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RECOVERY AND REUSE OF ASPHALT ROOFING WASTE

By
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February 2, 1984

Work Performed Under Contract No. AC07-82CE40558

Manville Service Corporation
Research and Development Center
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Final Report Prepared for:

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ABSTRACT

Burning of asphalt roofing waste as a fuel and incorporating asphalt roofing waste in bituminous paving were identified as the two outstanding resource recovery concepts out of ten studied. Four additional concepts might be worth considering under different market or technical circumstances. Another four concepts were rated as worth no further consideration at this time. This study of the recovery of the resource represented in asphalt roofing waste has identified the sources and quantities of roofing waste. About six million cubic yards of scrap roofing are generated annually in the United States, about 94 percent from removal of old roofing at the job site and the remainder from roofing material production at factories. Waste disposal is a growing problem for manufacturers and contractors. Nearly all roofing waste is hauled to landfills at a considerable expense to roofing contractors and manufacturers. Recovery of the roofing waste resource should require only a modest economic incentive. The asphalt contained in roofing waste represents an energy resource of more than 7×10^{13} Btu/year. Another 1×10^{13} Btu/year may be contained in field-applied asphalt on commercial building roofs. The two concepts recommended by this study appear to offer the broadest applicability, the most favorable economics, and the highest potential for near-term implementation to reuse this resource.

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SUMMARY

This study has reviewed asphalt roofing waste as a recoverable energy resource. Two of ten candidate concepts were identified as being superior in technical and economic viability, broad applicability, and near-term implementation:

- Mass burning of asphalt roofing waste
- Incorporation of asphalt roofing waste in asphalt paving mixes.

Additional research is required on each of these methods in order to b commercially implement and recover the 7 to 8 x 10^{13} Btu represented in asphalt roofing waste.

Asphalt Roofing Waste Resource

Nationwide annual shipments of asphalt roofing products and new/reroof market data were used to estimate the energy represented in the asphalt roofing waste resource. This was about 7 x 10^{13} Btu in 1981 based on roofing products waste. Another 1 x 10^{13} Btu may be found in the field applied asphalt in worn out, torn off, built-up, commercial roofing. This energy resource has been identified in quantity for various state locations and by source such as factory, residential roofing contractor and commercial roofing contractor. Five of the most heavily populated states account for about one-third of the waste. Ten states contribute about one-half of the waste. Factories generate about six percent of all roofing waste. Residential reroofing (worn out shingles) account for about three-fourths of the waste.

Disposal of Roofing Waste

Roofing waste disposal was viewed as a growing problem by both manufacturers and roofing contractors. It was conservatively estimated that at least 95 percent of all roofing waste is destined for landfill disposal. Minor amounts of fresh, factory waste are processed into plank and board products; burned in one special boiler; and mixed into paving by one paving contractor. Disposal of nearly all roofing waste involves self or contractor collection at the factory or job site and hauling to private or public

landfills. Roofing waste is, in many cases, banned from municipal waste landfills and must be hauled to demolition landfills. Disposal costs nationwide are usually in the range of $5 to $15 per ton. The estimated weighted average asphalt content of a ton of waste is 800 pounds, equivalent to about 13-1/2 x 10^6 Btu.

The volume of roofing waste hauled to landfills is about six million cubic yards annually. Eliminating or significantly reducing this volume would have a significant environmental impact. Other environmental considerations include the sulfur content of asphalt and the asbestos content of many roofing wastes.

Recovery of Asphalt Roofing Waste

The key to acquiring roofing waste for further processing is to offer an economically attractive alternative to landfill disposal. The primary incentive to contractors and manufacturers would be economic; i.e., reduction of their $5-15 per ton disposal cost. A reasonably convenient and free dump site should serve to acquire nearly all roofing waste in an urban area. The free dump site might be at a roofing factory, a power plant, an intermediate collection center or other location suitable to the end use of the waste.

Re-Use of Asphalt Roofing Waste

Ten concepts for recovering energy from asphalt roofing waste were studied. Two of the ten concepts were identified as being superior to the others and deserving of additional research. These are:

- Burn roofing waste as fuel.
- Incorporate roofing waste in asphalt paving.

Criteria used in comparing candidate concepts inluded:

- Investment
- Operating cost
- Use both field and factory waste
- Energy recovery
- Technical viability
- Likelihood of commercial acceptance
- Lead time to commercial implementation

Four additional concepts were identified as offering some commercial merit. Each might be worthy of consideration if economic conditions were to change or if additional research were accomplished to improve their viability.

1. Convert asphalt in roofing waste to No. 6 oil - Extraction with No. 2 oil followed by filtration and concentration might produce a No. 6 oil. Laboratory research would be required to demonstrate and confirm this concept.

2. Recover asphalt by solvent extraction. This process uses existing technology and has been demonstrated. The estimated high cost of recovered asphalt rules this concept out at today's asphalt selling prices.

3. Recycle roofing scrap as filler. This is an old concept which might be worth some new research because of the drastic shift from cellulose to fiber glass in roofing production. Applicable only to fresh, factory scrap it would have little impact on national energy recovery.

4. Roofing scrap in new products. Very little potential was found for increasing the use of roofing scrap as an ingredient in new products. This concept is also applicable principally to fresh, factory scrap only.

Four concepts were ruled out from further consideration at this time:

1. Recover Fuel by Fluid Coking
2. Recover Fuel by Pyrolysis

These concepts are very similar. They have an enormous capital investment requirement compared to other alternatives.

3. Recover Asphalt by Thermal Extraction
4. Recover Asphalt by Hydraulic Extraction

Both of these concepts are viewed as unlikely for asphalt recovery. Their efficiency of recovery is judged low based on published information. Considerable research on a laboratory scale would be needed prior to process development. The likelihood of an economic process resulting from such research was rated low.

1.0 - INTRODUCTION AND BACKGROUND

About 12 million barrels of asphalt are consumed annually in the U. S. production of roofing materials. The production of asphalt roofing is second only to the production of bituminous paving in the consumption of asphalt. An opportunity exists to recover the asphalt from roofing scrap for recycling or reuse as a substitute for fresh petroleum-based fuels or feedstocks. Such recovery offers an opportunity not only to reclaim the significant energy value of asphalt, but also to reduce the environmental impact of roofing waste disposal.

At present, at least 95 percent of all roofing waste is hauled to landfills. Some landfills may not permit the dumping of roofing and other "demolition" wastes. Trucks hauling the scrap may tie up unloading space with unreasonably long, manual off-loading. Roofing contractors, manufacturers and contract waste haulers may have to travel long distances to dispose of factory and job-site roofing waste, and may have to pay very high tipping fees. A reasonable, less costly disposal alternative would be welcomed by all parties.

Asphalt roofing waste is generated as factory production scrap and as job-site demolition waste of worn-out roofing removed when new roofing is applied. Factory scrap is relatively clean and its composition is identifiable. It is available at the factory in somewhat predictable quantities. For these reasons, factory scrap is an excellent candidate for recycle or reuse concepts. However, factory scrap accounts for only about six percent of all roofing waste. The job-site reroofing waste must be the major target for significant environmental and energy recovery impact.

The constituents of asphalt roofing (production) waste from factories depend upon product mix and compositions, and may include (weight percents):

- Asphalt - 25 to 40 percent

- Mineral filler (finely ground limestone, silica, dolomite, etc.) - 15 to 20 percent

- Mineral granules (ceramic coated natural rock about the size of coarse sand) - 20 to 30 percent

- Glass fiber mat
- Paper felt

(Glass fiber mat and paper felt) - 2 to 15 percent

- Sand and talc surfacing on one or both sides of some products - 1 to 5 percent
- Polyester film - minor.

Job-site waste may add to this list:

- Asbestos felt
- Asphalt cements containing asbestos
- Coal tar pitch
- Coal tar saturant
- Coarse rock aggregate
- Sheet metal flashing/edging
- Nails
- Wood
- Insulation boards composed of such things as:
    - Perlite
    - Wood Fiber
    - Polystyrene
    - Polyurethane
    - Foam Glass
    - Glass Fiber
- Miscellaneous trash.

Roofing scrap, if intercepted prior to delivery to a landfill, can be acquired in a form segregated from other types of waste. Concepts for salvaging the energy represented in scrap roofing include:

- Burn scrap as fuel
- Convert asphalt to No. 6 oil
- Convert asphalt to feedstock by coking
- Convert asphalt to syncrude by pyrolysis
- Recover asphalt with solvent
- Recover asphalt by thermal means

- Recover asphalt hydraulically
- Recycle scrap for use as a shingle coating filler
- Develop paving mixes
- Develop new products with roofing scrap as a major ingredient.

A search of patent literature and discussions with roofing manufacturers disclosed that many of these ideas have been researched and that some proprietary research is continuing. Recent literature on the treatment of scrap tires was pertinent to a few of the ideas relating to roofing scrap. There are some constituents in job-site waste which may preclude certain candidate reuse or recycle schemes. For example, nails might rule out road paving mixes for surfacing courses where factory waste is now used to a very small extent. Unknown and uncontrollable amounts of asbestos will influence the choice of alternatives as will coal tar bitumen which would be incompatible with asphalts in certain new product ideas.

The purpose of this study was to identify the most promising methods by which the energy in factory and job-site roofing waste can be recovered. The several sections of this report describe the quantity and location of the asphalt roofing waste resource, the present disposal methods and practices, some scenarios for roofing waste collection and recovery, and a number of technically potential reuse alternatives. The alternatives are then compared and the most favorable are selected based on technical, economic, energy impact, and implementation considerations. Conclusions are presented together with recommendations for further development of alternatives for recovery and reuse of asphalt roofing waste.

2.0 - ASPHALT ROOFING WASTE RESOURCE

Asphalt-bearing shingles and roll products are used to cover more than 90 percent of all buildings in the United States. The waste generated during asphalt roofing production and roof replacement, combined with the energy value of asphalt (about 17,000 Btu/pound as a fuel), suggest a significant potential resource for recovery and substitution in place of fresh asphalt or petroleum feedstock. The magnitude of the energy resource represented by asphalt roofing waste is a critical consideration in the analysis of how, or even whether, to select and develop a recovery and reuse program. The following discussions provide assumptions and estimates for the quantity of asphalt roofing waste, its geographic location and distribution within the United States, and the energy represented by the asphalt in the roofing waste.

2.1 - Quantities of Roofing Waste

The most reasonable basis for estimating the total quantity of United States asphalt roofing waste was determined to be the annual production of new asphalt roofing products. Factory scrap may be estimated as a nominal percentage of total asphalt roofing material production, and job-site waste quantity can be related to total product with a few justified assumptions based on industry data. Roofing market data are provided by manufacturers to the Asphalt Roofing Manufacturer's Association (ARMA). These data are collated and subdivided according to state and to broad divisions of product types. The Department of Commerce, Bureau of the Census, Current Industrial Reports and their Census of Manufacturers are additional sources of roofing market data.

Assumptions for Factory Scrap - Specific information on manufacturing waste in the production of asphalt roofing is not directly available. Such details of plant production data are considered confidential by manufacturers. Therefore, a "textbook" scrap rate of 5 percent was used to estimate the quantity of factory asphalt roofing waste. Interviews with roofing manufacturers confirmed that this percentage was a reasonable assumption.

