION LEVEL, ONLY PROBABILITIES ASSOCIATED WITH PRE-PLANNED COMPARISONS SHOULD BE USED.

APPENDIX E

TESTING METHODS

PLIABILITY

I. PURPOSE

To determine the pliability of the shingle.

II. EQUIPMENT

A 1-1/2 inch diameter mandrel and an environmental room to maintain the test temperature at 40°F. ± 2°F.

III. PROCEDURE

Cut ten (10) 1" x 6" pieces from selected shingles with a utility knife in the machine direction (MD). Condition the samples and the 1-1/2 inch diameter mandrel in a room maintained at 40°F. ± 2°F for at least two hours.

Bend each sample at a uniform rate over the 1-1/2 inch diameter mandrel through a 180± angle. Rank the samples as follows:

No cracks	0
Trace cracks	2
Slight cracks	4
Moderate cracks	6
Severe cracks	8
Broken-in-half	10

The result is the sum of ten (10) samples bent at 40°F.

STIFFNESS

I. SCOPE

This procedure describes the method for measuring the stiffness, yield angle and yield moment of fiber glass roofing in bending of preconditioned samples at 32F and 72F.

II. SPECIMEN

1. Cut 4 samples 1" x 3.5" for each MD and CD stiffness.
2. To test MD stiffness - Cut 3.5" dimension in machine direction.
3. To test CD stiffness - Cut 3.5" dimension in cross-direction.
4. Condition at selected temperature.

III. APPARATUS

1. Paper cutter
2. Tinius Olsen Stiffness Tester, 6 in/lb capacity, No. 151,345
3. Conditioning apparatus as described

IV. PROCEDURE

Use the 1 in/lb pendulum weight for standard condition samples at 72F, and the 4 in/lb pendulum wt for condition samples at 32F. Place a sample in the jaws of the testing machine as shown on page 226. For samples with granules, place the sample in the tester jaws with the granule side up. Zero the machine so that with the sample just touching the underside of the roller bearing pin, the angle pointer, the zero reading of the angular deflection scale and the zero of the load scale all line up.

Engage the motor by depressing the motor lever. The angular deflection is read at the point of the angle pointer, and the percent of full scale load is read at the zero mark of the angular deflection scale. Record the percent of full scale load supported at 5 degree deflection intervals on the stiffness test record (Figure E-1).

Repeat the above procedure for three more samples and record the readings on the same stiffness test record graph.

V. CALCULATION AND REPORTING

1. Stiffness

Average the percent of full scale load supported for the four samples at 5 degree deflection. Divide this average by 200 for 1 in/lb or 83.3 for 3 in/lb weights, and report the result as:

$$\frac{\text{in. lb.}}{(^{\circ}/\text{in.})\text{in.}}$$

(See example, Figure E-1)

2. Yield Angle

The yield angle is the angle of deflection at which the greatest load is supported. If for a particular sample two angles are recorded with the same greatest load, the higher angle is the yield angle. Average the yield angles for the four samples and report the result as degrees.

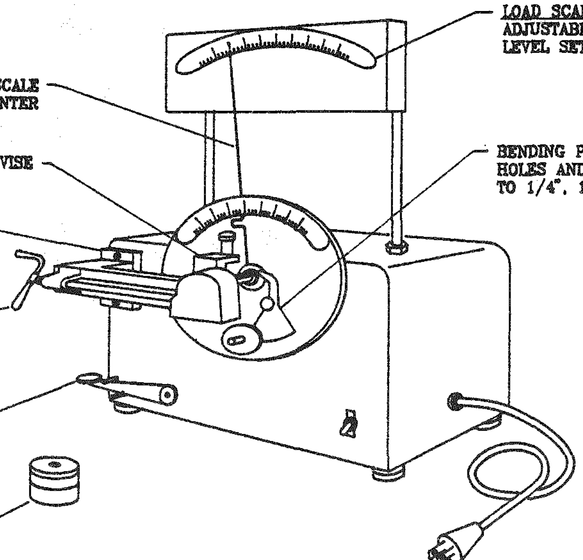
(See example, Figure E-1)

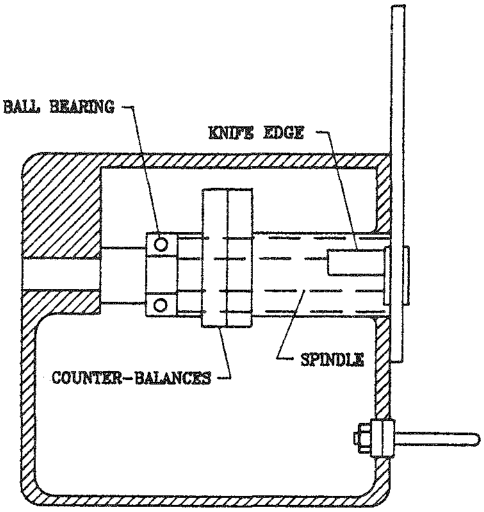
3. Yield Moment

Average the maximum loads supported for the four samples as read from chart in percent. Divide the average by 100 and report the result as:

$\frac{\text{in. lb.}}{\text{in.}}$ (See example, Figure E-1)

STIFFNESS TESTER
6 INCH / POUND CAPACITY





CAUTION:
THE PENDULUM, AT FULL LOAD DEFLECTION, SWINGS 30°. DO NOT OVERLOAD THE MACHINE AND FORCE THE PENDULUM PAST THE 100% READING. TO DO SO MIGHT JAM AND INJURE THE KNIFE-EDGE SUPPORT BEARING.

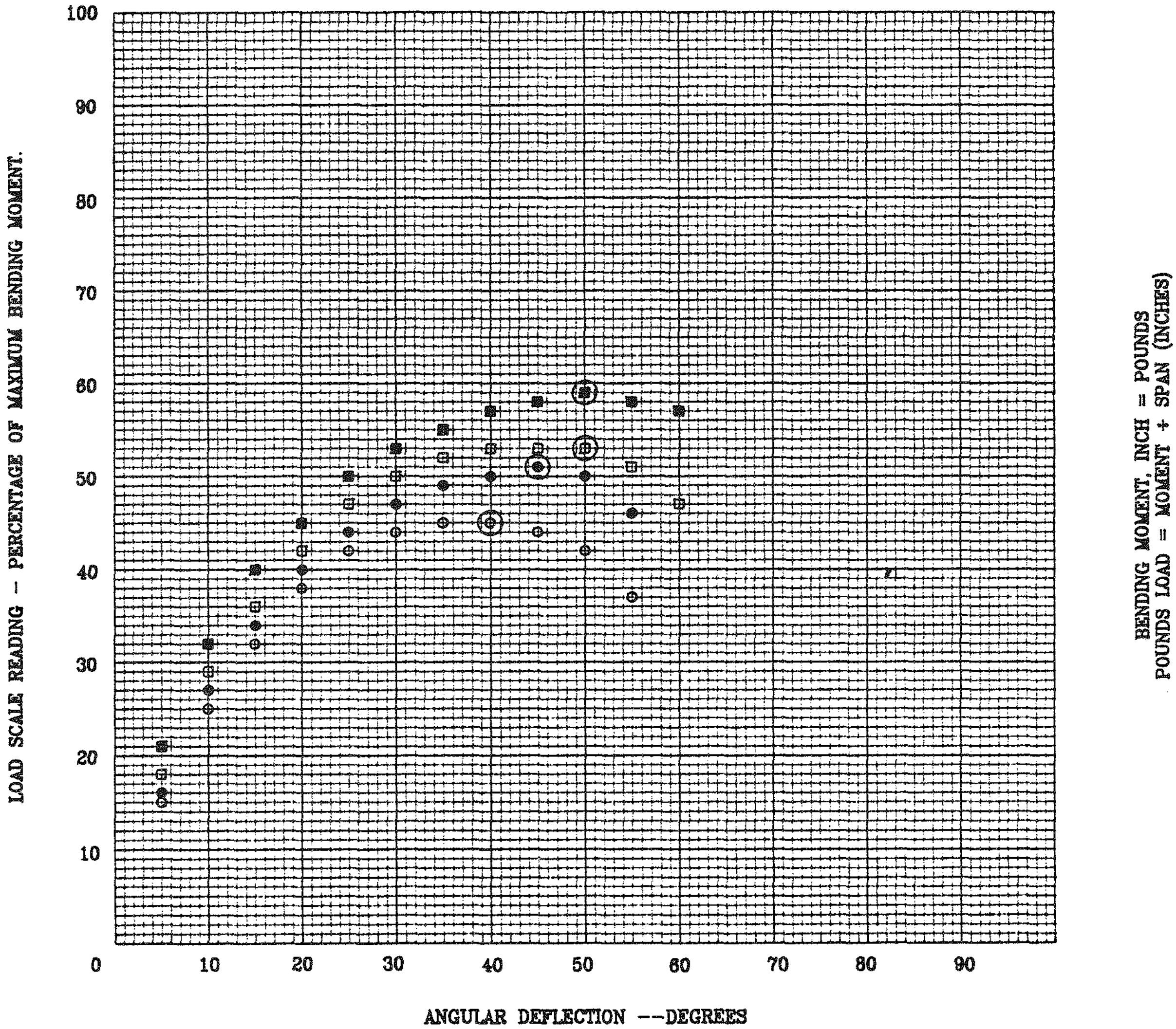
PENDULUM CAN BE SLIPPED OFF ITS SPINDLE FOR ACCESS TO BEARINGS, AFTER VISE BRACKET AND DRIVE GEAR HAVE BEEN REMOVED.

BEARINGS
AS SHOWN IN THE SECTIONAL VIEW ABOVE, THE PENDULUM IS SWUNG ON TO BEARINGS: A KNIFE EDGE IN FRONT AND A BALL BEARING IN THE REAR. LUBRICATE BALL BEARINGS SPARINGLY, ONE DROP OF CLOCK OIL ONLY. IF BEARING BECOMES SLUGGISH, WASH OUT WITH ETHER, BLOW DRY AND RE-LUBRICATE.

TINIUS OLSEN TESTING MACHINE CO.
EASTON ROAD,
WILLOW GROVE, PENNSYLVANIA

STIFFNESS TEST RECORD

TINIUS OLSEN TOUR – MARSHALL TESTER 2 in. / lb. CAPACITY



	○	●	□	■	AVERAGE	
STIFFNESS:	15	16	18	21	17.5	$\frac{17.5}{250} = 0.070 \frac{\text{(in. lb.)}}{\text{(°/in.) in.}}$
YIELD ANGLE:	40	45	50	50	46.25	46°
YIELD MOMENT:	45	51	53	52	52	$\frac{52}{100} = \frac{0.52 \text{ in. lb.}}{\text{in.}}$

FIGURE E-1 – EXAMPLE

NAIL HOLDING TEST METHOD FOR RESIDENTIAL SHINGLES

I. SCOPE

This procedure describes a method for determining the nail holding strength of shingles.

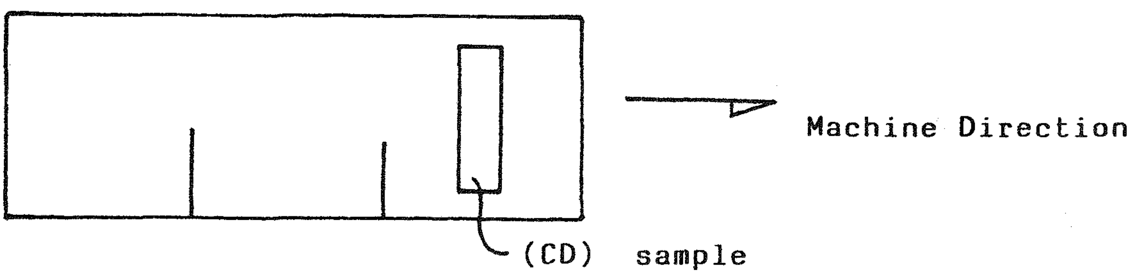
II. APPARATUS

The equipment used in this test method consists of the following items.

1. Tensile test equipment, any one of several on the market today, i.e., Scott pendulum, Instron, etc.
2. Metal "jig" for holding the sample and sample block (Figure E-2).
3. Standard 7/8 x 11 gauge roofing nail with a 3/8 in. diameter nail head.
4. Wooden sample blocks made of white pine, 3-1/2 in. x 1-1/2 in. x 25/32 in. in dimensions.

III. TEST SPECIMENS

Ten 2 in. x 8 in. rectangular specimens cut in the cross machine direction (CD) unless values are required in both directions.



IV. TEST CONDITIONS

Temperature: Ambient or room temperature unless otherwise specified.

Jaw Span: The distance between the upper jaw and the wooden test block should be 3-1/2 inches.

Pull Rate: Scott Pendulum - 12 inches per minute.
Instron - 5 inches per minute crosshead speed.

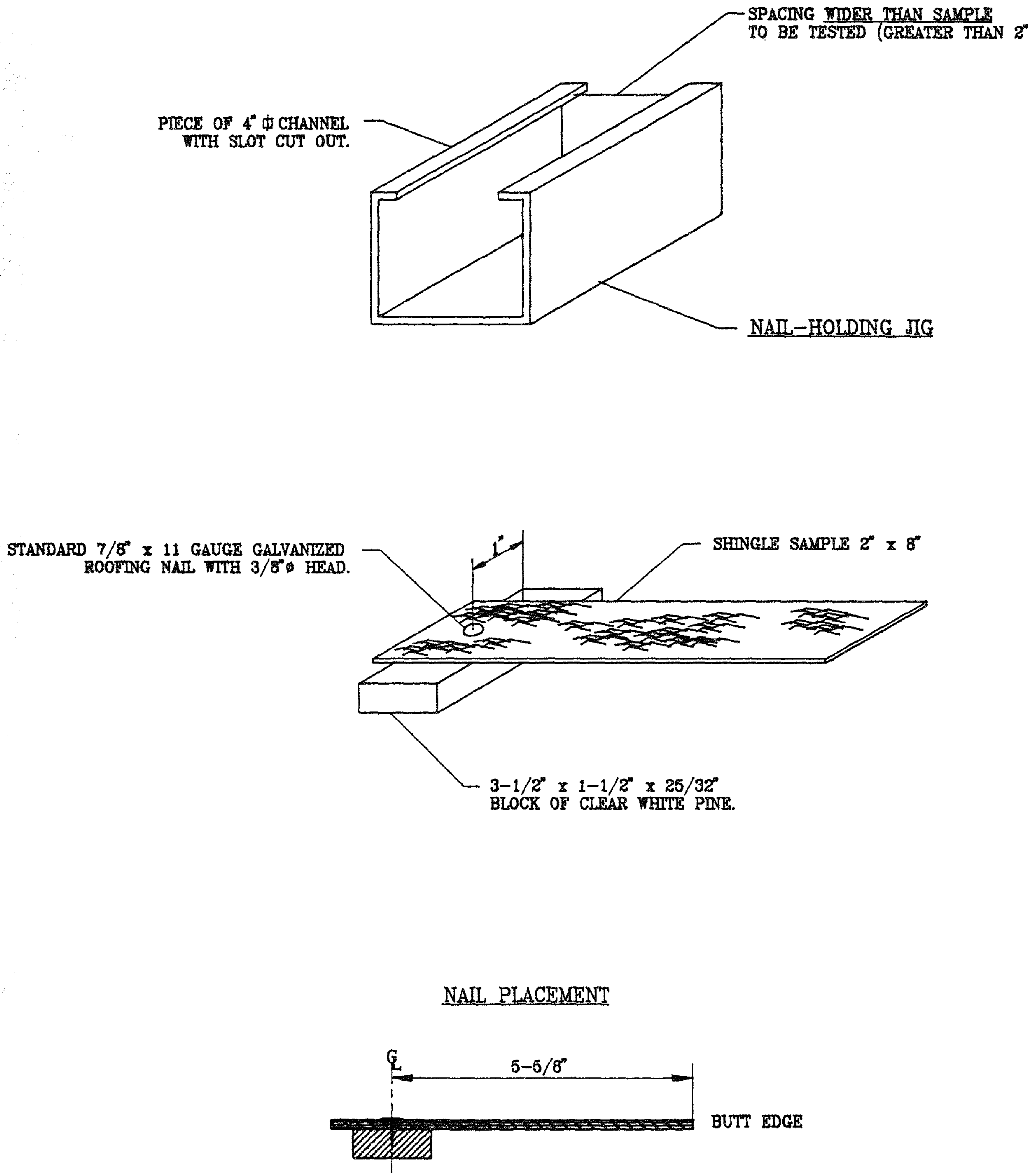

SPACING WIDER THAN SAMPLE
TO BE TESTED (GREATER THAN 2")
PIECE OF 4" ⌀ CHANNEL
WITH SLOT CUT OUT.
NAIL-HOLDING JIG
STANDARD 7/8" x 11 GAUGE GALVANIZED
ROOFING NAIL WITH 3/8"ø HEAD.
1"
SHINGLE SAMPLE 2" x 8"
3-1/2" x 1-1/2" x 25/32"
BLOCK OF CLEAR WHITE PINE.
NAIL PLACEMENT
CL
5-5/8"
BUTT EDGE

FIGURE E-2

V. PROCEDURE

Place the shingle test sample on the block and secure the sample with the roofing nail, placing it in the center of the 2 inch width and 5-5/8 inches from the butt edge of shingle specimen (Figure E-3).

Be sure the head of the roofing nail is just touching the shingle surface. Embedded nails or too high a nailing will yield erroneous results.

The block and test samples are then placed into the "angle iron jig", Figures E-2 and E-4. The jig is clamped or fixed to a stationary base or into the lower jaw of the tensile equipment and secured.

The sample is then loaded and tested to failure.

VI. RESULTS

The maximum load in lbs to failure is read directly from the scale or digital readout and recorded. An average value of the ten specimens is reported in lbs.

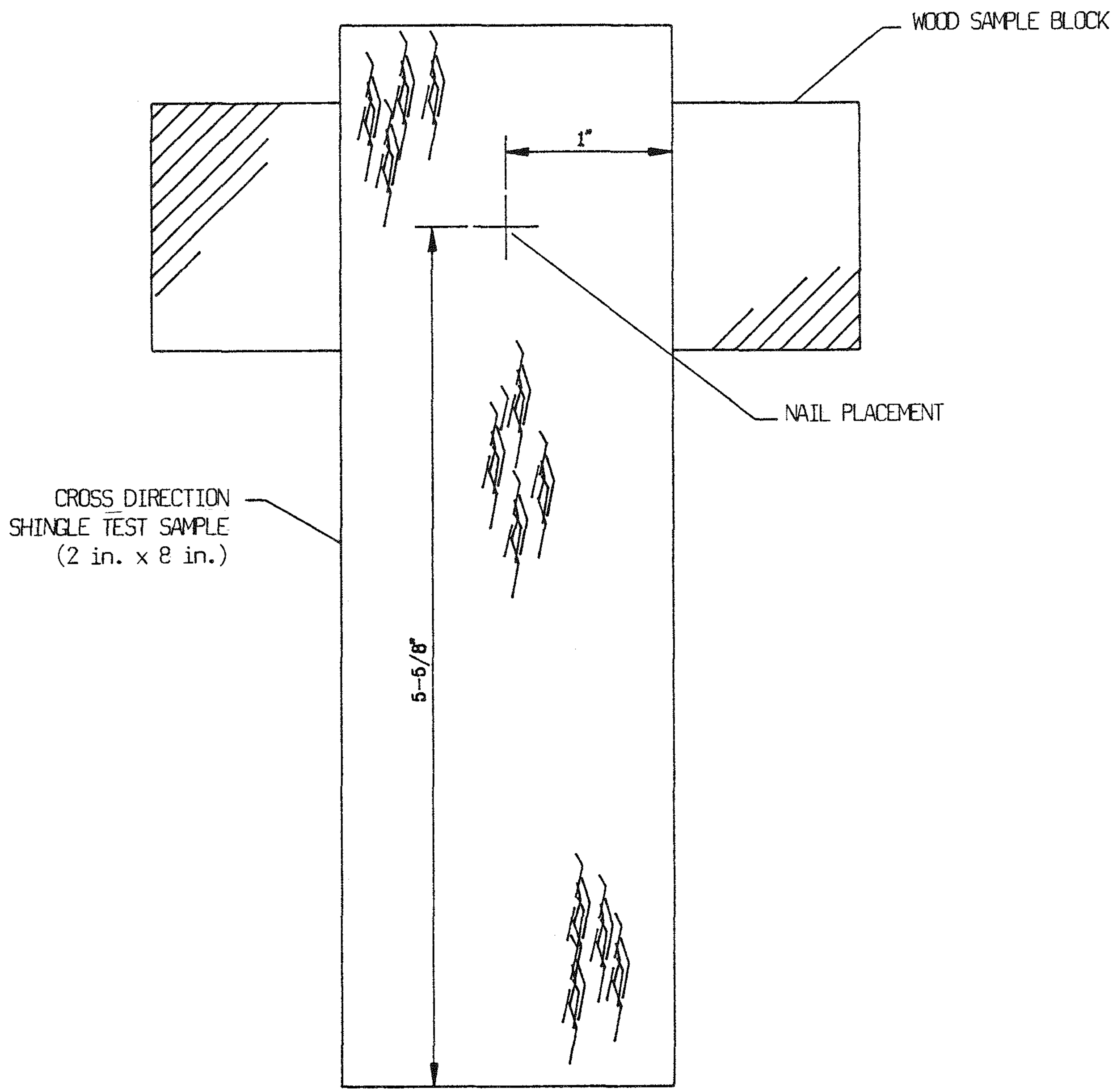
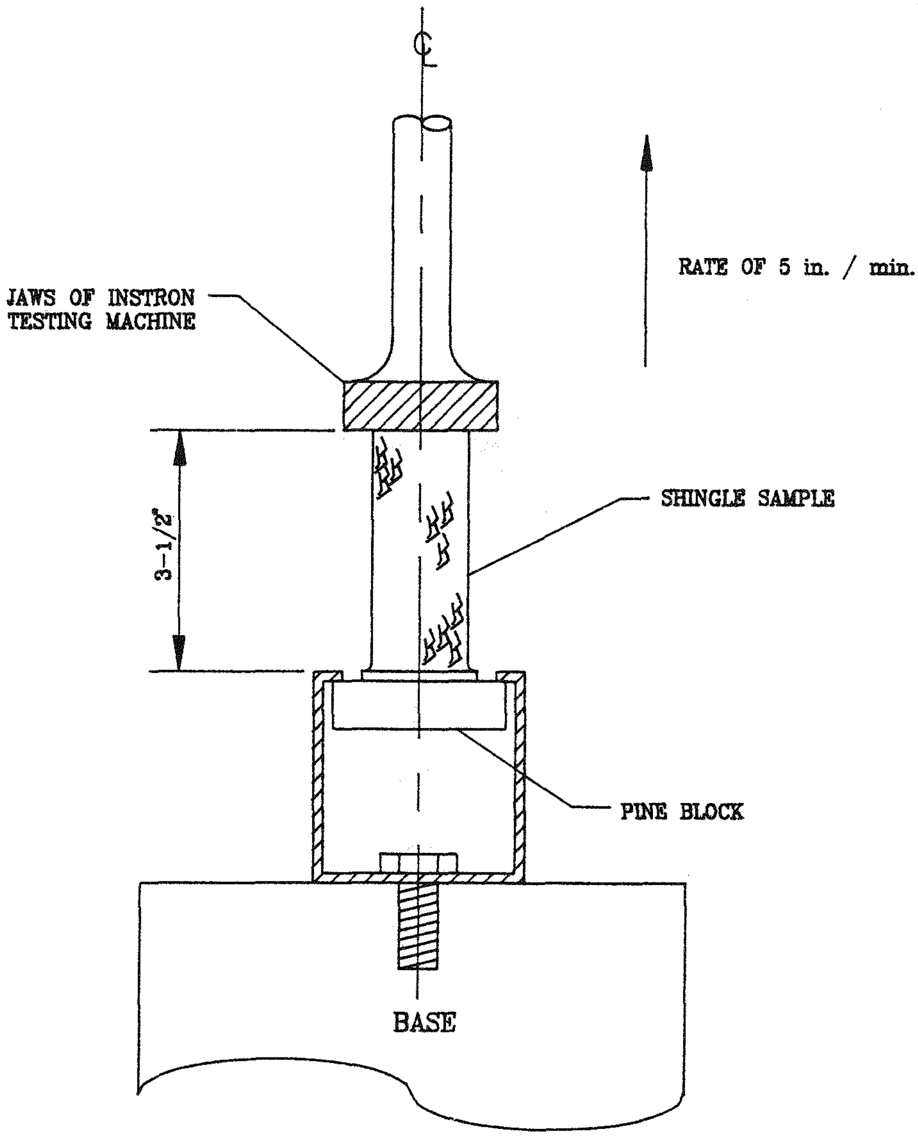