Assumptions for Job-Site Waste - It was assumed that one worn out roof is torn off for each reroof application. This is not strictly true for every structure. However, building codes and structural considerations mandate the removal of all layers of old roofing at least every second or third application. This leads to a long-term "average" of one old roof removed as waste for each re-roofing application. A report by Housing Industry Dynamics and FIND/SVP[1] provides insight into the market division between reroofing and new construction roofing. About 61 percent of all built-up roofing is used for reroofing and 62 percent of all residential roofing is applied for covering existing roofs.

The Asphalt Roofing Manufacturer's Association publishes an annual summary of product shipments broken down according to classes of products and state. These "shipments" data represent sales since all shipments are in response to purchase orders. Annual sales are reported to be a close approximation of annual production. Shipments data can, therefore, be used to estimate waste generated using the 5 percent factory scrap rate and 61-62 percent reroofing statistics. A summary of these estimates is shown in Table 2.1.

Several types of product shipments are summarized in Table 2.1. Each product has a different asphalt content according to type and, with some variance, among manufacturers. A typical organic felt shingle may contain 80 pounds of asphalt per square and a typical fiber glass shingle may contain 50 pounds of asphalt per square. The proportion of fiber glass shingles in the product mix has grown from 8 percent in 1977 to 39 percent in 1981. Calculation of the energy represented in asphalt roofing waste requires assumptions about the asphalt content of various products and the product mix.

2.2 - Location of Asphalt Roofing Waste

Factory asphalt roofing waste is located at a discreet number of sites, the hundred or so United States manufacturing plants. Figure 2.1 shows the locations of these plants. It will be noted from Figure 2.1 that roofing factories tend to be located near major population centers.

The quantity of factory waste at each of these locations could be estimated by applying the assumed scrap rate to the total production of the plant.

FIGURE 2.1

ASPHALT ROOFING PLANTS

23 PRODUCERS 109 LOCATIONS

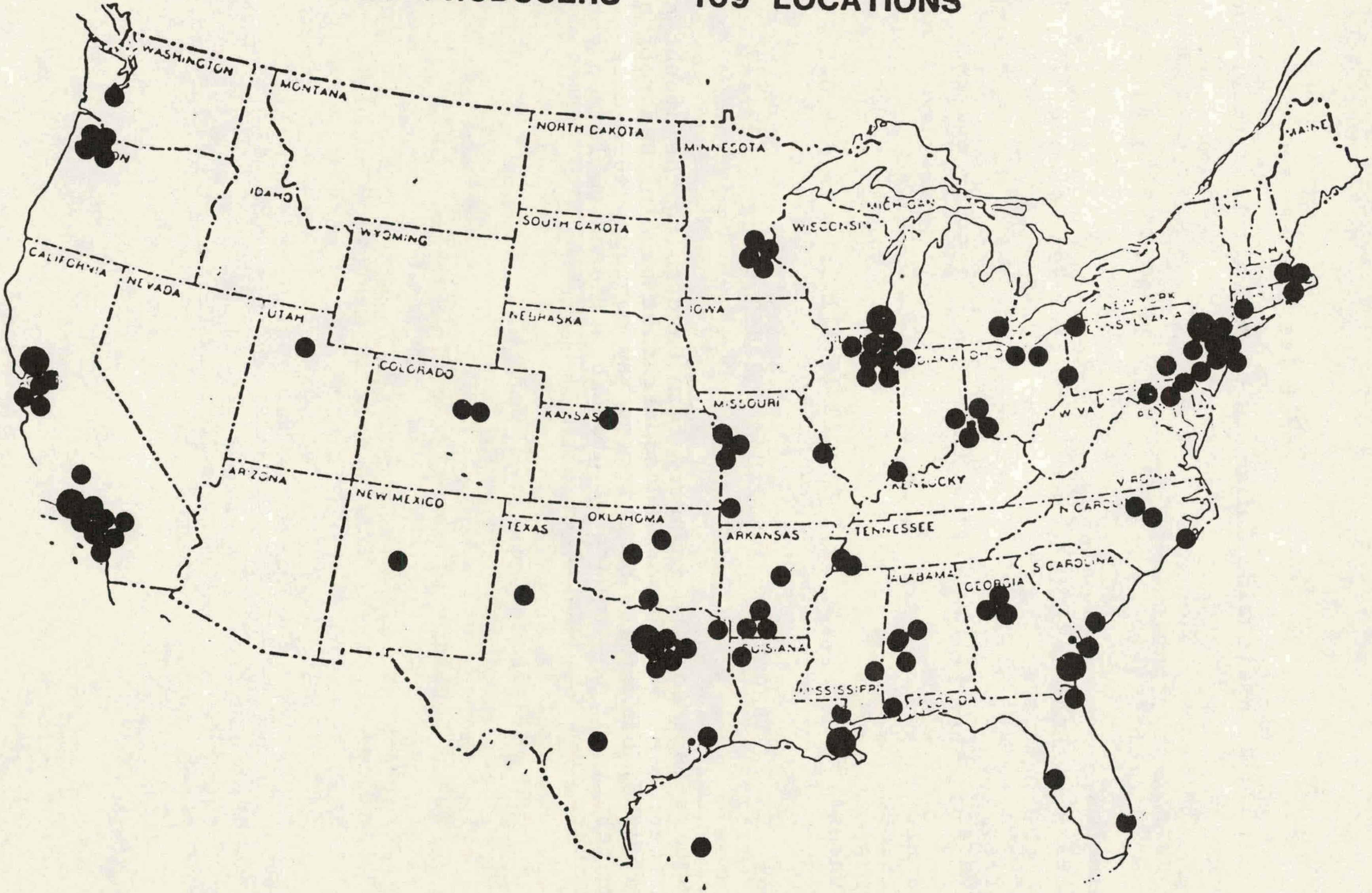


Table 2.1

Annual Nationwide Shipments of Asphalt Roofing Products

	1977	1978	1979	1980	1981
Shingles, Squares*	69,927,505	69,610,036	68,103,534	62,460,775	58,235,194
Smooth Rolls, squares*	17,034,133	17,926,955	29,535,939	17,584,676	12,589,263
Granule Surfaced Rolls, squares*	12,103,911	12,283,301	15,411,330	15,539,045	14,126,315
Felt, tons	880,761	872,044	1,050,883	772,247	779,910

* Square is a roofing industry term describing the amount of material used to cover 100 square feet of finished roof area. For example, one square of shingles may contain 240 square feet of material and one square of granule surfaced rolls may contain 108 square feet of material.

Job-site roofing waste is, at first consideration, available for disposal in quantities proportional to the number and size of buildings throughout the country, suggesting the possibility of estimating waste quantity on the basis of population density. Difficulties in this approach include appropriate consideration of regional building uses and styles (causing wide variation in the "average" roofed area per unit of population) and local environmental and weather factors (affecting roofing life and replacement rate). As an alternative, the geographic distribution of reroofing waste was assumed to be directly related to the destination of new roofing shipments. Products destination data, indicated by the ARMA data, show that ten states receive about 50 percent of the asphalt roofing shipments each year. Excerpts of these data are presented in Tables 2.2 and 2.3 for shingles and built-up roofing respectively. Five of the most heavily populated states (Texas, Florida, California, Illinois, and Ohio) account for about one-third of total roofing shipments and, by assumption, account for a like proportion of job-site asphalt roofing waste. Presumably, distribution of reroofing waste within a state could be very roughly estimated on a population basis. Clearly, an accurate determination of waste quantity for any location would require a survey of local distributors and roofing contractors.

2.3 - Energy Content in Asphalt Roofing Waste

For purposes of quantifying the energy resource represented by asphalt roofing waste, credit is taken only for the energy value of the asphalt component. The following assumptions were used for calculating energy content:

- Asphalt contains 17,000 Btu/pound.

- Organic felt shingles contain 80 pounds of asphalt per square. Standards of Underwriter's Laboratories and American Society of Testing and Materials make this statistic quite uniform among manufacturers.

- Glass fiber shingles contain 50 pounds of asphalt per square. There may be considerable variation here. A fifty pound value was selected based on analysis of many commercially available shingles from several manufacturers.

Table 2.2

Roofing Shipments Distribution by State

(Shingles)

	1977	1978	1979	1980	1981
Texas	8.1%	7.8%	7.7%	11.0%	14.0%
Florida	3.3	4.0	4.8	7.0	7.2
California	4.6	4.9	4.4	6.2	5.1
Illinois	6.2	5.9	6.4	4.8	4.7
Ohio	4.9	4.4	4.4	4.6	4.4
Pennsylvania	4.5	4.7	4.1	4.3	3.8
Georgia			3.3	3.7	3.6
North Carolina	3.5	3.7	3.6	3.7	3.5
Missouri					3.0
New Jersey					2.9
Indiana	3.7	3.7		3.0	
Michigan	4.5	4.4	4.1	2.8	
Alabama			3.4		
New York	3.9	3.8			
TOTAL	47.2	47.3	46.2	51.1	52.2

Table 2.3

Roofing Shipments Distribution by State

(Built-Up Roofing)

	1977	**1978**	**1979**	**1980**	**1981**
California	13.9%	14.1%	12.5%	15.7%	13.1%
Texas	10.5	11.6	8.8	12.6	9.8
New Jersey					6.6
Florida	8.8	10.0	11.3	9.3	6.4
Illinois	5.3	5.8	4.2	4.9	4.5
Ohio	3.2	3.0	1.9	2.8	4.3
New York				2.7	4.2
North Carolina			1.4	2.8	4.0
Pennsylvania	3.5	3.1	2.5	2.9	3.8
Georgia		2.6	5.7	2.5	3.8
Louisiana	2.8	2.8	2.7	2.7	
Colorado	4.4	2.6		2.5	
Alabama	2.6		8.9		
Tennessee			4.7		
Mississippi			2.5		
Michigan	2.9	3.1			
TOTAL	57.9	58.7	67.1	61.4	60.5

- Smooth rolls contain 26-1/2 pounds of asphalt per square.
- Granule surfaced rolls contain 28 pounds of asphalt per square.
- The percent by weight of asphalt in felt has grown from 55 percent in 1977 to 67 percent in 1981 because of the changing product mix.
- The factory scrap rate is 5 percent of production.
- Residential re-roofing and commercial reroofing account for 62 percent and 61 percent of their respective total roofing products shipments.

Table 2.4 presents the estimates resulting from the energy content calculations in the years 1977 through 1981. Using the result for the most recent year, the total national energy resource contained in asphalt roofing waste is 7.2 x 10^{13} Btu (0.07 quad) annually, the equivalent of some 12 million barrels of crude oil each year. Also shown in Table 2.4 are the estimated contributions of factory versus field scrap, and residential versus commercial roofing waste. The factory scrap, assumed to be 5 percent of total production, contributes about 6 to 6-1/2 percent to the total energy resource. The contributions of scrap from new and used residential roofing is consistently about 80 percent of the total. Note that the energy represented in field applied, hot mopping asphalt is not represented here. This may add another 1.1 x 10^{13} Btu annually in built-up roofing removed at job sites.

Table 2.4

Energy in Asphalt Roofing Scrap

	1977	**1978**	**1979**	**1980**	**1981**
Total x 10^{13}	8.3	8.6	9.2	7.9	7.2
Factory	0.6	0.6	0.7	0.6	0.5
Field	7.7	8.0	8.5	7.3	6.7
Residential	6.5	6.9	7.1	6.2	5.6
Commercial	1.8	1.7	2.1	1.7	1.6

The annual variations in Btu's from roofing scrap are affected by the national economy, new residential and commercial construction, and variations in product mix.

It is estimated that the annual energy resource from roofing waste will decrease to about 5.5×10^{13} Btu by the year 2000. This estimate is based on the following assumptions:

- Fiber glass shingles will nearly totally replace felt shingles by the year 2000
- Single-ply, polymer sheets will displace a major portion of asphalt roofing rolled goods by the year 2000
- Fiber glass shingles will last longer than felt-based shingles
- The average roof area on new residences will decrease.

It is important to note that this "future" estimate is a prediction only of the energy represented by the asphalt in roofing waste. No forecast is made of roofing shipments and none should be implied from data or trends reflected in Tables 2.1 and 2.4.

In each of the last five years, five states have accounted for about 1/3 of the national energy resource represented in the asphalt of roofing waste as shown in Table 2.5. This suggests that it may be possible to identify a number of locations or regions in the United States having much higher than average opportunity for recovering the energy represented in roofing waste. For example, if asphalt reclamation could be effected for 25 percent of the reroofing scrap in the top five states, the energy contribution would amount to an equivalent of about one million barrels of oil annually. The magnitude of this energy resource indicates justification for further study of recovery and reuse of asphalt roofing waste.

Table 2.5

Top Five States Contribution to Total National Waste Roofing Energy Resource

	1977	**1978**	**1979**	**1980**	**1981**
Texas	8.6%	8.4%	9.6%	11.3%	13.1%
Florida	4.4	5.2	7.3	7.5	7.0
California	6.3	6.7	7.2	8.2	6.2
Illinois	6.0	5.9	7.3	4.8	4.7
Ohio	4.6	4.1	4.8	4.2	4.4
% of Total Energy Value	29.9	30.3	36.2	36.0	35.4

Even though job-site roofing waste represents the vast majority of the energy resource, it is interesting to note the significance of the factory scrap energy resource in terms of plant energy requirements. Industry data indicate production energy requirements are about 50,000 Btu/square of roofing product or nominally 225 Btu/pound product. The energy value of the asphalt in one pound of clean factory scrap is about 5,000-6,000 Btu; recovery of the asphalt from factory scrap at five percent of total production is therefore equivalent to 250-300 Btu/pound of product. Theoretically, appropriate recovery and reuse on-site of the factory scrap could provide all of the plant production energy requirements.

3.0 - DISPOSAL OF ROOFING WASTE

Reclamation of the energy resource represented by asphalt roofing waste will take place only if important incentives are provided to those generating the waste. Telephone interviews confirmed that disposal of factory and job-site roofing waste was viewed as a growing problem by both manufacturers of asphalt roofing and roofing installers. Several manufacturers indicated that they have spent considerable funds researching potential methods for dealing with their individual waste disposal problem, with little success. Roofing contractors noted increasing disposal costs as a concern. A prime incentive to asphalt roofing recovery and reuse would be to provide an attractive alternative to present methods of waste disposal. The following discussions review current factory and job-site waste disposal methods, collection procedures, disposal costs, and environmental concerns.

3.1 - Roofing Waste Disposal Methods

Landfilling accounts for nearly all roofing waste disposal. Roofing contractors mentioned no other method available to them and they handle about 94 percent of the roofing waste. Factory waste is predominantly landfilled. Therefore, (conservatively) at least 95 percent of all roofing waste is destined for landfill disposal.

3.1.1 - Factory Scrap Disposal

Most factories were reported to landfill all production scrap. Only one factory was mentioned as never landfilling roofing waste. A few factories had disposal alternatives including the following selected examples:

Burning - Allied Materials at Stroud, Oklahoma burns all of their roofing waste in a boiler supplied by Basic Environmental Engineering, Inc. The steam produced is used at an adjacent refinery.

A west coast factory reported shipping some of their waste to a second, non-roofing factory having a high energy demand. Here the roofing waste was burned with other wastes in a rotating, traveling grate incinerator to generate steam. Agricultural waste was mentioned as the principal fuel for this operation.

Solvent Extraction - Telephone interviews indicated that one manufacturer might be recovering asphalt from factory waste using a proprietary solvent extraction process at one location. This manufacturer declined to comment on the indications, but did demonstrate a willingness to cooperate in other facets of the waste study.

Manville Corporation reported having made a thorough study of a commercial solvent extraction process offered by Clermont Engineering. Manville rejected the process on specific grounds which might not apply to other manufacturers or other factory locations. Technical feasibility of the process has been demonstrated in a pilot plant operation.

New Products - The volume of factory roofing waste converted into new products is extremely small. Interviews covering over 1/3 of the nation's 100 or so roofing factories identified only three which diverted even a very small portion of their waste into new products.

Two roofing manufacturers, Manville and Jim Walter, convert a small portion of their product waste into new products. These products include industrial flooring blocks which are used in high traffic factory and service areas, and roof walkway blocks. Another source reported selling some waste from one factory to a manufacturer of reservoir lining boards.

Paving - Jim Walter Corporation reported selling a small portion of the waste from one factory to a concern which used this waste in asphaltic paving mixes. It was reported that field generated waste from re-roofing would not be suitable for this end use because it was "dirty", i.e., containing sheet metal, coarse gravel, wood and many nails. One paving contractor in New Jersey, Tri-County Asphalt, does use factory waste from perhaps several factories in paving mixes according to U. S. Patent 4,325,641 issued to Stephen R. Babus and George T. Tucker. The process uses only factory waste derived from shingles in the form of "tab-cut-outs"", which are small 1/4-inch by 5-inch pieces. Only one commercial unit has been built. New units would have to be custom designed and manufactured. Tri-County Asphalt has indicated that about one percent of the paving mix is composed of shingle waste.

Sale - It was reported that several manufacturers sell waste shingles to salvage operations. Although this probably represents a small fraction of total factories waste, it could be a strong deterent to a manufacturer's desire to participate in an energy reclamation program since he may recover as much as 60 percent of material cost through salvage sale.

3.1.2 - Job-Site Waste Disposal

Nearly all roofing contractors have but one waste disposal alternative - landfill. Both public and private landfills are used. The operator of one large and successful waste incinerator stated that roofing waste presents no technical problems and had occasionally been burned in their steam-generating, municipal waste incinerator. This operator claimed that time-consuming, hand-unloading of pickup trucks was the major barrier to regular acceptance of roofing waste. Roofing contractors expressed both concern and frustration that they had no alternative to disposing of roofing waste in landfills; that waste disposal costs are increasing; and that the number of available landfills is diminishing, requiring ever-increasing hauling distances.

3.2 - Waste Collection and Disposal Procedures

Disposal of nearly all roofing waste involves collection at the factory or job site, hauling to private or public landfills, and interment in the landfill area.

3.2.1 - Factory Waste

The bulk of factory waste is hauled to public (usually) or private (occasionally) landfills by contract waste haulers. "Roll-away" containers are left at the factory to be picked up when filled to capacity. The most frequently mentioned container size was 20 cubic yards holding 17 to 30 tons, depending on size distribution and compaction of the waste. Some manufacturers may haul their own waste to either municipal or private landfills. A few instances of factory-owned, off-site landfills were mentioned, as was one factory site landfill. Hauling distance for waste disposal varies; distances ten to fifteen miles were most frequently mentioned. Twenty-five miles was the longest haul disclosed in interviews with manufacturers.

3.2.2 - Job-Site Waste

Roofing contractors haul their own waste to landfills when the job is small enough or their truck large enough. Private waste disposal contractors are hired for large reroofing jobs as well as in areas where the landfill operation may prohibit private dumpings. Private waste contractors typically leave a 20 cubic yard roll-away container at the job site and move it when filled. Waste from a very large majority of the reroofing jobs is hauled by the roofing contractor. However, private disposal firms handle a significant tonnage of roofing waste because they service the large reroofing jobs. Results of interviews did not permit an estimate of the relative quantities of roofing waste hauled by roofers and disposal contractors.

3.2.3 - Landfill Treatment

While specific landfill practices vary widely, one common circumstance related to treatment of roofing wastes did emerge: recovery of scrap roofing from landfill sites is not at all likely. At most landfills, little or no distinction is made between roofing and other waste. The hauler is directed to a specific dump site usually based on the volume or weight of load and type of hauling vehicle. The roofing waste is dumped in an area of mixed municipal and other waste, and typically backfilled. Some landfills, particularly in larger metropolitan areas, may have a designated area for "demolition waste". Here the roofing waste becomes mixed with concrete, rocks, metal and wood structural components, and a variety of other materials. In the case of factory-owned landfills, all or part of the landfill site may be dedicated to factory scrap. However, even at such dedicated disposal sites, the mixing of the roofing waste with dirt and rocks during grading and backfilling make retrieval for asphalt recovery unlikely.

3.3 - Waste Disposal Costs

Asphalt roofing manufacturers and roofing contractors typically incur the same landfill waste disposal costs. These costs are extremely variable and are affected by the following factors:

- Waste hauling charge

  - Distance to landfill
  - Who hauls the load (disposal contractor or waste generator)
  - Size (volume or weight) of load

- Landfill charge (acceptance or tipping fee).

Table 3.1 presents examples of the ranges of costs disclosed by contacts with waste haulers, contractors and manufacturers. Data have been included to permit a calculation of disposal cost per ton of roofing waste. Note that the disposal cost may be significantly influenced by the weight of the load (the density of roofing waste may vary between 1685 and 2970 pounds per cubic yard).

Nationwide, asphalt roofing waste disposal costs most typically are within the range of \$5 to \$15 per ton. Application of product mix data and asphalt content assumptions presented previously permits calculation of approximately 800 pounds of asphalt per ton of asphalt roofing waste; the energy value of the waste is therefore about 13-1/2 x 10^6 Btu per ton of asphalt roofing waste. Note that this value is for "clean" roofing waste and may vary widely depending on actual roofing products, gravel content, etc. In addition, job-site waste will contain nails and may contain other demolition waste which could drastically reduce the per ton energy in the load of roofing waste.

3.4 - Environmental Concerns

The disposal of asphalt roofing waste is nearly all by landfill, with the potential of incineration in some instances, mixed with other elements of solid waste. The major environmental impact of asphalt roofing waste disposal is the contribution to packing of landfill sites which are becoming more difficult and costly to acquire and maintain. Asphalt roofing wastes contribute on the order of 6 million cubic yards annually to the landfill load.

There are relatively few constituents of asphalt roofing waste that present a pollution problem at the landfill or during waste incineration. Sulfur, chlorides, vanadium and most other potentially hazardous materials found in asphalt are directly related to the specific crude oil from which the asphalt was taken. For example, the sulfur content of asphalts varies in the range of 1/2 percent to 7 percent.

TABLE 3.1

ASPHALT ROOFING WASTE DISPOSAL COSTS

Basis	Waste Hauler Northeast 20 Yards*	Waste Hauler Midwest 20 Yards*		Waste Hauler West 20 Yards*	Self Hauled Low Cost 16 Yards*	Self Hauled High Cost 1/2 Yard*
	26 Tons	30 Tons	17 Tons	26 Tons	24 Tons	1/2 Tons
Container Fee	$262	$85	$ 85	$300		
Disposal Fee	-	50	120	-		
Landfill Charge	$4/ton	$1.25/Yd	$2.75/Yd	-	$1.25/Yd	$4/ton
Truck Driver, 1 hr (1)	-	-	-	-	$14.00	-
Truck Driver, 2 hr (1)	-	-	-	-	-	$27.40
16 Ton Truck, 1 hr (1)	-	-	-	-	$32.48	-
Pickup Truck, 2 hr (1)	-	-	-	-	-	$5.92
Total Cost of Load	$366	$160	$260	$300	$66.58	$35.32
Net Cost per Ton	$14.08	$5.33	$15.29	$11.54	$2.77	$70.64

* Cubic Yard(s).
(1) Repair and Remodeling Cost Data; VII; Robert Snow Means Co., Inc. (1982).