WOOD SAMPLE BLOCK
1"
NAIL PLACEMENT
CROSS DIRECTION
SHINGLE TEST SAMPLE
(2 in. x 8 in.)
5-5/8"

FIGURE E-3



CL
RATE OF 5 in. / min.
JAWS OF INSTRON
TESTING MACHINE
3-1/2"
SHINGLE SAMPLE
PINE BLOCK
BASE

FIGURE E-4

PROPOSED ASTM METHOD OF TEST FOR DETERMINING MAXIMUM MOISTURE ABSORPTION CAPABILITY AND MAXIMUM DIMENSIONAL GAIN POTENTIAL OF ROOFING FELTS AND MEMBRANES

1.0 SCOPE

1.1 This method covers testing designed to determine the maximum moisture absorption capability and maximum dimensional gain potential of roofing felts and membranes after continuous immersion in water at specified temperatures.

2.0 REFERENCED DOCUMENTS

2.1 ASTM Standards

D146 - Methods of sampling and Testing Bitumen Saturated Felts and Woven Fabrics for Roofing and Waterproofing.

D228 - Methods of Testing Asphalt Roll, Roofing Cap Sheets and Shingles.

D2829 - Recommended Practice for Sampling and Analysis of Built-Up Roofs.

D3617 - Practice for Sampling and Analysis of New Built-Up Roof Membranes.

3.0 SUMMARY OF METHOD

3.1 This method subjects 5 in. wide x 34 in. long (127 x 864 mm) specimens of roofing felts or membranes to water immersion at specified temperatures, and determines their maximum moisture absorption capability and/or maximum dimensional gain.

4.0 SIGNIFICANCE AND USE

4.1 This test method provides a quick and inexpensive means of evaluating the maximum potential of any given roofing felt or membrane for water absorption and dimensional gain.

5. APPARATUS

5.1 A stainless steel water bath with a removable top having dimensions of 18 in. wide (457 mm) x 36 in. long (914 mm) x 10 in. deep (254 mm).

5.2 A steel rule graduated in .03 inch (0.80 mm) increments.

5.3 Thermometer - An ASTM Low Softening Point Thermometer, having a range from -2 to +80C, or +30 to 180F. and conforming to the requirements for thermometer 15C or 15F, as prescribed in ASTM Specification E1 for ASTM Thermometers.

5.4 Balance - The balance must have a maximum capacity of 200 and 2,000 grams when weighing felts or membranes respectively.

6.0 SAMPLING TEST SPECIMENS

6.1 When taking samples from an actual roof or roll of felt, cut test specimens in the machine and transverse direction by using a 5 x 34 in. (127 x 864 mm) metal template as described in ASTM D2829 Recommended Practice for Sampling and Analysis of Built-up Roofing.

6.2 Package each field specimen separately and protect from damages in a sealed plastic bag prior to shipment.

6.3 Cut triplicate specimens for roofing felts or membranes in both the machine and the transverse direction for evaluation.

7.0 PREPARATION OF LABORATORY MEMBRANE SPECIMENS

7.1 Condition all components at 25 $\pm$1 degree C. (77 $\pm$2 degrees F.) for 24 hours prior to constructing membrane specimens. Use felts and asphalts which comply to requirements, outlined in ASTM specifications.

7.2 Prepare membrane specimens at least 3 x 4 ft (0.91 x 1.22 mm) as required for testing a specific roofing membrane. Then cut test specimens as detailed in Section 6.1.

8.0 PROCEDURE

8.1 Space reference marks 32 in. (815 mm) apart on each test specimen by cutting hairline scratches in the form of a cross, one inch (2.5 mm) in from either edge of the specimen length. The reference marks shall be as thin as possible, and be less than .03 inch (.80 mm).

8.2 Weigh the conditioned specimen to the nearest hundredths of a gram for felts and the nearest gram for membranes. A 6 x 36 in. (150 x 915 mm) aluminum lightweight support on a pan balance is recommended while weighing membrane specimens to keep them from bending.

8.3 Measure the specimen's length to the nearest .032 in. (0.8 mm) immediately after weighing. The long dimension is always the one subjected to test its maximum dimensional gain.

8.4 Place the conditioned test specimens in a water bath maintained at 25 degrees C. (77F) or 50 degrees C. (122F.) by laying them on their sides and placing aluminum spacers between specimens so water can penetrate from all sides. Be certain that the water depth is a minimum of one inch (25 mm) above the specimens at all times.

8.5 At testing intervals outlined in Section 8.9, remove each test specimen from the water bath and hold it parallel to the bath length so the excess water from the specimen will drip back into the bath. Place each specimen on new Teri-Wipers (manufactured by Kimberly-Clark.)

8.6 Invert the specimen so both sides allow the Teri-Wipers to absorb a portion of its surface water.

8.7 Draw a second Teri-Wiper over the specimen surface, both in the forward and reverse direction, without applying hand pressure to it. Invert the specimen and repeat the procedure.

8.8 Weigh the specimens and check the dimensions until constant data is achieved in two or more successive determinations.

8.9 Testing Intervals

8.9.1 Saturated Felts or Fabrics - Test hourly for a period of eight (8) hours, then daily until the maximum moisture absorption capability and maximum dimensional gain is achieved.

8.9.2 Coated Felts and Membranes - Test daily for the first week, then weekly for the next three determinations, and monthly thereafter until its maximum moisture absorption capability and maximum dimensional gain is achieved.

8.9.3 Record all data and average the percent moisture absorbed and dimensional gain for the triplicate specimens in each direction and at each testing interval.

9.0 CALCULATIONS

9.1 Calculate % moisture absorbed and dimensional gain as follows:

$$\% \text{ moisture absorbed} = \frac{\text{moisture gain}}{\text{dry weight}} \times 100\%$$

$$\% \text{ dimension gain} = \frac{\text{dimensional gain}}{\text{initial dimension prior to water immersion}} \times 100\%$$

10.0 REPORT

10.1 The report shall include the following:

10.1.1 Complete description of the felts or membranes tested, including identification of all components, if possible.

10.1.2 Orientation of the specimens with respect to the reinforcing felt or fabric.

10.1.3 Source and location from which field samples were obtained, the data obtained, and the date constructed; for laboratory prepared membranes, the date constructed.

10.1.4 Composition of each of the felts employed, when applicable.

10.1.5 Conditioning and testing procedure followed, including both temperature and date of test.

10.1.6 Computed average of maximum moisture absorption capability and maximum dimensional gain in each direction.

11.0 PRECISION AND ACCURACY

11.1 Because of the variations in felts and fabrics, repeatability and reproducibility may vary depending upon the type of felt of fabric and/or the number of plies in the membrane. Reproducibility may be expected to vary approximately ± 10% about the mean for similar felts and membranes.

HANDLEABILITY TEST

I. SCOPE

This test is to assess the handleability or application characteristics of fiber glass shingles. Tests may be conducted at any temperature from 30 to 105°F.

II. EQUIPMENT

Walk-in, temperature-controlled room capable of maintaining temperatures in the desired range within ± 5°F.

III. PROCEDURE

Shingles are placed in the refrigerator at the desired temperature and allowed to remain until they have reached the temperature at which the refrigerator is set. The shingles are then handled by flexing, sliding, dropping, etc., to duplicate the type of abuse the shingle would receive during application.

IV. RATING

This test is completed subjectively; a control lot of shingles is always tested along with the experimental shingles, and the shingle under test is compared to the control. .A judgment decision is made based on this comparison as to whether the test shingles are handleable or not at the test temperatures.

ASPHALT ADHESION OF EMBEDDED GRANULES (DRY)

I. SCOPE

This method covers a test to determine asphalt adhesion of embedded granules under dry conditions.

II. SPECIMEN

Three 2" x 10" strips of roofing from each sample (one sample per lane) with long dimension parallel to machine direction.

III. APPARATUS

1. Granule Embedding test machine (3M Company)
    a. Specimen Holder
    b. Brush - Contact: 3M Company
Industrial Mineral Prod. Div.
St. Paul, MN

    To be replaced when bristle length is outside range of 9/16" to 1/2"
2. Paper cutter
3. Balance - 1000 gm capacity with 0.1 gm accuracy

IV. PROCEDURE

1. Conduct test at room temperature of 72± 5°F.
2. Cut test specimens using paper cutter.
3. Tap individual strips lightly three times on long edge to remove loose granules.
4. Weigh the three strips from each sample together, record weight to nearest 0.1 g.
5. Clamp an individual strip in holder, gently lower brush assembly onto specimen, set counter to zero and start machine. (Test machine stops automatically after 50 cycles.)
6. After completion of 50 cycles, remove test specimen from holder. Tap gently three times on long edge to remove loose granules.
7. Repeat steps 5 & 6 for all three strips in the group.
8. Reweigh tested specimens together - record weight.

V. CALCULATION AND REPORTING RESULTS

Average granule weight loss in gms/sample =

$$\frac{\text{Wt(gms) 3 strips before test (-) wt(gms) 3 strips after test}}{\text{Number of Strips}}$$

Report average granule weight loss for each sample.

APPENDIX F

OUTDOOR EXPOSURE TEST LOCATIONS

Small panels covered with each of the experimental and base line shingles are exposed in Houston, TX; Hagerstown, MD; and Savannah, GA. Each panel contains several square feet.

The exposure sponsors, listed below, maintain roof exposure farms for the benefit of the industry. The shingles from this DOE sponsored research are available for inspection by the roofing industry and DOE and the tests will be maintained until conclusive results have been achieved.

Houston, TX contact
Mr. Charles R. Lea, Division Quality Manager
3M Company
Industrial Mineral Products Division
3M Center, Building 225-2N-07
St Paul, MN 551444

Hagerstown, MD contact
Mr. David Little, National Sales Manager
GAF Chemicals Corporation, Mineral Products
PED
P. O. Box 1418
34 Charles Street
Hagerstown, MD 21740

The shingles exposed in Savannah, GA are at the Manville Factory and the contact is:

Mr. Ed Nelson, Manager
Manville Sales Corporation
1 Foundation Drive
Savannah, GA 31408

Each of the experimental and baseline shingle lots has been exposed on houses in Massachusetts, Georgia, and Colorado. The homeowners have informally agreed to permit inspection of these shingles at least once each year. A change in ownership might deny future access to the roofs. However, most of the houses are sighted so that at least one roof face containing all four shingle lots may be easily viewed from the street. The locations of the houses and their owners are shown on the next eleven pages together with a map showing the locations of the shingle lots on each roof.

Mr. Michael Keith
Gurnet Road and Pine Street
Duxbury,MA 02332

Map of roof not available at time of printing.

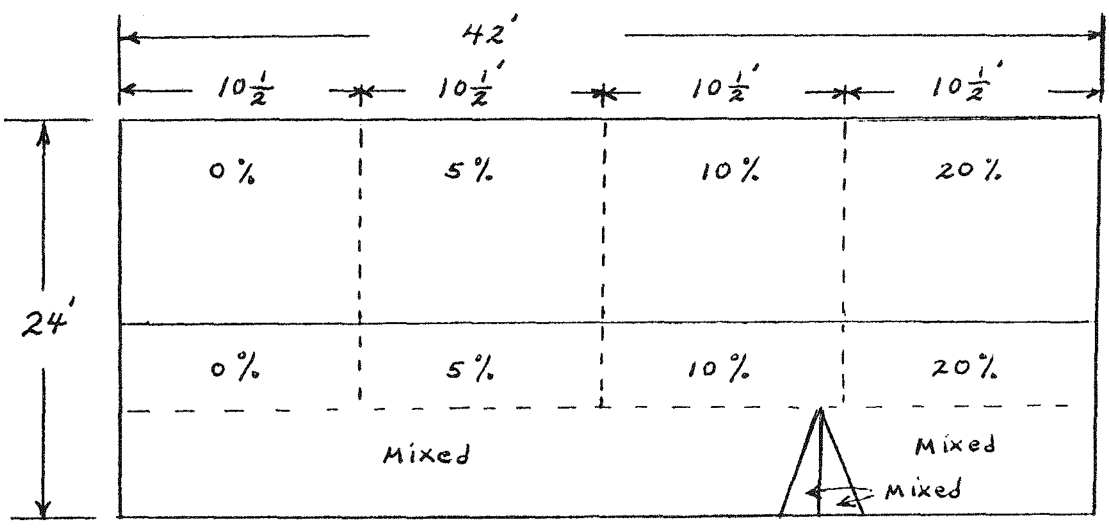
Mrs. Patricia Campbell
20 Middlesex Avenue
Norton, Massachusetts 02766

Reroofed on April 22, 1989 over
old 3 Tab Asphalt Shingles

Slope: 5"/12"

Wind Seal 80, Wood Blende
0%, 0 Experiment, 5 Squares
5%, 5 Experiment, 5 Squares
10%, 10 Experiment, 5 Squares
20%, 20 Experiment, 5 Squares

^
N



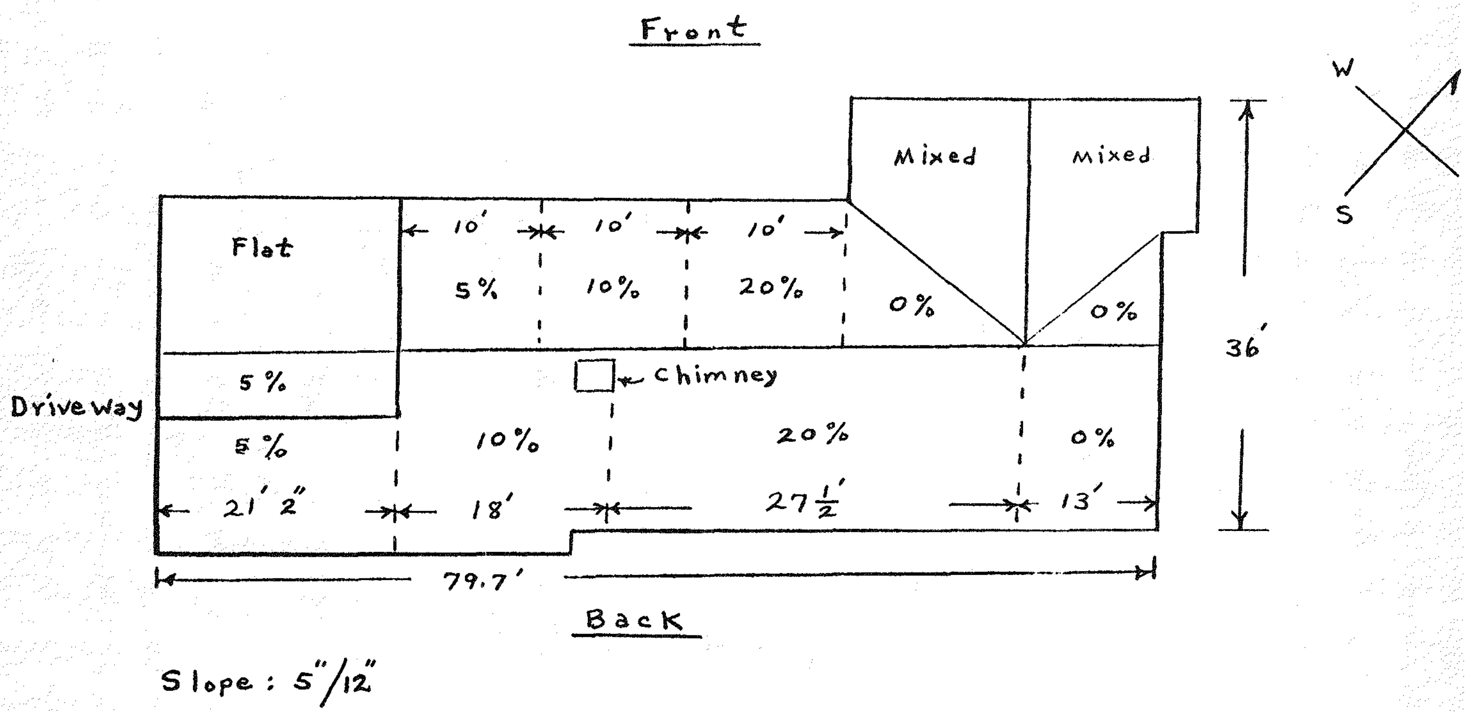
Front

Mr. Tony Palmucci
470 High Street
North Attleboro, Massachusetts

Reroofed on July 3-9, 1989
over old 3 tab asphalt shingles

Reroofed on July 3-9, 1989
over old 3 tab asphalt shingles

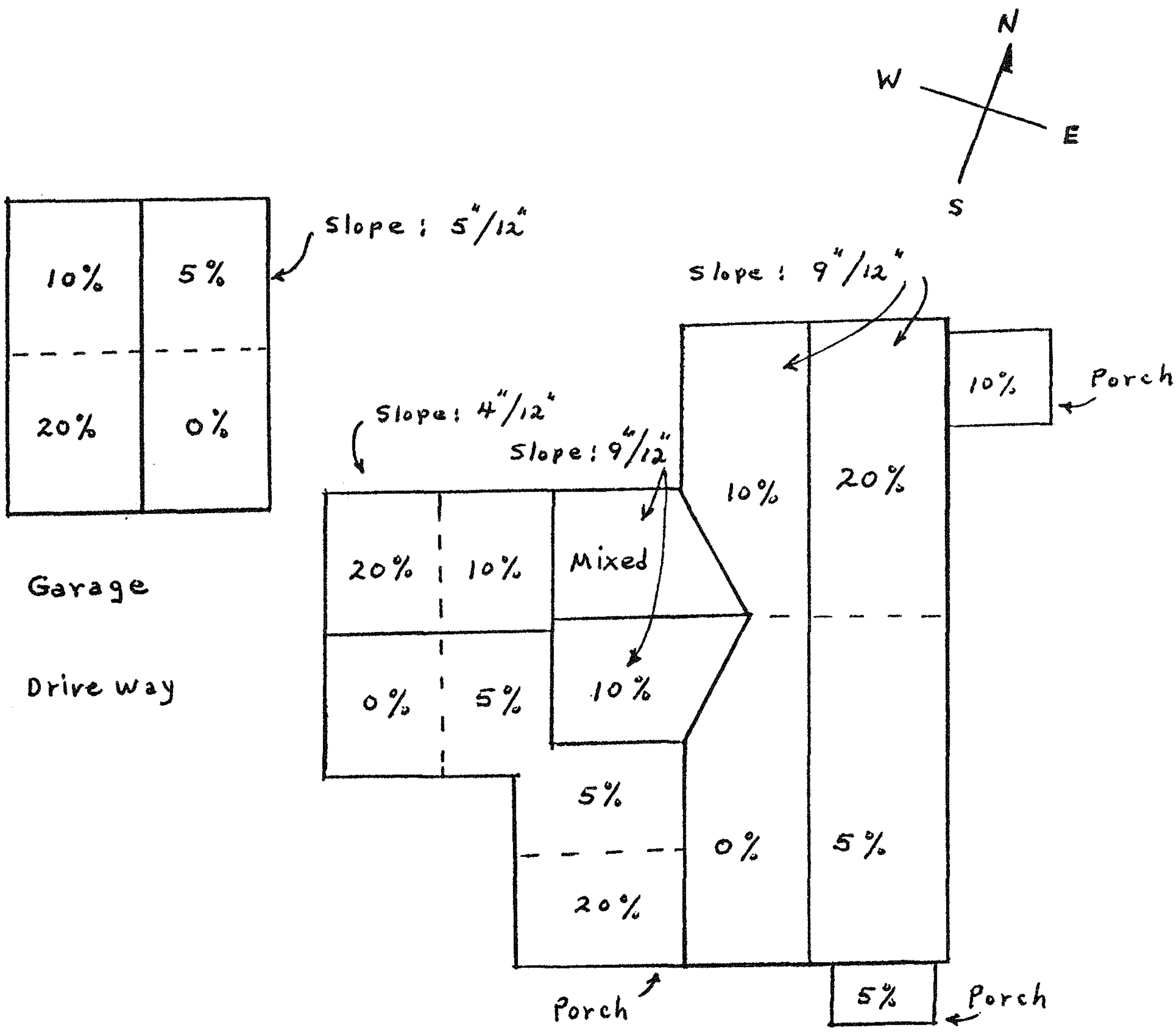
Wind Seal 80, Wood Blende
0%, 0 Experiment, 9 Squares
5%, 5 Experiment, 9 Squares
10%, 10 Experiment, 9 Squares
20%, 20 Experiment, 9 Squares