It is believed that sulfur has not been reported as a problem in the few experiences with roofing waste incineration because much roofing waste contains limestone or dolomite which can react with the sulfur in asphalt thus keeping SO_2 out of the stack gasses.

One potentially hazardous material, asbestos, deserves some special consideration. Asphalt roofing waste from removal of most worn out roofs will contain some asbestos fiber. The asbestos content of a load of job-site waste may vary from very small, if the roof consisted of wood fiber felts, to very large, if asbestos felts had been used. Asbestos-containing roofing products are NOT subject to EPA's part 61 of Title 40, Code of Federal Regulations revised July 1, 1979. Therefore, landfilling poses no problem. Asbestos is considered a hazardous material in the free state.[2] Incineration at a low temperature might be construed to free the asbestos from its bound-in state. However, incineration at 1800°F or higher would break down the asbestos and convert it to a mineral such as Fosterite which is not listed by EPA as a hazardous material. Asbestos has not been a concern in the present scheme of roofing waste disposal. It might become a concern under some of the methods proposed for resource recovery. The environmental concerns associated with combustion and other reuse concepts will be addressed later in this report.

4.0 - RECOVERY OF ASPHALT ROOFING WASTE

Every working day considerable quantities of asphalt roofing waste are trucked to landfills all over the country at both a cost and inconvenience to manufacturers and installers of asphalt roofing. Recovery of roofing waste from landfill sites is not likely. Therefore, recovery of roofing waste for reuse will require that it be secured prior to landfilling.

4.1 - Availability of Waste

Nearly all roofing waste is hauled to landfills. Much of this waste is hauled by the waste generator; i.e., manufacturers haul factory waste and roofing contractors haul job-site waste. Waste disposal contractors haul some factory waste and some large-job reroofing waste. It is "on-the-road" every working day and segregated to a large extent from other types of waste until it is landfilled. Except for isolated instances involving clean factory scrap, roofing waste has no commercial value and there is no competition for its acquisition. Asphalt roofing waste is, therefore, available in large quantities.

The key to successfully acquiring this available waste is an economically attractive alternative to landfill disposal. For factory scrap which might be reused on-site, the elimination of all or part of the present disposal system is an incentive to be added to the profitable material reclamation. For job-site waste, the primary incentive to the roofing contractor is reduction of disposal cost. In previous discussions, typical disposal costs for roofing waste were estimated to be within the range of $5 to $15 per ton.

4.2 - Acquisition and Collection of Roofing Waste

The cost components of asphalt roofing waste disposal by present methods were shown to be hauling charge and landfill charge. The landfill charge, or tipping fee, is typically several dollars per ton and may constitute 25 to 50 percent of the total disposal costs for large loads. For small waste quantities (i.e., contractor pickup truck load), the tipping fee may be a less significant percentage of total disposal cost, and dump site distance becomes an important factor.

It appears that nearly all roofing waste in an urban area could be acquired merely by providing a reasonably convenient, free dumping site. Convenience would be measured in terms of driving distance/time and waiting time. Criteria for such a site might be set to be competitive with present, typical distance and times. Longer distances and times might be acceptable if the hauler were compensated for his load of roofing waste. Driving distance should not exceed 25 miles (one way). Driving time should not exceed 3/4 hour (each way) and waiting time should not exceed ten minutes. A free dump, or collection site, which met these criteria should be attractive to roofing manufacturers and roofing contractors. Waste haulers would also be expected utilize such a facility.

There are a number of potential scenarios for acquiring and collecting roofing waste. Different choices might be appropriate for different re-use concepts. For example, reprocessing of roofing waste at roofing factories might involve a roofing manufacturer as the prime collection agent. Or, combustion at a few major, new generating facilities might involve major, national waste hauling firms. The final collection center (the reuse facility) might or might not be near a roofing manufacturing location. Intermediate collection centers might or might not be necessary. An appopriate acquisition and collection system for asphalt roofing waste must be determined on the basis of reuse concept, location, and business arrangements.

4.3 - Cost for Acquiring and Collecting Roofing Waste

The cost to collect roofing waste at a reuse or reprocessing facility will be influenced by the type, size and location of such facilities. It is expected that waste transportation methods will be those presently used. Cost ranges have been estimated for two possible cases to demonstrate variation. Data for these two cases are shown in Table 4.1

Case 1 - Facilities Located at Roofing Factories - The manufacturer's cost will be inter-factory movement of waste in roll-off or dumpster containers which he now owns.

The cost of acquiring the contractor's waste will have two components.

1. The contractor will haul the waste to the roofing factory in his own truck when the job site is within about twenty-five miles of the roofing factory.

2. The contractor will haul the waste to a collection point operated by the roofing factory or a collecting agent when the job site is more than about twenty-five miles from the factory. Collection points could be located fifty miles apart but no more than about 100 miles from the factory. Contractors may continue to use a waste hauling company for very large jobs. The approximate distance shown in this and the following case was derived from the 1985 price for coal of $2.82 per 10^6 Btu(3) and a $0.30 per ton mile trucking cost. So, roofing waste was calculated to have a maximum value of $24.45 per ton.

In Case 1 the manufacturer has incurred a $10.84 per ton cost for collecting the contractor's scrap.

Case 2 - Facilities Located at New Sites - A contract waste hauler is employed to acquire and transport all roofing waste to the processing facility. This may involve roll-off containers at roofing factories, roll-off containers at very large reroofing jobs and containers or compactors located about 50 miles apart for use by contractors hauling small quantities themselves. These latter collection points will be no further than 100 miles from the processing factory.

Note that no "cost" has been shown in Table 4.1 for waste haulers as their costs are reflected in their prices charged to the manufacturer and contractor in Case 2.

It is not surprising that these two examples of waste acquisition scenarios reflect costs in the same range as those now reflected for transporting roofing waste to landfills. More detailed acquisition cost estimates cannot reasonably be made until all the specifics of a given reuse plan can be addressed (which is not within the scope of this study). However, it has been indicated that asphalt roofing waste can be reasonably acquired by providing an appropriate alternative to landfilling.

Table 4.1

Pro-Forma Cost Elements for Two Cases of Roofing Waste Acquisition

(Max case per 20 yards or 17 tons)

	CASE 1		CASE 2	
	Cost to Manufact.	Cost to Contract.	Cost to Manufact.	Cost to Contract.
Inter-Plant Truck	$5.41	-	-	-
Contractor Truck - 5 Tons, 20 miles	-	$40.60	-	$40.60
Contractor Driver	-	54.40	-	54.40
Roll-off Container	Neg.	-	$85.00	85.00
Disposal Charge	-	-	120.00	120.00
Disposal Trucks	129.92	-	-	-
Truck Drivers	54.40	-	-	-
SUMMARY:				
Factory Waste, $/Ton	0.32	-	12.06	-
Contractor Waste, $/Ton	-	5.59	-	-
Contractor Waste, $/Ton	10.84	5.59	-	17.65

5.0 - REUSE OF ASPHALT ROOFING WASTE

Ten concepts for recovering energy from asphalt roofing waste have been studied. Engineering estimates have been prepared for production facilities, capital investment, operating costs, and product costs wherever these are applicable. These estimates are judged to be accurate within 30 percent. They provide the basis for comparing the alternatives and selecting candidate(s) having cost-effective, commercial potential. Potential market sizes and selling prices have also been estimated where appropriate.

Only factory scrap is suitable for reuse in some of the concepts. An average five percent of total production has been assumed for factory scrap consisting of rolls of felt roofing, discarded, whole shingles, and small pieces, called tabs, cut from the shingles to create an appearance effect. The tabs are estimated to account for 30 percent of the total factory scrap. The roofing scrap is "clean", segregated from other plant trash at almost all factories. The composition is usually well known.

Field scrap (job site waste) consists of all types of roofing products. Although the specific worn-out roofing products from any one reroofing job may be identifiable, the material is likely to be weathered, which changes some constituent properties, and may be contaminated with nails, sheet metal, lumber or other demolition waste which can affect the utilization in some of the reuse concepts.

Because quantities of clean waste are available on site, it has been assumed in evaluation of the ten concepts that no field scrap would be returned to the factory for in-plant reuse. It might, however, be prudent or convenient for some of the reuse concepts to locate a roofing waste collection and processing facility at or near a roofing products plant.

5.1 - Burn Roofing Waste as Fuel

In determining the strategies for utilizing asphalt roofing waste as fuel, it was assumed that factory scrap would be available in sufficient quantities to satisfy factory in-house uses for an alternate energy source and that new equipment to burn exclusively the clean production waste would be constructed and connected to the existing energy system. For field waste, possible alternatives include contribution of asphalt roofing materials to the feedstock for existing municipal or privately operated energy recovery facilities (more than sixty now exist in the United States) or construction of a new facility in a location of high roofing waste availability. In the first case, field waste would be combined as a relatively small fraction with processed solid waste or biomass. Depending on existing operations, the roofing waste might require no special preparation and could be co-processed with existing feedstock (e.g., when combined with municipal solid waste for energy recovery), or might require special treatment to make it compatible (e.g., when combined with hogged wood fuel or other specific biomass wastes). In the second case, the new facility would be designed specifically for asphalt roofing waste and would share most physical and operational characteristics with a factory scrap-fueled system except for the need for more extensive preprocessing.

When roofing waste is burned, its analysis as a fuel would appear as follows:

	Broad Range	**Typical**
Asphalt (hydrocarbon fuel), % by weight	20-45	40
Organic felt (carbohydrate fuel), %	0-15	6
Ash (as silicate minerals, silica, lime, etc.) %	20-60	52
Sulfur, %	0.2-2.2	1.1
Nitrogen, %	0.1-0.4	0.2
Chlorides (as ferric chloride), %	0.0-0.15	<0.05
Vanadium, ppm	0.4-240	75
Nickel, ppm	2-50	20