Mr. Jeffrey P. Forgit
83 Crescent Street
Franklin, Massachusetts 02038

Shingles installed May 23 and 26, 1989

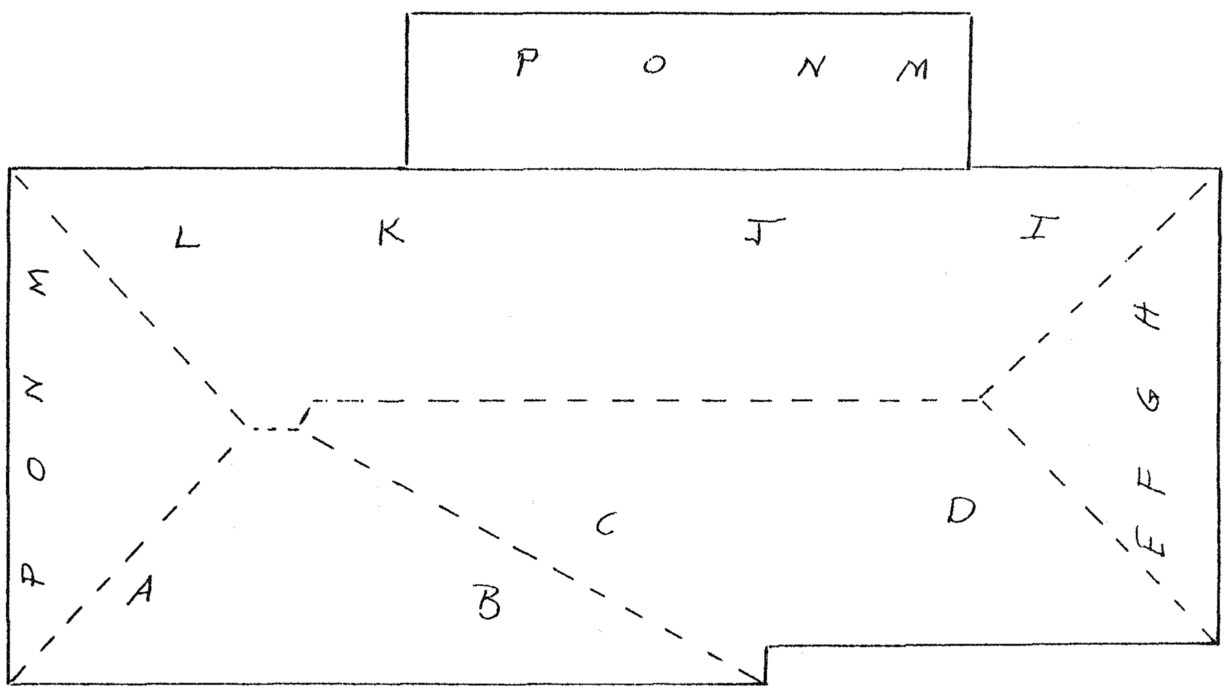
		Wind Seal 80, Wood Blende
Deck:	Boards	0%, 0 Experiment, 8-1/3 Squares
Felt:	15 Type Saturated Felt	5%, 5 Experiment, 8-1/3 Squares
	or Ice & Water Barrier	10%, 10 Experiment, 8-1/3 Squares
	Along Eaves & Valleys	20%, 20 Experiment, 8-1/3 Squares



Mr. John Waida
8732 East Briarwood
Englewood, Colorado 80110

A = 8 bundles 0	E = 2 bundles 0	I = 7 bundles 10	M = 2 bundles 10
B = 8 bundles 10	F = 2 bundles 10	J = 7 bundles 0	N = 2 bundles 0
C = 8 bundles 20	G = 2 bundles 20	K = 7 bundles 5	O = 2 bundles 5
D = balance 5	H = balance 5	L = balance 20	P = balance 20

^
N



Street

Charles and Maxine Pretti
2417 West Bradbury Avenue
Littleton, Colorado 80120

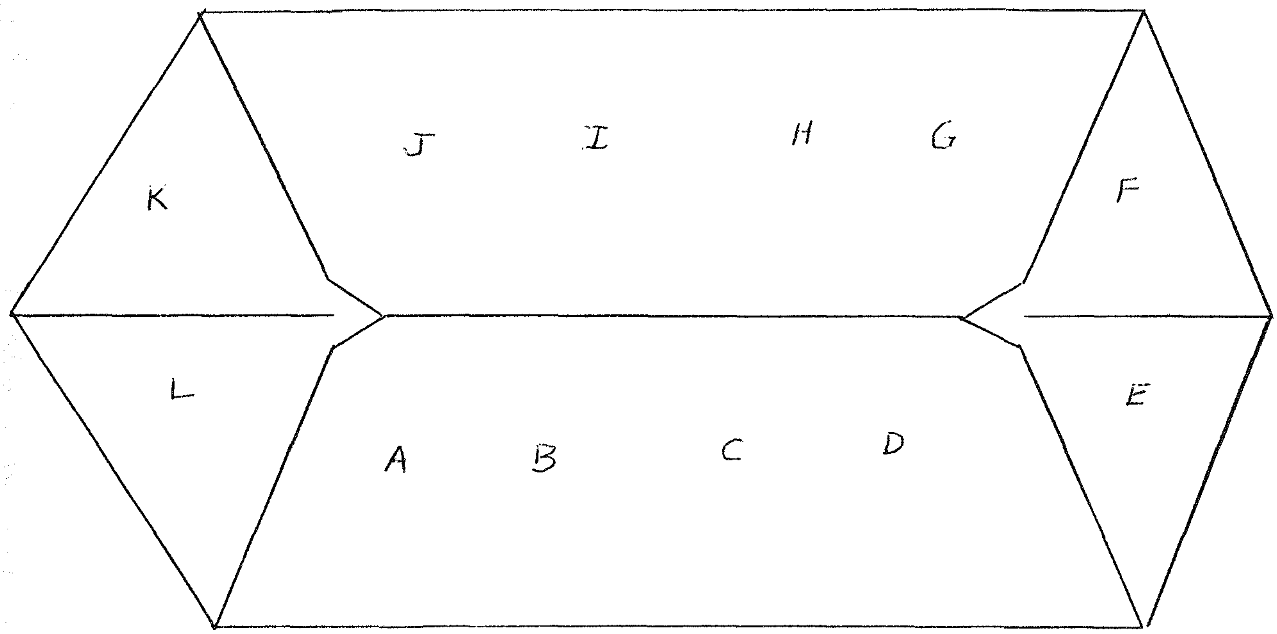
A = 7 bundles 5
B = 7 bundles 0
C = 7 bundles 20
D = balance 10

E = all 5
F = all 0

G = 7 bundles 10
H = 7 bundles 20
I = 7 bundles 0
J = balance 5

K = all 20
L = all 10

^
N



Street

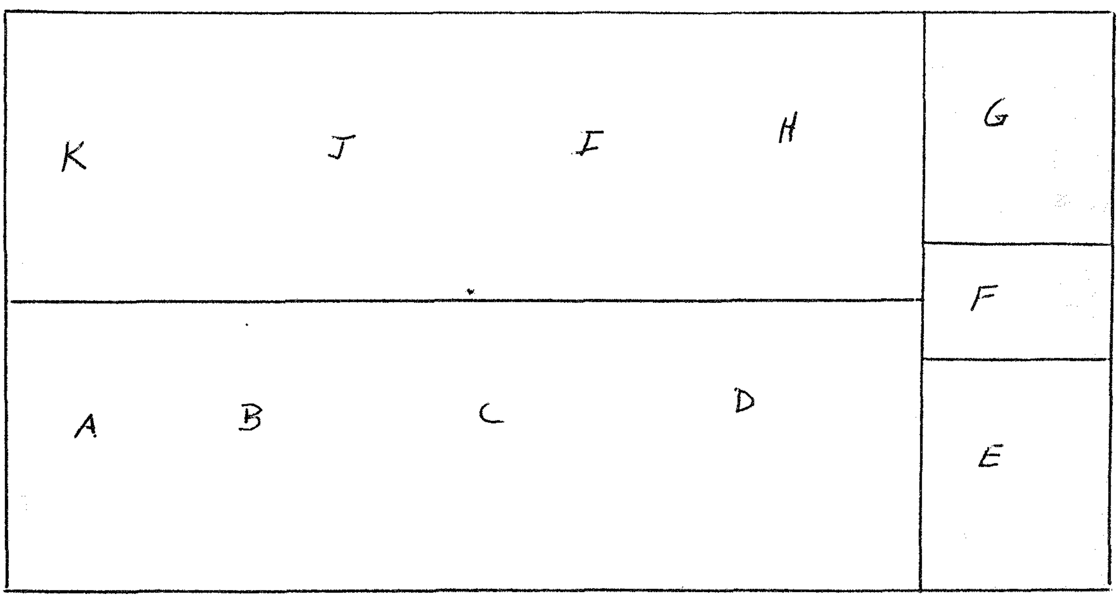
Mr. Clayton Bernard
12511 West Florida
Lakewood, CO 80028

A=6 bundles 20
B=6 bundles 10
C=6 bundles 0
D=balance 5

E=4 bundles 5
F=2 bundles mixed
G=4 bundles 10

H=6 bundles 0
I=6 bundles 5
J=6 bundles 20
K=balance 10

^
N



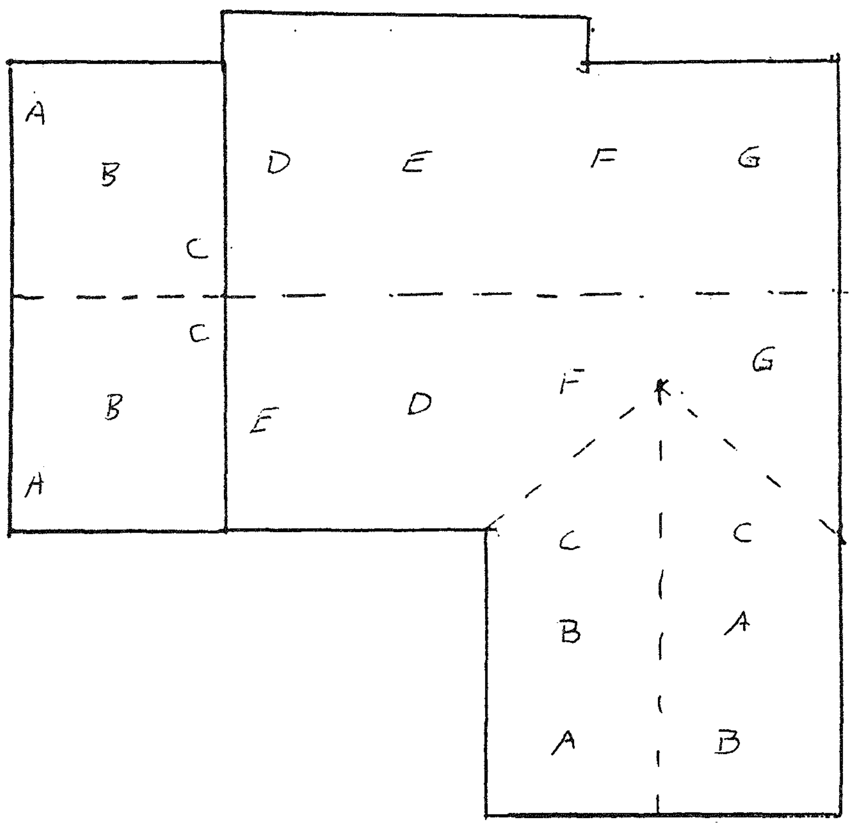
Street

Mr. Bart Vanden Plas
2106 East 115th Place
Northglenn, Colorado

A=2 bundles 0
B=2 bundles 5
C=Balance 20

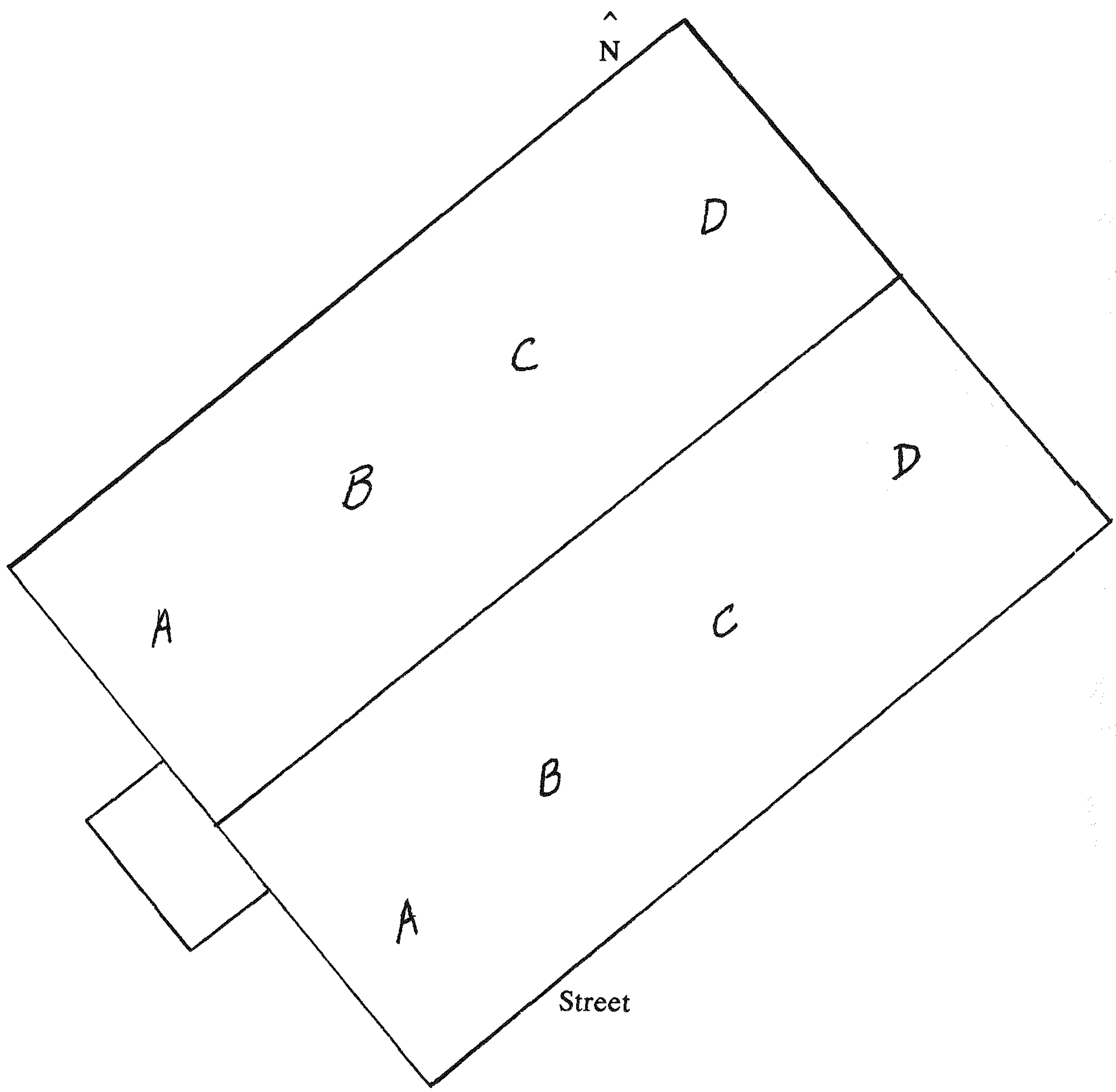
D=5 bundles 20
E=3 bundles 10
F=5 bundles 5
G=balance 0

^
N
Street



Harvest Assembly of God Church
off service road at junction of Highways 301 and 72
opposite Sylvania Station Shopping Center
Sylvania, Georgia

A = 10 bundles 5
B = 10 bundles 0
C = 10 bundles 20
D = balance 10
entrance = mixed
Shingles were installed "racked" which is straight up the roof.



Thaggard Construction Company
27 Country Walk Drive
Savannah, Georgia

Map of roof not available at time of printing.

Thaggard Construction Company
117 Country Walk Drive
Savannah, Georgia

Map of roof not available at time of printing.

APPENDIX G

FINANCIAL DATA AND CALCULATIONS

TABLE G-1: SUMMARY OF INPUTS FOR FINANCIAL ANALYSIS

Factory Capacity	220,000 tons per year 2.0MM squares per year
Shingle Weight	220 lb per square
Coating Composition	130 lb per square 35% asphalt 65% filler
Waste Composition	24.9% asphalt 75.1% filler

Coating Compositions for Three Levels of Waste Generation

	Annual Rate of Waste Generation			
	0% (baseline)	3% 6600 t/yr	5% 11000 t/yr	7% 15400 t/y
	Formula - % by Weight			
Asphalt	35.0%	33.7%	32.9%	32.0%
Filler	65.0%	61.2%	58.6%	56.1%
Scrap	0.0%	5.1%	8.5%	11.9%

- Acquisition of on-site factory waste	= $ 0.35/ton
- Disposal of factory waste	= $100.00/ton high = $ 60.00/ton med = $ 20.00/ton low
- Asphalt coating	= $134.00/ton
- Filler	= $ 22.80/ton
- Crew Size	1/shift
- Production Labor	$9.00/hr / 5000 hr
- Maintenance Labor	$13.00/hr / 2080 hr
- Waste Processing Energy	0.039 KWH/lb 4.5 Btu/lb
- Factory Operating Energy	0.0041 KWH/lb 61.0 Btu/lb

- Variable annual, added costs depend on the quantity of waste processed.

National average energy costs:

Industrial No. 2 Fuel Oil	$.053/gal $3.82/MM Btu
Industrial Natural Gas	$2.83/Mcf $2.75/MM Btu
Industrial Electricity	$0.0456/KW $13.36/MM Btu

	Annual Rate of Waste Generation		
	3%	5%	7%
	6600 t/yr	11000 t/yr	15400 t/yr
Electricity	$ 25943	$ 43238	$ 60533
Fuel	2378	3963	5548
Labor	45000	45000	45000
Maintenance	60040	82040	104040
Total	133361	174241	215121

- Insurance = $ 500 yr

- Equipment cost for scrap processing, handling, and mixing

	Annual Rate of Waste Generation		
	3%	5%	7%
	6600 t/yr	11000 t/yr	15400 t/yr
Capital	2085000	2515000	2850000
Operating funds (borrowed)	160000	200000	245000
(total process cost less depreciation from Table F-2)			

Financial Assumptions

- Base year is Year 0
- Future dollar values are not discounted for inflation
- 100% external financing
- 10% interest on borrowed funds
- 12% discount rate
- 10 year debt life
- 7 year depreciation life, assume accelerated depreciation
- 40% overall tax rate on taxable earnings

INSTALLED CAPITAL EQUIPMENT COST

Assumptions made in developing this estimate were -

1. A building addition is required.
2. Power supply from utility and transformers is adequate. Additional distribution is required in the factory.
3. Existing steam or hot oil system is adequate.
4. Existing fume control system has adequate capacity.

	6600 tpy	11000 tpy	15400 tpy
Waste Processing Equipment	$1,000M	$1,250M	$1,400M
Handling Equipment (conveyors, elevator)	100	150	200
Scale System	75	75	75
Building	200	275	350
Electrical			
Main Service Distribution	25	25	25
Starters	25	25	25
Equipment Installation	360	385	410
Mechanical			
Electrical			
Piping			
Fume System Ductwork			
Insulation			
Surge Mixer, Pump, and Drive	100	100	100
Subtotal	$1,885	$2,285	$2,585
Contingency	100	105	115
Engineering and Management	100	125	150
TOTAL	**$2,085**	**$2,515**	**$2,850**

RWPROCBD TABLE G-2 CALCULATION OF COST TO PROCESS ROOFING WASTE
05-24-89
TJP

DIRECT COST =========== ELEMENT	UNIT	COST $/ UNIT	QTY/TON OF WASTE	6600TPY COST/T	6600TPY COST/ 6600T	11000TPY COST/T	11000TPY COST/ 11000T	15400TPY COST/T	15400TPY COST/ 15400T
WASTE	TONS	0.3500	1.0000	0.3500	2310	0.3500	3850	0.3500	5390
ENERGY									
ELEC.:	KWH	0.0456	86.2000	3.9307	25943				
			86.2000			3.9307	43238		
			86.2000					3.9307	60533
GAS:	MMBTU	2.7500	0.1310	0.3603	2378				
			0.1310			0.3603	3963		
			0.1310					0.3603	5548
DIR. LABOR	MNHR	9.0000	0.7576	6.8182	45000				
			0.4545			4.0909	45000		
			0.3247					2.9221	45000
TOTAL DIRECT COST				11.4592	75631	8.7319	•96051	7.5630	116471
INDIRECT COST =============									
MAINT. LABOR	MNHR	13.0000	0.3152	4.0970	27040				
			0.1891			2.4582	27040		
			0.1351					1.7558	27040
MAINT. MATERIAL	TON	5.0000	1.0000	5.0000	33000				
		5.0000	1.0000			5.0000	55000		
		5.0000	1.0000					5.0000	77000
TEB	MNHR	3.0525	1.0727	3.2745	21612				
			0.6436			1.9647	21612		
			0.4597					1.4034	21612
DEPRECIATION	TON	15.7955	1.0000	15.7955	104250				
		11.4318	1.0000			11.4318	125750		
		9.2532	1.0000					9.2532	142500
TOTAL INDIRECT COST				28.1670	185902	20.8547	229402	17.4125	268152
TOTAL PROCESS COST				39.6261	261533	29.5866	325453	24.9755	384623

RWPROFIN TABLE G-3 PRO FORMA INCOME STATEMENTS
05-24-89
TJP

REVENUE (SAVINGS):

	6600 TONS			11000 TONS			15400 TONS		
	CASE 1	CASE 2	CASE 3	CASE 1	CASE 2	CASE 3	CASE 1	CASE 2	CASE 3
DISPOSAL COST/TON (TABLE G-4)	$20.00	$60.00	$100.00	$20.00	$60.00	$100.00	$20.00	$60.00	$100.00
ASPHALT COST/TON (TABLE G-4)	$134.00	$134.00	$134.00	$134.00	$134.00	$134.00	$134.00	$134.00	$134.00
FILLER COST/TON (TABLE G-4)	$22.80	$22.80	$22.80	$22.80	$22.80	$22.80	$22.80	$22.80	$22.80
AVOIDED DISPOSAL COST (TABLE G-4)	132,000	396,000	660,000	220,000	660,000	1,100,000	308,000	924,000	1,540,000
ASPHALT SUBSTITUTION (TABLE G-4)									
6600T @ 25% = 1650T	221,100	221,100	221,100						
11000T @ 25% = 2750T				368,500	368,500	368,500			
15400T @ 25% = 3850T							515,900	515,900	515,900
FILLER SUBSTITUTION (TABLE G-4)									
6600T @ 75% = 4950T	112,860	112,860	112,860						
11000T @ 75% = 8250T				188,100	188,100	188,100			
15400T @ 75% = 11550T							263,340	263,340	263,340
TOTAL SAVINGS (TABLE G-4)	465,960	729,960	993,960	776,600	1,216,600	1,656,600	1,087,240	1,703,240	2,319,240
PROCESS COST (TABLES G-2 & G-4)	261,533	261,533	261,533	325,453	325,453	325,453	384,623	384,623	384,623
GROSS PROFIT (TABLE G-4)	204,427	468,427	732,427	451,147	891,147	1,331,147	702,617	1,318,617	1,934,617
GEN'L. & ADMIN. (TABLE G-4)									
PRINCIPAL & INTEREST	365,363	365,363	365,363	441,854	441,854	441,854	503,697	503,697	503,697
INSURANCE	500	500	500	500	500	500	500	500	500
TOTAL G & A	365,863	365,863	365,863	442,354	442,354	442,354	504,197	504,197	504,197
PRE-TAX INCOME (TABLE G-4)	(161,436)	102,564	366,564	8,793	448,793	888,793	198,420	814,420	1,430,420
NET INCOME (TABLE G-4)	(96,862)	61,538	219,938	5,276	269,276	533,276	119,052	488,652	858,252