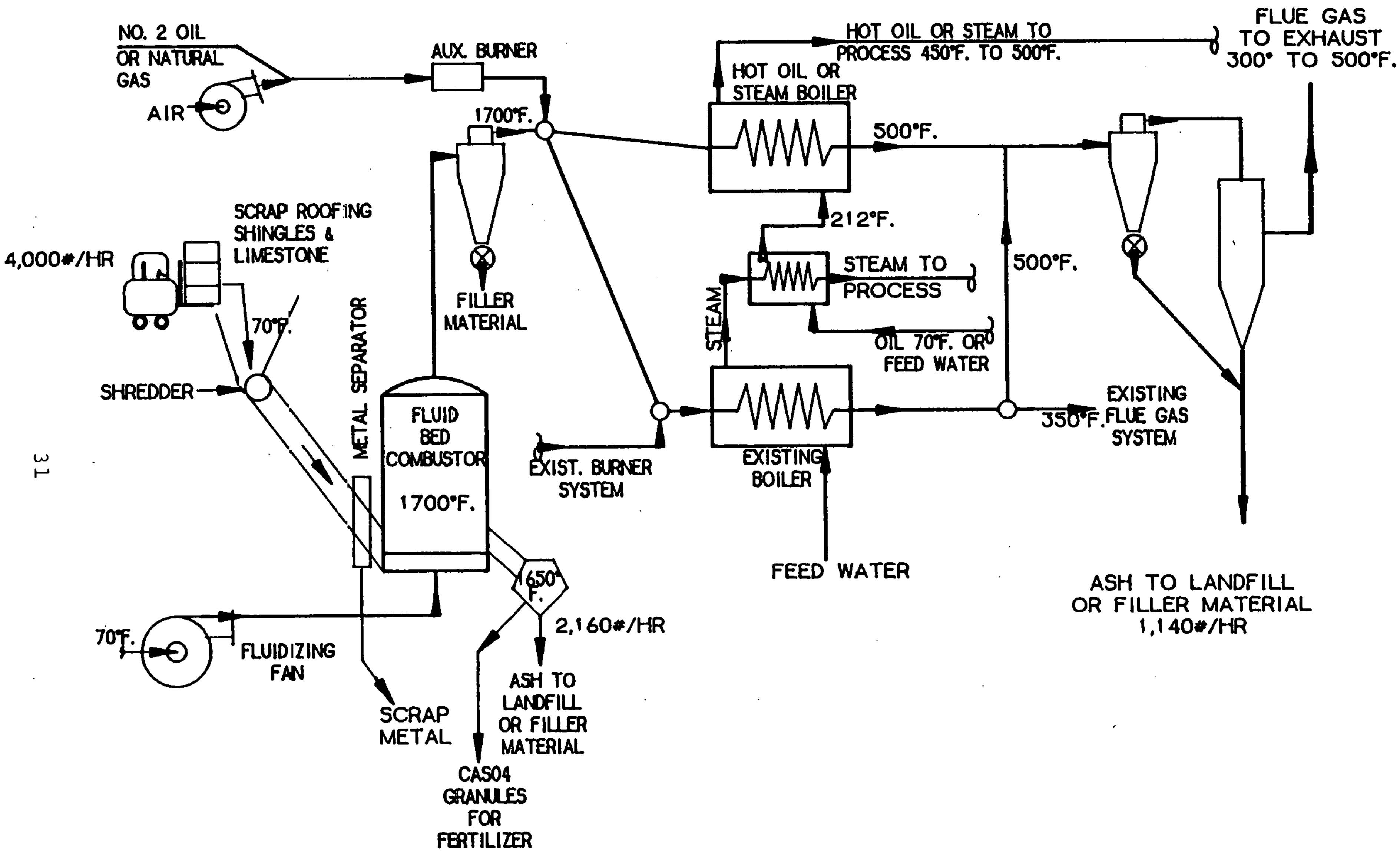
This analysis assumes the presence of a representative portion of worn-out, built-up roofing with its attendant mopping asphalts and coarse aggregate.

Many existing solid waste combustion systems are of traveling grate (rotary or linear) design, developed for cellulosic wastes with relatively low net energy content. While the energy value of asphalt is much higher, the relatively high content of non-combustibles in roofing waste yields a material not unlike cellulosic wastes in energy content. Co-preparation should yield a combined feedstock compatible with existing combustion systems. It can be theorized, however, that existing and planned waste energy recovery systems might utilize only a moderate portion of roofing waste.

Two types of combustion systems for burning (exclusively) asphalt roofing waste were studied as a basis for new facilities. The pulse hearth incinerator (traveling piston or "ram" stoker) appears well suited to asphalt waste handling and combustion. A system of this type has been in use for several years burning clean scrap at one factory and has met all EPA standards for emissions during that time. More general application to field scrap would appear to require only additional waste pre-processing. The fluidized bed combustor has been under development for some time and is indicated to have the potential for more complete combustion leading to higher theoretical energy conversion efficiency and reduction of emissions. It was learned that fluid bed experiments with asphalt roofing waste have been conducted on a pilot plant scale.

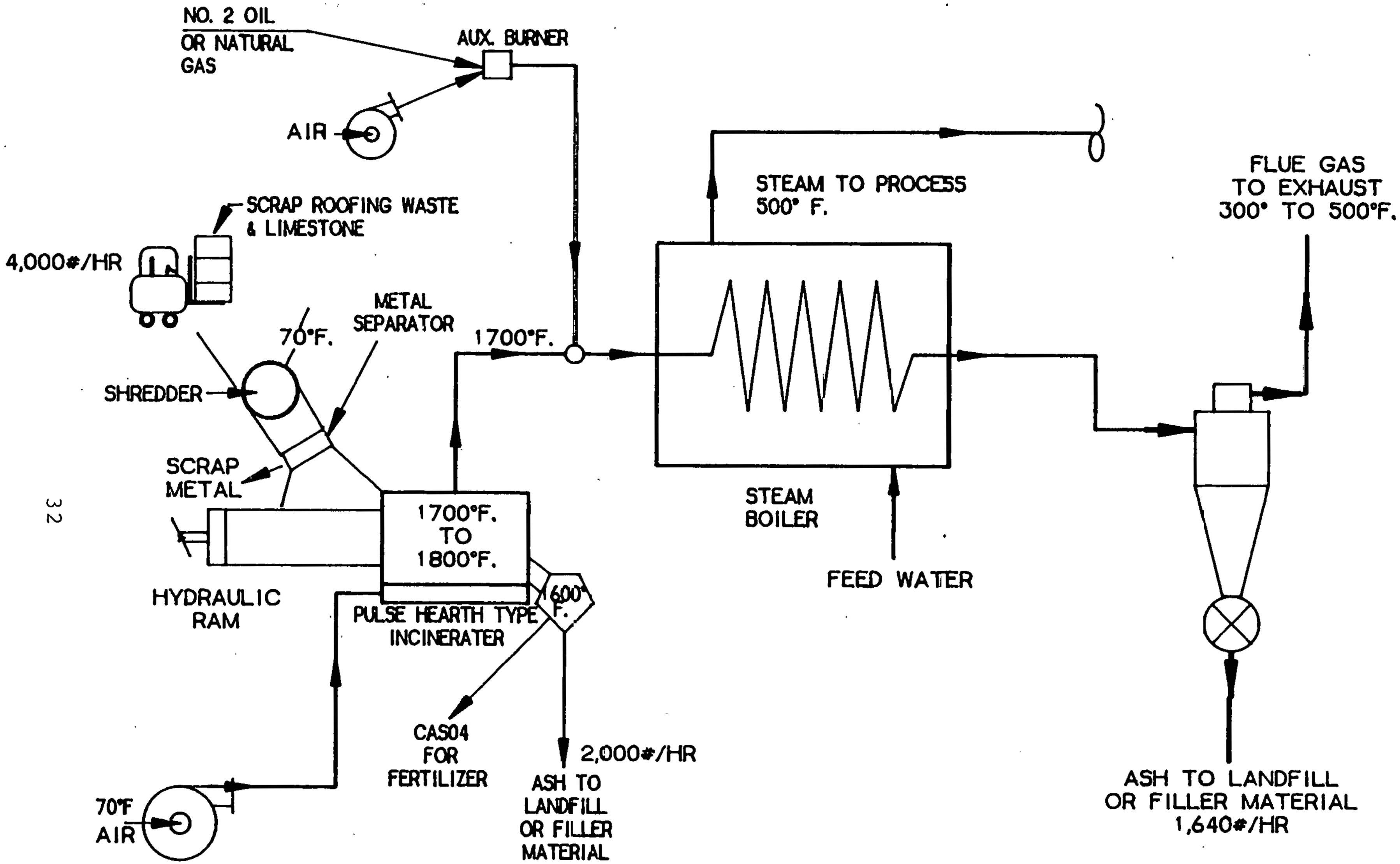
Figures 5.1 and 5.2 present equipment and flow charts for a fluidized bed and a pulse hearth combustion system respectively. In each case, prepared asphalt roofing waste is fed to the combustion system through a shredder and a metal separator. It should be noted that, for job-site waste, appropriate pre-processing to remove larger non-combustibles (e.g., metal flashing, large rocks or concrete, etc.) would be necessary. The extent of size reduction would be determined by requirements of the combustion system, and the shredder designed accordingly; fluid bed (suspension) combustors would be expected to require the more extensive size reduction of the two systems. The in-line metal separator would be a magnetic device primarily for removal of most of the roofing nails in the case of job-site waste.

The hot exhaust gases from the combustion system are available for the production of steam or perhaps for direct process heat. The more general case is shown in Figure 5.2 where the hot combustion gases are directed to a steam boiler; the steam is made available to a nearby energy customer. Exhaust past the steam boiler is delivered to an electroscrubber or other emissions control system prior to release up the flue. A possible combined application is exemplified in Figure 5.1 (applicable only to factory on-site utilization of roofing waste). The hot exhaust could be directed to an existing waste heat boiler or to two new units, either a steam boiler or a hot oil system. Some roofing plants have converted to hot oil systems for process use. In these systems a heat transfer oil replaces steam thus providing higher temperature which is better suited to asphalt systems where the in-process asphalt must be maintained at a temperature near 400°F.