TABLE G-4: ECONOMIC ANALYSIS OF RECYCLING SHINGLE SCRAP INTO NEW SHINGLES

FACTORY REJECTS 3%

	CASE 1	CASE 2	CASE 3
INVESTMENT	2,085,000	2,085,000	2,085,000
FINANCED OPERATING COSTS	160,000	160,000	160,000
TONS	6,600	6,600	6,600
ASPHALT 25%	1650.00	1650.00	1650.00
FILLER 75%	4950.00	4950.00	4950.00
ASPHALT COST/TON	$134.00	$134.00	$134.00
FILLER COST/TON	$22.80	$22.80	$22.80
DISPOSAL COST/TON	$20.00	$60.00	$100.00
ACQUISITION/TON	$0.3500	$0.3500	$0.3500
ELECTRICITY/TON	$3.9307	$3.9307	$3.9307
GAS/TON	$0.3603	$0.3603	$0.3603
DIRECT LABOR/TON	$6.8182	$6.8182	$6.8182
IND LABOR/TON	$4.0970	$4.0970	$4.0970
TEB/TON	$3.2745	$3.2745	$3.2745
MATERIAL/TON	$5.0000	$5.0000	$5.0000

INCOME STATEMENT
==============

	CASE 1	CASE 2	CASE 3
REVENUE:			
ASPHALT SAVINGS	221,100	221,100	221,100
FILLER SAVINGS	112,860	112,860	112,860
DISPOSAL SAVINGS	132,000	396,000	660,000
TOTAL SAVINGS	465,960	729,960	993,960
DIRECT COSTS:			
ACQUISITION COSTS	2,310	2,310	2,310
ELECTRICITY	25,943	25,943	25,943
GAS	2,378	2,378	2,378
DIRECT LABOR	45,000	45,000	45,000
TOTAL DIRECT COSTS	75,631	75,631	75,631
INDIRECT COSTS:			
MAINT. LABOR	27,040	27,040	27,040
TAX EMP BENEFITS	21,612	21,612	21,612
MAINT.MATERIAL	33,000	33,000	33,000
BOOK DEPRECIATION 20YR	104,250	104,250	104,250
TOTAL INDIRECT COSTS	185,902	185,902	185,902
TOTAL PROCESS COST	261,533	261,533	261,533
GROSS PROFIT	204,427	468,427	732,427
GENERAL & ADMINISTRATIVE			
PRINCIPAL & INT 10 YEAR	365,363	365,363	365,363
INSURANCE	500	500	500
TOTAL G & A	365,863	365,863	365,863
PRE-TAX INCOME	(161,436)	102,564	366,564
NET INCOME	(96,862)	61,538	219,938

	CASE 1	CASE 2	CASE 3
ACCELERATED DEPRECIATION			
ACCEL DEP YR1	595,714	595,714	595,714
ACCEL DEP YR2	425,510	425,510	425,510
ACCEL DEP YR3	303,936	303,936	303,936
ACCEL DEP YR4	217,097	217,097	217,097
ACCEL DEP YR5	180,914	180,914	180,914
ACCEL DEP YR6	180,914	180,914	180,914
ACCEL DEP YR7	180,914	180,914	180,914
DEP YR 8 THRU 20	0	0	0
CASH NET INCOME (C.N.I.)			
INVESTMENT	(2,085,000)	(2,085,000)	(2,085,000)
YEAR 1	407,568	565,968	724,368
YEAR 2	339,487	497,887	656,287
YEAR 3	290,857	449,257	607,657
YEAR 4	256,121	414,521	572,921
YEAR 5	241,648	400,048	558,448
YEAR 6	241,648	400,048	558,448
YEAR 7	241,648	400,048	558,448
YEAR 8	169,283	327,683	486,083
YEAR 9	169,283	327,683	486,083
YEAR 10	169,283	327,683	486,083
IRR 10 YR	4.3%	16.7%	26.8%
NET PRES VALUE 10YR/12%	(527,893)	367,102	1,262,097
PAYBACK YEARS	7.4	4.4	3.2
DISCOUNTED PAYBACK			
INTEREST RATE	12.0%	12.0%	12.0%
INVESTMENT	(2,085,000)	(2,085,000)	(2,085,000)
YEAR 1	363,900	505,329	646,757
YEAR 2	270,637	396,912	523,188
YEAR 3	207,026	319,772	432,518
YEAR 4	162,770	263,436	364,102
YEAR 5	137,118	226,998	316,879
YEAR 6	122,427	202,677	282,927
YEAR 7	109,309	180,962	252,614
YEAR 8	68,370	132,346	196,321
YEAR 9	61,045	118,166	175,286
YEAR 10	54,504	105,505	156,506
PAYBACK YEARS	>10.0	6.9	4.4

ACCELERATED DEPRECIATION = DOUBLE DECLINING BALANCE METHOD
TAX RATE = 40%
TAX = PRE-TAX INCOME X TAX RATE
NET INCOME = PRE-TAX INCOME LESS TAX

CASH NET INCOME = NET INCOME PLUS TAX RATE X (ACCEL DEPR MINUS BOOK DEPR) PLUS BOOK DEPR PLUS 60% OF THAT PART OF PRINCIPAL AND INTEREST WHICH REPAYS THE CAPITAL INVESTMENT.

FACTORY REJECTS 5%

	CASE 1	CASE 2	CASE 3
INVESTMENT	2,515,000	2,515,000	2,515,000
FINANCED OPERATING COSTS	200,000	200,000	200,000
TONS	11,000	11,000	11,000
ASPHALT 25%	2750.00	2750.00	2750.00
FILLER 75%	8250.00	8250.00	8250.00
ASPHALT COST/TON	$134.00	$134.00	$134.00
FILLER COST/TON	$22.80	$22.80	$22.80
DISPOSAL COST/TON	$20.00	$60.00	$100.00
ACQUISITION/TON	$0.3500	$0.3500	$0.3500
ELECTRICITY/TON	$3.9307	$3.9307	$3.9307
GAS/TON	$0.3603	$0.3603	$0.3603
DIRECT LABOR/TON	$4.0909	$4.0909	$4.0909
IND LABOR/TON	$2.4582	$2.4582	$2.4582
TEB/TON	$1.9647	$1.9647	$1.9647
MATERIAL/TON	$5.0000	$5.0000	$5.0000

INCOME STATEMENT
==============

	CASE 1	CASE 2	CASE 3
REVENUE:			
ASPHALT SAVINGS	368,500	368,500	368,500
FILLER SAVINGS	188,100	188,100	188,100
DISPOSAL SAVINGS	220,000	660,000	1,100,000
TOTAL SAVINGS	776,600	1,216,600	1,656,600
DIRECT COSTS:			
ACQUISITION COSTS	3,850	3,850	3,850
ELECTRICITY	43,238	43,238	43,238
GAS	3,963	3,963	3,963
DIRECT LABOR	45,000	45,000	45,000
TOTAL DIRECT COSTS	96,051	96,051	96,051
INDIRECT COSTS:			
MAINT. LABOR	27,040	27,040	27,040
TAX EMP BENEFITS	21,612	21,612	21,612
MAINT.MATERIAL	55,000	55,000	55,000
BOOK DEPRECIATION 20YR	125,750	125,750	125,750
TOTAL INDIRECT COSTS	229,402	229,402	229,402
TOTAL PROCESS COST	325,453	325,453	325,453
GROSS PROFIT	451,147	891,147	1,331,147
GENERAL & ADMINISTRATIVE			
PRINCIPAL & INT 10 YEAR	441,854	441,854	441,854
INSURANCE	500	500	500
TOTAL G & A	442,354	442,354	442,354
PRE-TAX INCOME	8,793	448,793	888,793
NET INCOME	5,276	269,276	533,276

	CASE 1	CASE 2	CASE 3
ACCELERATED DEPRECIATION			
ACCEL DEP YR1	718,571	718,571	718,571
ACCEL DEP YR2	513,265	513,265	513,265
ACCEL DEP YR3	366,618	366,618	366,618
ACCEL DEP YR4	261,870	261,870	261,870
ACCEL DEP YR5	218,225	218,225	218,225
ACCEL DEP YR6	218,225	218,225	218,225
ACCEL DEP YR7	218,225	218,225	218,225
DEP YR 8 THRU 20	0	0	0
CASH NET INCOME (C.N.I.)			
INVESTMENT	(2,515,000)	(2,515,000)	(2,515,000)
YEAR 1	613,737	877,737	1,141,737
YEAR 2	531,615	795,615	1,059,615
YEAR 3	472,956	736,956	1,000,956
YEAR 4	431,057	695,057	959,057
YEAR 5	413,599	677,599	941,599
YEAR 6	413,599	677,599	941,599
YEAR 7	413,599	677,599	941,599
YEAR 8	326,309	590,309	854,309
YEAR 9	326,309	590,309	854,309
YEAR 10	326,309	590,309	854,309
IRR 10 YR	12.6%	27.0%	39.5%
NET PRES VALUE 10YR/12%	53,209	1,544,868	3,036,526
PAYBACK YEARS	5.1	3.2	2.3
DISCOUNTED PAYBACK			
INTEREST RATE	12.0%	12.0%	12.0%
INVESTMENT	(2,515,000)	(2,515,000)	(2,515,000)
YEAR 1	547,980	783,694	1,019,408
YEAR 2	423,800	634,259	844,718
YEAR 3	336,641	524,551	712,461
YEAR 4	273,944	441,721	609,498
YEAR 5	234,687	384,488	534,288
YEAR 6	209,542	343,293	477,043
YEAR 7	187,091	306,511	425,931
YEAR 8	131,791	238,416	345,041
YEAR 9	117,670	212,871	308,072
YEAR 10	105,063	190,064	275,065
PAYBACK YEARS	9.5	4.3	2.9

ACCELERATED DEPRECIATION = DOUBLE DECLINING BALANCE METHOD
TAX RATE = 40%
TAX = PRE-TAX INCOME X TAX RATE
NET INCOME = PRE-TAX INCOME LESS TAX

CASH NET INCOME = NET INCOME PLUS TAX RATE X (ACCEL DEPR MINUS BOOK DEPR) PLUS BOOK DEPR PLUS 60% OF THAT PART OF PRINCIPAL AND INTEREST WHICH REPAYS THE CAPITAL INVESTMENT.