FLUIDIZED BED COMBUSTION SYSTEM FOR ROOFING WASTE

FIGURE 5.1



PULSE HEARTH TYPE COMBUSTION SYSTEM FOR ROOFING WASTE

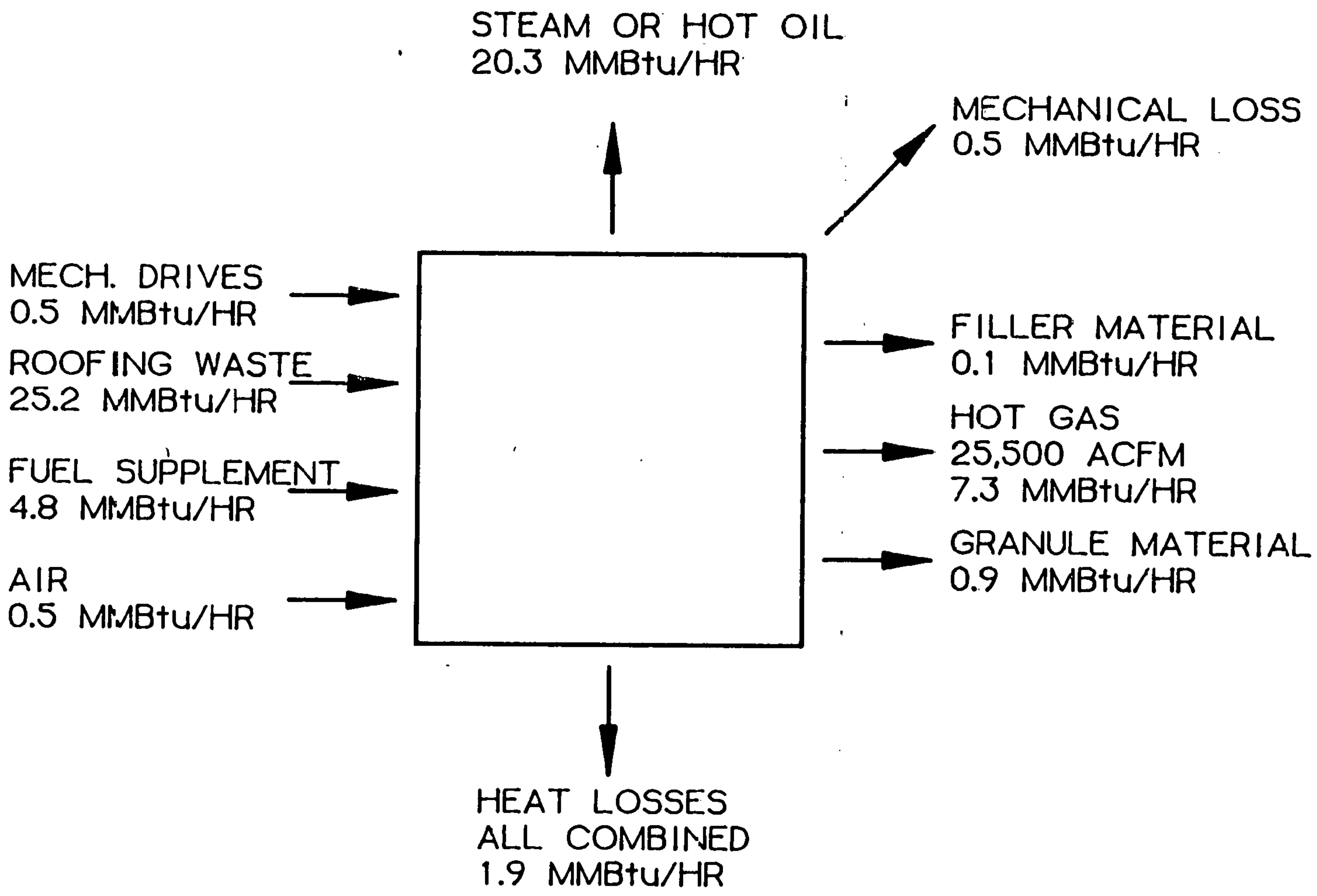
FIGURE 5.2

Figures 5.3 and 5.4 provide tentative energy balances for the fluidized bed and pulse hearth combustion systems for the applications shown in the respective flow charts. Steam generation efficiencies are indicated to be on the order of 65-69 percent. Note that an additional fuel input (most likely natural gas) is shown. It is believed that supplemental fuel will be required for complete firing of the roofing waste combustibles.

Combustion of asphalt roofing waste was examined with respect to pollution control and environmental treatment of combustion products. Discussions with personnel involved in preliminary fluidized bed tests (Bird and Son) and in the pulse hearth combustion of factory scrap (Allied Materials Corp.) contributed to the following observations.

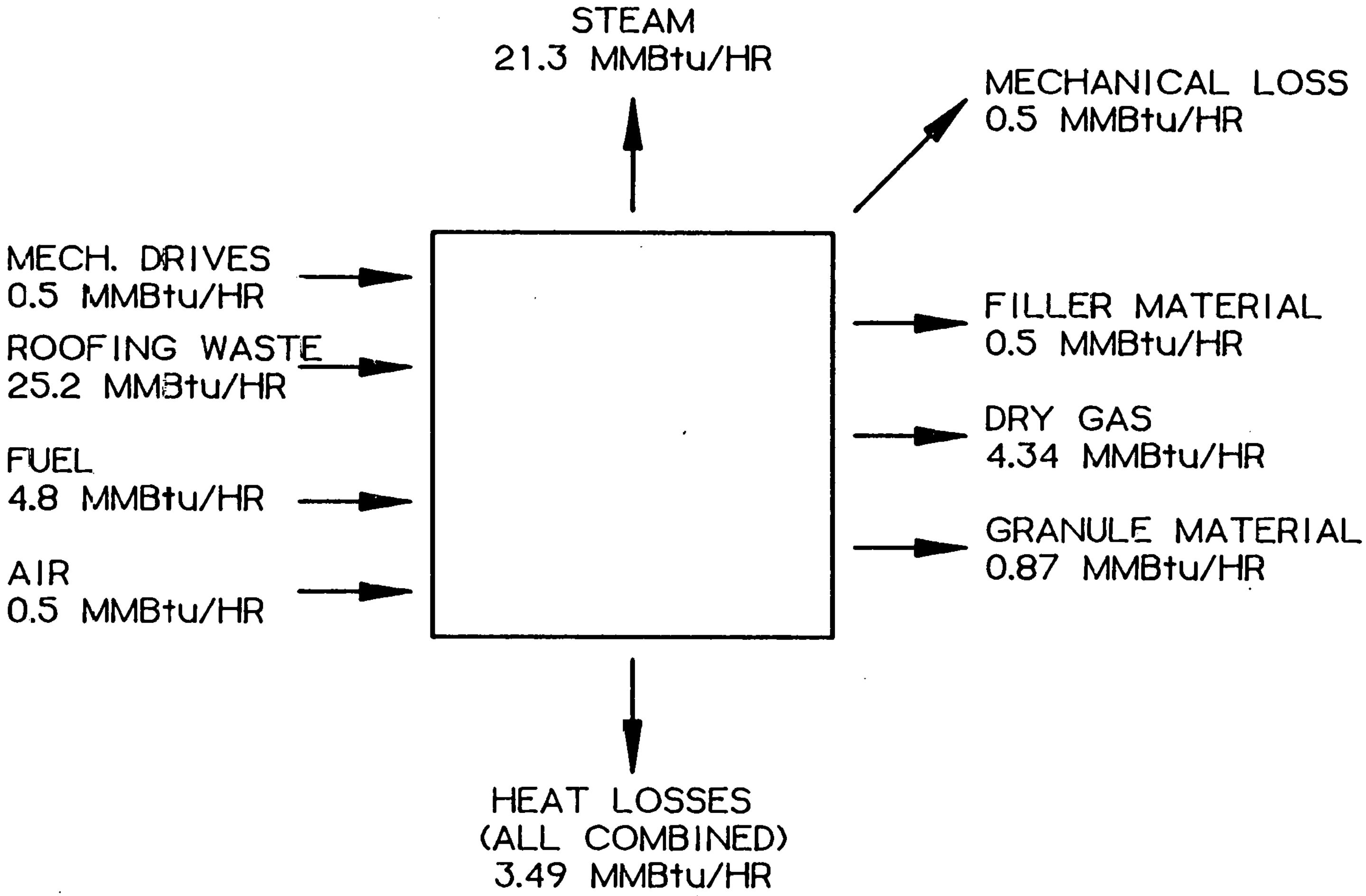
Asbestos Treatment - Most old roofing removed during reroofing will contain some asbestos, considered a hazardous material only in the free state.[2] Incineration of roofing waste at a relatively low combustion temperature might be construed to free the asbetos from its bound state. Combustion at high temperature will break down the asbestos and convert it to a benign mineral (Fosterite, not listed by the EPA as a hazardous material); a combustion temperature of at least 1800°F is required. The only known fluidized bed combustion testing of asphalt roofing waste was conducted at 1700°F. The designer of the fluid bed unit has indicated that the system should not be operated above 1700°F due to possible adverse effects on sulphur capture, high NO_x production, and the potential for fusing the fine particulates causing buildup in the unit. The operation of the pulse hearth system has been limited to asbestos-free factory roofing scrap. Combustion temperatures have been similar to those for the fluid bed tests (about 1700°F). However, the manufacturer's representative suggested that higher temperature operation (above 1800°F) might be readily accommodated. Additional testing for either system will be necessary to determine the optimum operating temperature.

SO_2 Control - Combustion tests and operation with new scrap have indicated the amount of limestone present as filler in some roofing materials is sufficient to react with sulphur in the asphalt to reduce SO_2 emissions to an acceptable level. In actual practice with field waste, however, it will likely be necessary to add additional limestone. The requirements for limestone addition (physical and chemical characteristics, quantities, feed



ENERGY BALANCE FOR FLUIDIZED BED COMBUSTION SYSTEM
USING ROOFING WASTE
(2 TONS/HR RATE)

FIGURE 5.3



ENERGY BALANCE FOR
PULSE HEARTH INCINERATOR COMBUSTION SYSTEM
USING ROOFING WASTE
(2 TONS/HR RATE)

FIGURE 5.4

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methods, etc.) need to be determined for each combustion system. Some of the most successful fluid bed installations for SO_2 control use a spray dryer concept with the limestone introduced in wet form. It is anticipated that the mixing action of the pulse hearth system will promote the sulfur-calcium carbonate rection during combustion.

Other Asphalt Constituents - Minor amounts of chloride, vanadium, nickel, and other elements are present in roofing waste because they are constituents of the petroleum from which the asphalt was derived. Such constituents are also present in the conventional fuel oils for which the roofing waste may substitute, and they present no special problems in combustion at these low amounts.

Particulate Collection - Initial tests of fluid bed roofing scrap combustion indicated the need for a particulate control system with a removal efficiency of about 90 percent. The preliminary tests used an electrified gravel bed filter which appeared to work satisfactorily. However, this type unit has limited commercial experience. Other methods of particulate collection appear equally suitable; e.g., a bag house with high temperature bags and air dilution to reduce the fluid gas temperature. The pulse hearth combustor can apparently be operated without an additional particulate collection system. The combustion system design features low air velocity and low turbulence in the main combustion chamber, and includes two reburn tunnels. In compliance operation has been achieved without additional air pollution control devices. However, additional testing will be needed to assure that particulate control will be satisfactory at various operating levels.

Residue Disposal - Based on very limited tests, it appears that granules can be recovered during the process from the fluidized bed system and that some of the filler material can be recovered from the particulate collection system. For the pulse hearth combustor, recovery of materials from the ash residue may also be technically possible. However, the cost of recovery and the low potential for economic reuse of the materials indicates it is more likely that combustion residue will be discarded, probably by landfill disposal. The residue constituents should pose no disposal problems.

Capital and operating costs have been estimated for the two combustion systems assuming capacities of 4,000 pounds/hour roofing scrap, 6,000 hours/year operation (12,000 TPY). Two cases are presented: recovery and utilization (steam production) and recovery only. In the first case, capital estimates are based on the most general steam production application and include the cost of the steam boiler, all pollution control systems, and feedstock preparation equipment. The feedstock is assumed to be job-site roofing wastes, obtained at zero net acquisition cost, from which large non-combustible items are manually separated prior to system feed. Operating costs include this waste pre-processing as well as operation and maintenance of all feed preparation, combustion, steam production and emission control components, the capital depreciation, and any purchased energy costs.

The second case includes all considerations of the first case except that the heat produced by burning the asphalt waste is made available to existing steam boilers or other nearby energy customers. This "recovery only" case is needed to provide a common basis for comparison with the other reuse concepts. In this second case, the capital and operating costs of the steam boiler and of emission systems ordinarily provided in oil or coal-fired systems have been subtracted. Boiler conversion efficiency has been accounted for as well.

	Case 1 With Steam Production	Case 2 Without Steam Production
Fluidized Bed System		
Capital Cost	$3,400,000 $283/annual ton	$2,200,000 $183/annual ton
Operating Cost	$850,000/yr $70.83/ton	$640,000/yr $53.33/ton
Recovery and Utilization	121,800 MMBtu/yr $6.98/MMBtu	- -
Recovery Only	- -	141,400 MMBtu/yr $4.53/MMBtu
Pulse Hearth System		
Capital Cost	$2,700,000 $225/annual ton	$1,500,000 $125/annual ton
Operating Cost	$560,000/yr $46.67/ton	$350,000/yr $29.17/ton
Recovery and Utilization	127,800 MMBtu/yr $4.38/MMBtu	- -
Recovery Only	- -	150,700 MMBtu/yr $2.32/MMBtu

5.2 - Convert Asphalt to No. 6 Fuel Oil Equivalent

No. 6 fuel oil is widely used as a fuel for large boilers. Petroleum refiners sometimes produce a No. 6 oil by blending asphalt with a higher distillate such as No. 2 oil or kerosene. Asphalts in roofing scrap are soluble in No. 2 heating oil. The potential exists, then, for recovery of the asphalt in roofing scrap by extraction with No. 2 oil. The equivalent No. 6 oil product could be utlized at the recovery facility to produce steam for sale or on-site use, or sold directly to customers as fuel.

Fuel oil specifications(4,5), and government surveys (6) provide a basis for calculating the ratios of asphalt in roofing scrap to No. 2 oil required to produce a No. 6 oil. This calculation is based on an average density of 0.986 gr/cc for No. 6 oil and 0.853 gr/cc for No. 2 oil.(6) This calculation takes the form:

$$\frac{0.853 \times \text{cc 2 oil} + 1.015 \times \text{cc asphalt}}{\text{cc 2 oil} + \text{cc asphalt}} = 0.986$$

The resulting mix ratio of No. 2 oil to asphalt in the equivalent No. 6 fuel product is about 0.218 by volume or 0.183 by weight. However, the product is quite viscous at ambient temperatures, barely pourable. A far greater concentration of No. 2 oil would be required if the resulting solution is to be easily separated by filtration from the solids in scrap roofing. Following filtration, the solution would be concentrated to specifications by distilling off the excess No. 2 oil for recycle to the process.

The coal tar pitch in some built-up roofings is not soluble in No. 2 oil. Introducing such products into the process will have a sudden and marked effect. The resulting decrease in product output and increase in scrap can be avoided by applying a simple chemical test to all incoming loads of scrap from re-roofing operations. Coal tar products could then be withheld from the process.

This process will reduce two tons of waste roofing to about 2,500 pounds of scrap. The volume reduction of scrap will be even more significant since asphalt is a low density constituent of roofing scrap. The conversion process will therefore reduce nationwide landfill requirements.

There is an additional potential for recovering raw materials from the scrap to be reused in roofing. An additional solvent extraction process might be used to recover granules and filler material from fresh factory scrap for reuse. The additional step was not analyzed because it seemed likely to be uneconomic at this time based on the analysis of solvent extraction presented in Section 5.5.

The equipment required to convert roofing scrap to No. 6 oil by the addition of No. 2 oil is relatively standard consisting primarily of agitated kettles, filter equipment, and equipment to condense the excess No. 2 oil from the process for reuse.

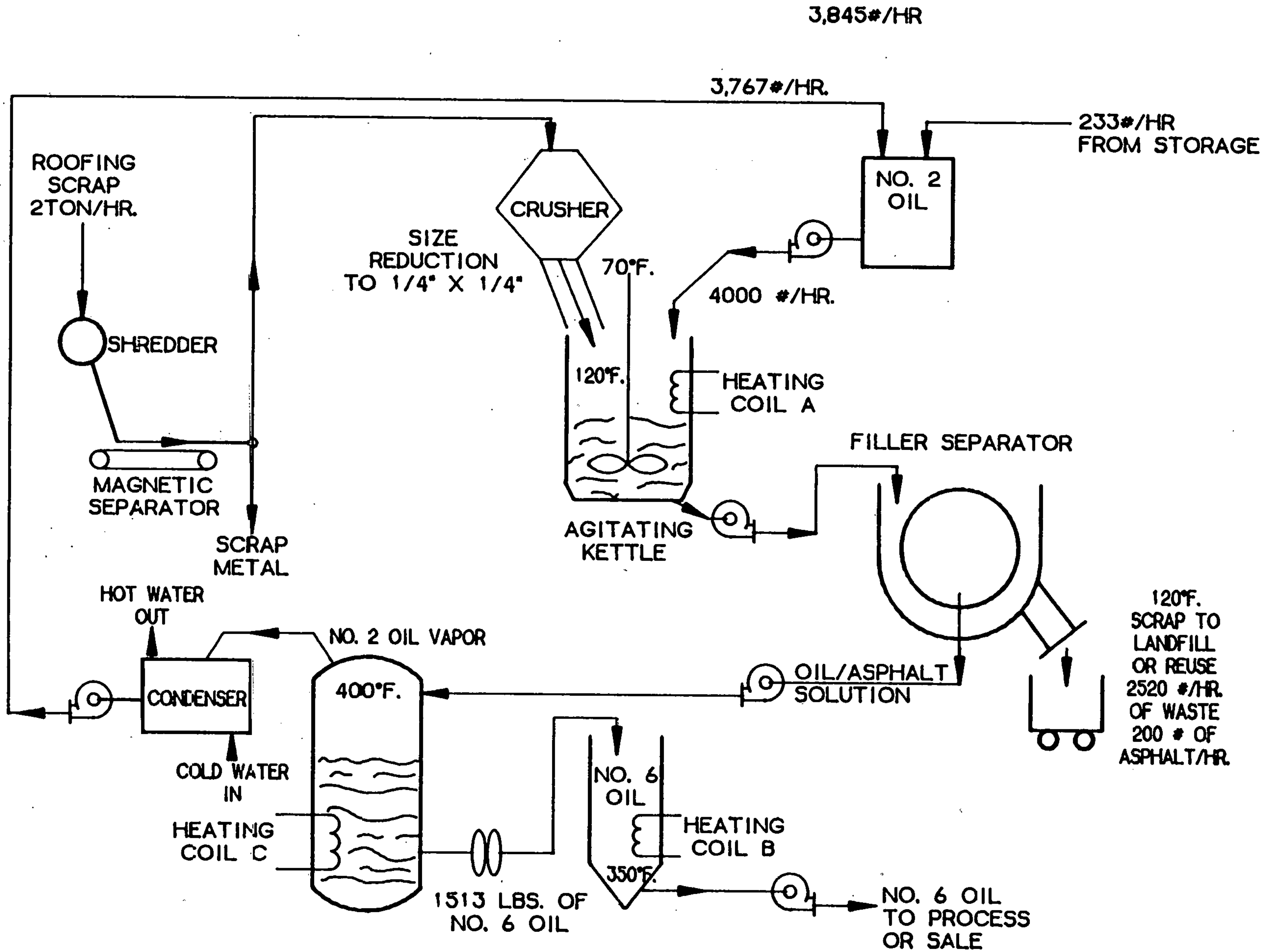
Figure 5.5 indicates the equipment arrangement and materials flow for this conversion process. After first removing large non-combustibles from the roofing waste, the material would pass through a shredder to reduce the feedstock to approximately 1/4-inch size, followed by magnetic separation to remove nails.

The prepared feed stock is introduced into an agitated kettle which is maintained at 120°F, along with No. 2 oil in a 50-50 mixture. After the solvent has dissolved the asphalt contained in the feed stock, the mixture is pumped to filter equipment which separates the No. 2 oil/asphalt solvated mixture from the solids consisting of glass mat/felt, granules, and filler.

The solvated mixture is then fed to a closed vessel heated to 400°F. The excess No. 2 oil is vaporized, condensed, and returned for use in the process. The remaining solvated mixture consists of approximately 15 percent No. 2 oil, 85 percent asphalt and is similar to a No. 6 oil. The product is pumped from the vessel and transported to a storage tank which is kept at 200°F.

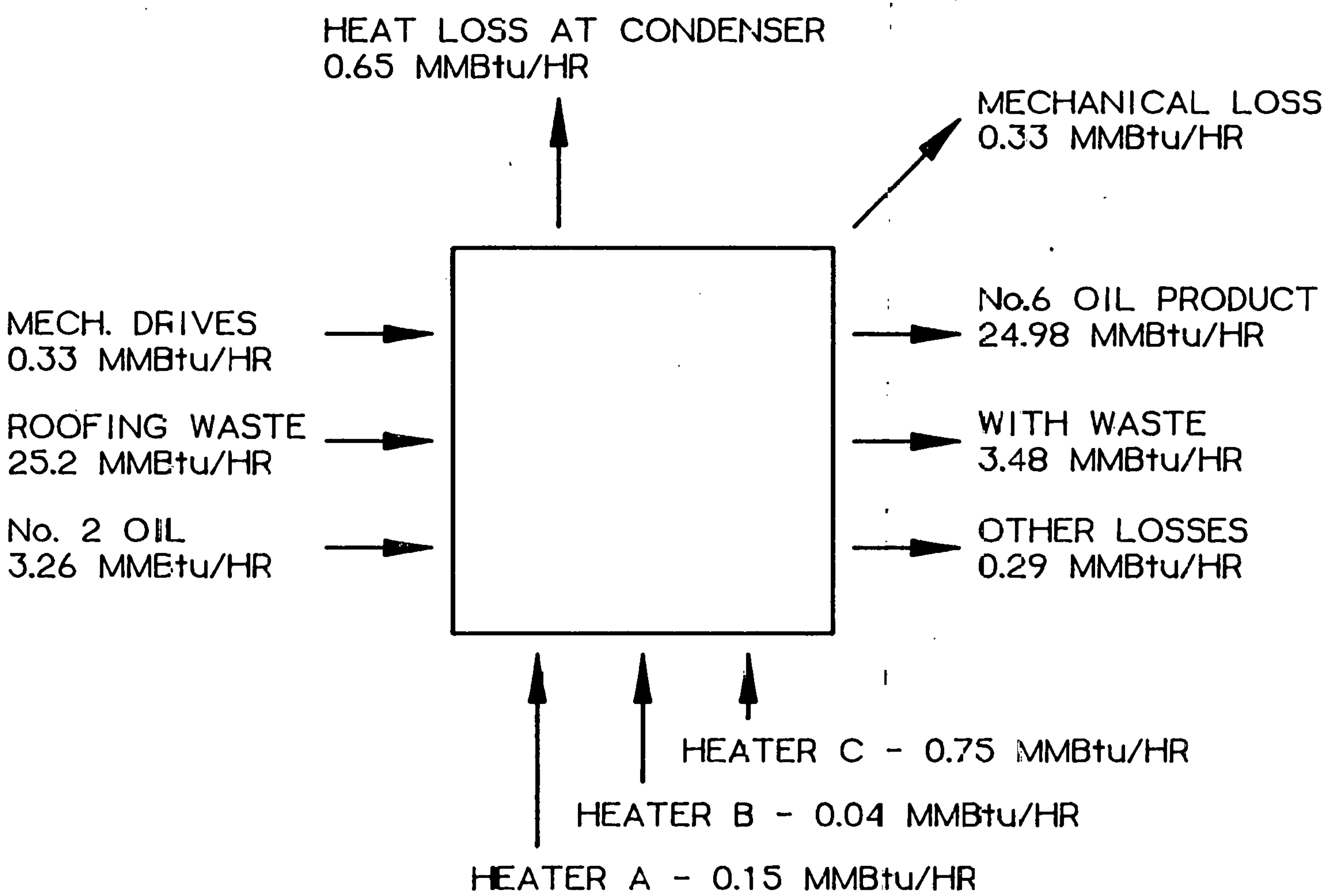
Figure 5.6 indicates the energy balance for this process. The balance reflects some loss of asphalt in the residue discharge (about 13.5 percent of feedstock asphalt content) and an ideal zero loss of No. 2 oil. The recovery efficiency of the asphalt energy in roofing waste is therefore 86.5 percent, with a net energy recovery of 34 percent. No credit is taken for the potential reuse of residues.