FACTORY REJECTS 7%

	CASE 1	CASE 2	CASE 3
INVESTMENT	2,850,000	2,850,000	2,850,000
FINANCED OPERATING COSTS	245,000	245,000	245,000
TONS	15,400	15,400	15,400
ASPHALT 25%	3850.00	3850.00	3850.00
FILLER 75%	1550.00	11550.00	11550.00
ASPHALT COST/TON	$134.00	$134.00	$134.00
FILLER COST/TON	$22.80	$22.80	$22.80
DISPOSAL COST/TON	$20.00	$60.00	$100.00
ACQUISITION/TON	$0.3500	$0.3500	$0.3500
ELECTRICITY/TON	$3.9307	$3.9307	$3.9307
GAS/TON	$0.3603	$0.3603	$0.3603
DIRECT LABOR/TON	$2.9221	$2.9221	$2.9221
IND LABOR/TON	$1.7558	$1.7558	$1.7558
TEB/TON	$1.4034	$1.4034	$1.4034
MATERIAL/TON	$5.0000	$5.0000	$5.0000

INCOME STATEMENT

==========================

	CASE 1	CASE 2	CASE 3
REVENUE:			
ASPHALT SAVINGS	515,900	515,900	515,900
FILLER SAVINGS	263,340	263,340	263,340
DISPOSAL SAVINGS	308,000	924,000	1,540,000
TOTAL SAVINGS	1,087,240	1,703,240	2,319,240
DIRECT COSTS:			
ACQUISITION COSTS	5,390	5,390	5,390
ELECTRICITY	60,533	60,533	60,533
GAS	5,548	5,548	5,548
DIRECT LABOR	45,000	45,000	45,000
TOTAL DIRECT COSTS	116,471	116,471	116,471
INDIRECT COSTS:			
MAINT. LABOR	27,040	27,040	27,040
TAX EMP BENEFITS	21,612	21,612	21,612
MAINT MATERIAL	77,000	77,000	77,000
BOOK DEPRECIATION 20YR	142,500	142,500	142,500
TOTAL INDIRECT COSTS	268,152	268,152	268,152
TOTAL PROCESS COST	384,623	384,623	384,623
GROSS PROFIT	702,617	1,318,617	1,934,617
GENERAL & ADMINISTRATIVE			
PRINCIPAL & INT 10 YEAR	503,697	503,697	503,697
INSURANCE	500	500	500
TOTAL G & A	504,197	504,197	504,197
PRE-TAX INCOME	198,420	814,420	1,430,420
NET INCOME	119,052	488,652	858,252

	CASE 1	CASE 2	CASE 3
ACCELERATED DEPRECIATION			
ACCEL DEP YR1	814,286	814,286	814,286
ACCEL DEP YR2	581,633	581,633	581,633
ACCEL DEP YR3	415,452	415,452	415,452
ACCEL DEP YR4	296,751	296,751	296,751
ACCEL DEP YR5	247,293	247,293	247,293
ACCEL DEP YR6	247,293	247,293	247,293
ACCEL DEP YR7	247,293	247,293	247,293
DEP YR 8 THRU 20	0	0	0
CASH NET INCOME (C.N.I.)			
INVESTMENT	(2,850,000)	(2,850,000)	(2,850,000)
YEAR 1	808,561	1,178,161	1,547,761
YEAR 2	715,500	1,085,100	1,454,700
YEAR 3	649,027	1,018,627	1,388,227
YEAR 4	601,547	971,147	1,340,747
YEAR 5	581,764	951,364	1,320,964
YEAR 6	581,764	951,364	1,320,964
YEAR 7	581,764	951,364	1,320,964
YEAR 8	482,847	852,447	1,222,047
YEAR 9	482,847	852,447	1,222,047
YEAR 10	482,847	852,447	1,222,047
IRR 10YR	18.4%	34.8%	49.5%
NET PRES VALUE 10YR/12%	699,185	2,787,508	4,875,830
PAYBACK YEARS	4.1	2.6	1.9
DISCOUNTED PAYBACK			
INTEREST RATE	12.0%	12.0%	12.0%
INVESTMENT	(2,850,000)	(2,850,000)	(2,850,000)
YEAR 1	721,929	1,051,929	1,381,929
YEAR 2	570,392	865,035	1,159,678
YEAR 3	461,965	725,039	988,113
YEAR 4	382,294	617,182	852,069
YEAR 5	330,108	539,829	749,550
YEAR 6	294,740	481,990	669,241
YEAR 7	263,160	430,349	597,537
YEAR 8	195,014	344,289	493,564
YEAR 9	174,119	307,401	440,682
YEAR 10	155,464	274,465	393,466
PAYBACK YEARS	6.3	3.3	2.3

ACCELERATED DEPRECIATION = DOUBLE DECLINING BALANCE METHOD
TAX RATE = 40%
TAX = PRE-TAX INCOME X TAX RATE
NET INCOME = PRE-TAX INCOME LESS TAX

CASH NET INCOME = NET INCOME PLUS TAX RATE X (ACCEL DEPR MINUS BOOK DEPR) PLUS BOOK DEPR PLUS 60% OF THAT PART OF PRINCIPAL AND INTEREST WHICH REPAYS THE CAPITAL INVESTMENT.

GLOSSARY

Discounted Return on Investment	First year cash net income (CNI) times first year present worth factor (PWF) at discount rate divided by net investment times 100.
Simple Payback	Time required for undiscounted cash flows to equal the net investment.
Discounted Payback	Time required for the cash flows, when discounted at the selected rate, to equal the net investment.
Internal Rate of Return (IRR)	The discount rate which will cause the net present value of an investment to be equal to zero.
Gross Savings	a) Gross savings divided by tons of waste. b) Gross savings divided by squares of shingles produced minus waste shingles produced.
Added Net Income	a) Net income divided by tons of waste b) Net income divided by annual squares of shingles produced minus waste shingles produced.

TABLE G-5 RESULTS OF FINANCIAL ANALYSIS

DISCOUNTED RETURN ON INVESTMENT - %

	Waste Generation Rate		
	3% 6600 t/yr	5% 11000 t/yr	7% 15400 t/yr
Disposal Cost: $100/ton	31.0	40.5	48.5
$ 60/ton	24.2	31.2	36.9
$ 20/ton	17.5	21.8	25.3

SIMPLE PAYBACK - YEARS

	Waste Generation Rate		
	3% 6600 t/yr	5% 11000 t/yr	7% 15400 t/yr
Disposal Cost: $100/ton	3.2	2.3	1.9
$ 60/ton	4.4	3.2	2.6
$ 20/ton	7.4	5.1	4.1

DISCOUNTED PAYBACK - YEARS

	Waste Generation Rate		
	3% 6600 t/yr	5% 11000 t/yr	7% 15450 t/yr
Disposal Cost: $100/ton	4.4	2.9	2.3
$ 60/ton	6.9	4.3	3.3
$ 20/ton	>10.0	9.5	6.3

INTERNAL RATE OF RETURN - %

	Waste Generation Rate		
	3% 6600 t/yr	5% 11000 t/yr	7% 15400 t/yr
Disposal Cost: $100/ton	26.8	39.5	49.5
$ 60/ton	16.7	27.0	34.8
$ 20/ton	4.3	12.6	18.4

GROSS SAVINGS - $ PER TON OF WASTE

	Waste Generation Rate		
	3% 6600 t/yr	5% 11000 t/yr	7% 15400 t/yr
Disposal Cost:			
$100/ton	150.60	150.60	150.60
$ 60/ton	110.60	110.60	110.60
$ 20/ton	70.60	70.60	70.60

GROSS SAVINGS - $ PER SQUARE OF SHINGLES

	Waste Generation Rate		
	3% 6600 t/yr	5% 11000 t/yr	7% 15400 t/yr
Disposal Cost:			
$100/ton	0.51	0.87	1.25
$ 60/ton	0.38	0.64	0.92
$ 20/ton	0.24	0.41	0.58

ADDED NET INCOME - $ PER TON OF WASTE

	Waste Generation Rate		
	3% 6600 t/yr	5% 11000 t/yr	7% 15400 t/yr
Disposal Cost:			
$100/ton	33.32	48.48	55.73
$ 60/ton	9.32	24.48	31.73
$ 20/ton	(14.68)	0.48	7.73

ADDED NET INCOME - $ PER SQUARE OF SHINGLES

	Waste Generation Rate		
	3% 6600 t/yr	5% 11000 t/yr	7% 15400 t/yr
Disposal Cost:			
$100/ton	0.11	0.28	0.46
$ 60/ton	0.03	0.14	0.26
$ 20/ton	(0.05)	0.00	0.06

APPENDIX H

MARKETING PLAN

COMMERCIAL DEVELOPMENT

The production, product quality, and financial success of the commercial scale research described in this report has set the stage for a major marketing effort by Bird, who holds the patent on the process for preparing roofing waste for recycle. The marketing plan has been designed to address expressed and potential questions from the customer base and to make the process available to all asphalt roofing manufacturers. The technology will be marketed on several different levels, each of which has been designed to appeal to different types of manufacturers. The overall plan contains two distinct phases: Phase 1 - Commercial Implementation and Demonstration; and Phase 2 - Sales and Marketing.

Phase 1 - Commercial Implementation and Demonstration

Bird will install a commercial scale recycling facility integrated with the continuous asphalt roofing manufacturing machinery at their Norwood, MA factory.

Commercial Implementation

The recycling facility to be installed at the Bird factory will be the first full scale unit. This unit will operate on a commercial basis recycling the factory waste into new asphalt shingles. Objectives which will be achieved by the operation of this facility include:

1. Optimizing of the process conditions for handling, preparing, and mixing of the waste.

2. Developing a thorough understanding of the process and its effects on roofing manufacture and quality on a continuous production basis.

3. Providing a demonstration facility for inspection by potential customers. Local and state agencies may also view the process to assess its favorable impact on waste disposal.

Financial participation in the first facility will be offered to three groups:

1. Suppliers of the process equipment to be used.

2. Federal, state and local agencies concerned with waste management.

3. Suppliers of raw materials.

Process Equipment Suppliers - Manufacturers of essential machinery such as the intensive mixer, roll mill, and asphalt mixer and pumps will benefit from widespread implementation. They will be offered an opportunity to support this project which will serve as a showcase for their products.

Government Agencies - Community benefits which are perceived include:

1. Reduction in the burden on landfills.

2. Increase in local employment.

3. Increase in locally invested capital.

4. Potential of future applicability to the recycling of worn out roofing.

Funding assistance will be sought for those agencies which have programs designed to support the perceived community benefits.

Raw Material Suppliers - Purchases of some virgin raw materials will be influenced and suppliers of the materials will be offered a chance to participate.

Demonstration

Potential customers will have questions about a new process which can best be answered by showing them an operating unit and the data derived from continuous, commercial operation. Some of the anticipated questions involve maintenance, process optimization, and materials handling.

The first unit will be a demonstration facility available for inspection by all prospective customers and interested agencies. Pertinent data derived from the operation will be made available to answer all questions concerning the process, materials handling, wear and maintenance, product quality, and financial benefits.

Phase 2 - Sales and Marketing

The first commercial operating unit will be the heart of the marketing program. All potential customers are easily identified through industrial sources. Each prospect will be contacted and acquainted with the benefits to his operation as quantified in this report. Questions and concerns will be addressed directly and by observations of the operating commercial facility.

Some sales prospects may have concerns about the basis of purchasing equipment and technology from a competing firm (Bird). Some prospects may be large companies with internal resources such that they may wish to do their own design and construction. Others may be so small as to require a turn-key operation. Yet others may be so small that the financial benefits could be realized only by pooling their waste resource with other nearby roofing factories.

The sales basis for this technology will be offered in three different vehicles.

1. Design, installation and start-up by a third independent party.

2. Simple licensing.

3. Regional facilities.

This sales program is designed to meet perceived needs and potential prejudices of all prospective customers. However, other vehicles can be assembled for unique circumstances which might arise.

Bird would make this technology available through one (or perhaps several) competent architectural/engineering firms so that customers would not have to deal with a competitor in the roofing business. Such a firm would have intimate involvement in the design and erection of the demonstration facility. Customers would have the option of purchasing as large a package of services and equipment as would suit their needs.

The second option of simple license of the patent would leave the customer free to design and construct on any basis he might choose.

Finally, Bird is prepared to explore with local agencies the potential for the installation of regional facilities to serve a number of small roofing factories in areas where no single factory might justify a captive facility. This resource recovery and recycle facility might, for example, be second-party or consortium-owned and be operated by Bird.