Capital costs for the process equipment and operating costs for conversion process at 12,000 TPY, including purchase of No. 2 fuel oil and ten year depreciation, are:



NO. 6 OIL EXTRACTION SYSTEM FOR FACTORY ROOFING WASTE

FIGURE 5.5



ENERGY BALANCE FOR NO. 6 OIL EXTRACTION SYSTEM
FROM ROOFING WASTE
(2 TONS/HR RATE)

FIGURE 5.6

Capital Cost: $550,000
$45.83/annual ton

Operating Cost: $420,000/yr
$35.00/ton

Recovery: 130,600 MMBtu/yr or: 817,000 gal/yr (fuel substitute)
$3.22/MMBtu $0.51/gal

5.3 - Convert Asphalt to Petroleum Feedstock by Fluid Coking

This reuse concept is discussed in the next subsection together with Pyrolysis because of a great number of common factors and considerations.

5.4 - Recover Crude Oil from Asphalt Roofing Waste by Pyrolysis

The conversion processes of asphalt roofing waste pyrolysis and fluid coking to produce gas oil or refinery feedstock were reviewed in much less detail. A number of general considerations indicate it would be unrealistic to treat such conversion processes on a parity basis with other concepts due to technology complexity. The conversion of heavy hydrocarbons such as asphalt to lighter hydrocarbons has been accompanlished and continues under development for various synthetic crude oils using coking or pyrolysis type processes. However, some of the technology is on the leading edge of the "state of the art", and economics for many of the initiatives do not look promising.

Fluid coking or pyrolysis conversion systems must be designed specific to the feedstock. For this reason, equipment items must be individually designed and developed. The "custom-made" nature of the equipment contributes to very high capital costs. The operation and maintenance of the equipment and the complexity of process control require skilled personnel of the type found in the petroleum refining and chemical processing industries; such skills are not abundant in the roofing or energy recovery industries. These factors contribute to high operating costs.

To be competitive, economics of scale must be applied to reduce total cost per unit of input or output. By comparison with synfuel initatiors, plant capacities of the order of 10,000 tons per hour might be considered. The capital cost of such a facility would be about $200 million(7) to $250 million(8), and would require approximately 20 percent of all roofing waste as feedstock. It is unlikely that such a fraction of roofing waste could be collected at one location with any practicality.

During this study, considerable information was accumulated on energy recovery from waste materials other than asphalt roofing scrap. Of particular interest were the various initiatives for waste tire conversion. Waste tires have been recognized as a potentially significant energy resource; disposal problems peculiar to whole tire landfilling have prompted the development of waste tire energy recovery technologies, including pyrolysis to reclaim useable hydrocarbons. A number of waste tire pyrolysis systems of the order of 5-500 tons per day input have been studied or designed and, in a few cases, operated. The products of tire pyrolysis are typically a medium - Btu gas, an oil not unlike crude oil, and combustible char ash, representing the approximate 90 percent hydrocarbon content of tires. Pyrolysis processing of tires was estimated to cost as little as $13/ton(9) in 1976 or approximately $20/ton of tire input in 1982 pricing. This assumes utilization of all or most of the generated gas as the primary energy source for the "destructive distillation" process. Unfortunately, only limited markets exist for the char product, and the oil may require some treatment to upgrade it for sale as a fuel oil.

The potential for development of comparably-sized asphalt roofing waste pyrolysis systems is very low. The hydrocarbon content of asphalt roofing is only about 40 percent that of tires. Product output would be equivalently less or, conversely, equivalent product output would require a system capacity 2.5 times larger. The gas product would be intimately mixed with the large proportion of non-combustibles in asphalt roofing with a low probability of recovery.

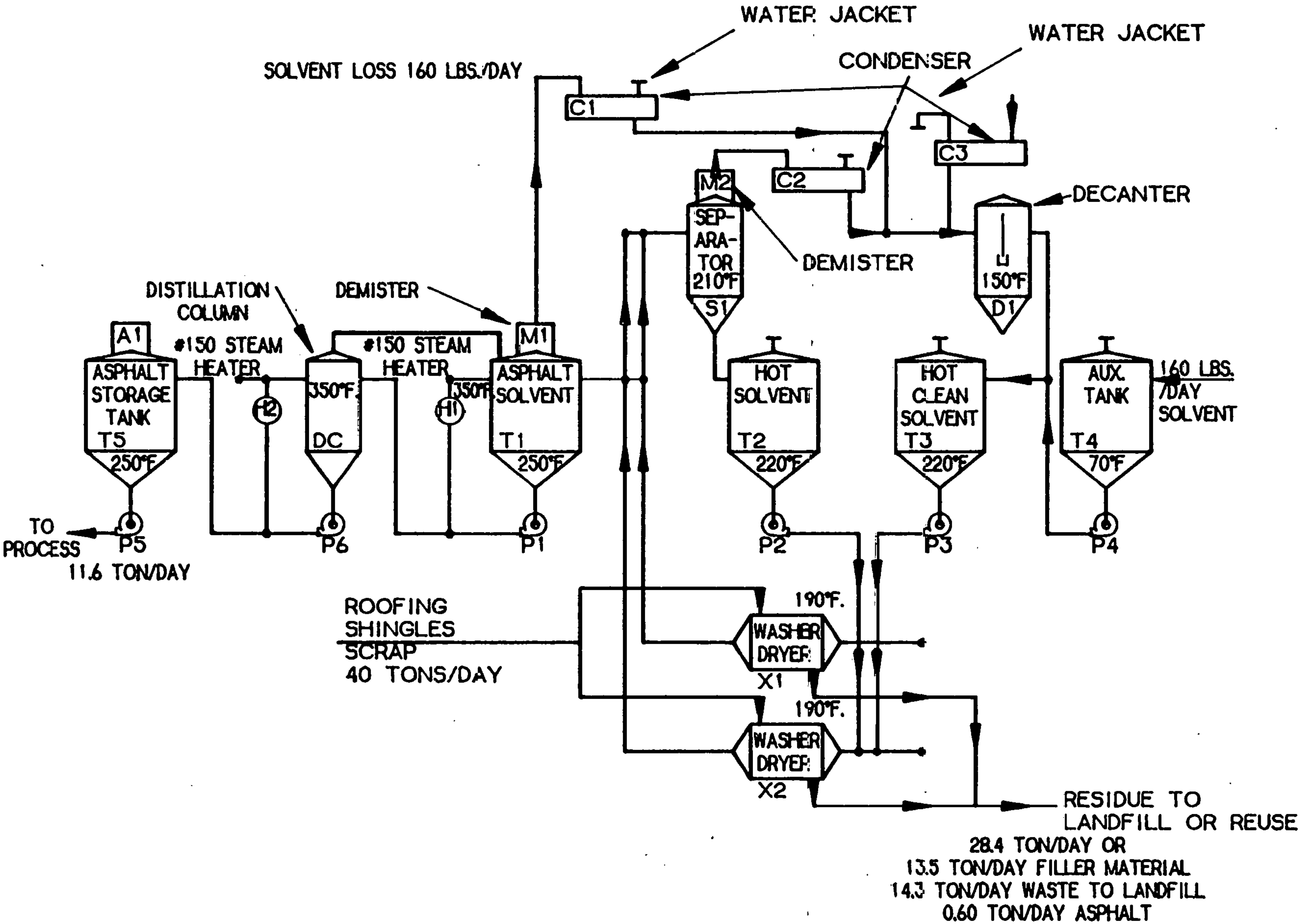
The one example of pyrolysis processing in few ton per hour capacity (tires) was sufficiently discouraging to bring to termination further study of coking or pyrolysis as reuse concepts for asphalt roofing waste.

5.5 - Recover Asphalt from Roofing Waste by Solvent Extraction

The solvent extraction process for the recovery of asphalt from roofing scrap is well known with several patents and much technical data available. Various solvents have been used. Perchlorethylene and heptane are the most popular. The asphalt impregnated waste is mixed with the solvent which separates the asphalt from the other roofing materials. It appears that the recovered asphalt from factory waste can readily be reused in manufacturing roofing. The remaining components consisting primarily of granules, filler, and glass mat/felt would have to be investigated further as to the possible reuse in manufacturing roofing. Granules reclaimed in one test were able to be reused but only on the unexposed portion of shingles. They exhibited poor adhesion; therefore, additional research work must be done to determine if granules can be reused in a cost-effective manner. It appears that the remainder of the components if reduced below 50 mesh could be reused as filler material in filled coating asphalt.

Figure 5.7 provides a graphic description of equipment and material flow for solvent extraction of asphalt from roofing waste. The system shown is suggested by Clermont Engineering Co., and is based on a feed rate of 40 tons/day. Clermont has an operational plant at their facilities in Appleton, Wisconsin using the process shown. The system has been tested for various feedstocks including reportedly successful tests on asphalt roofing waste conducted for a roofing manufacturer.

Using equipment nomenclature shown on the flowsheet, the process is described as follows:



SOLVENT EXTRACTION ASPHALT RECLAIM SYSTEM FROM ROOFING SHINGLES WASTE

FIGURE 5.7

The washer-dryers (X-1, X-2) are charged with roof scrap. The hatches are put in place and secured. Hot solvent from Tank T-2 is pumped by Pump P-2 into the washer-dryers. The washer-dryers rotate for ten miutes, then stop with the sump down. The hot asphalt-contaminated solvent will then flow to Tank T-1.

One half of the hot clean solvent in Tank T-3 is pumped into the now rotating washer-dryers. After eight minutes of washing, the washer-dryers stop and the solvent flows to Tank T-2. This cycle is repeated with the other half of the solvent from Tank T-3.

Next, steam is fed into the rotating washer-dryers. The reaction of the steam with the solvent causes the solvent to flash off and, along with the steam vapors, pass to Separator Tank S-1 where all free liquid drops out of the bottom and flows to Tank T-2. The vapors pass through Demister M-1 and are condensed in Condenser C-2. The condensed liquid flows to Decanter D-1 where the solvent and water separate. The water goes to the sewer and the solvent to Tank T-3. Tank T-3 fills to provide the solvent for the second and third wash of the next cycle. Should make-up solvent be required, it is drawn from Tank T-4.

Following the first wash, the contaminated solvent in Tank T-1 is circulated by Pump P-1 and heated by Heater H-1 to an elevated temperature. As the solvent re-enters Tank T-1, a portion of it flashes off and passes through Demister M-1 and on to Condenser C-1. The liquid then flows to Decanter D-1 from which the water flows to the sewer and the solvent to Tank T-3. As the concentration of the asphalt in the solvent in Tank T-1 increases, a liquid level sensor senses the level and at the proper time shuts off the heat and directs the liquid to flow to the Distillation Column (DC).

The operation of the distillation column is similar to that of Tank T-1. It is smaller and the operating temperature is higher. As the concentration increases, the level drops and the temperture increases. At the proper time, super-heated steam is introduced into the column. This steam aids in removing the last traces of solvent in the asphalt. Once the cycle is complete, the asphalt is pumped to Tank T-5 for storage.

Upon completing of the steam-out of the washer-dryers, the hatches are removed and the solids are dropped onto the storage conveyor. From there, the solids enter at a controlled rate into the separation and grading portion of the process. According to the material balance indicated in Figure 5.7, about 95 percent of the asphalt from the roofing waste is recoverable by this process; the remainder is in the solids residue. Solvent "loss" (inclusion primarily in the product asphalt) is estimated to be only 160 pounds/day for this 40 ton/day process.

The recovered asphalt product from solvent extraction is presently considered for reuse in roofing manufacture, substituting for fresh asphalt. Utilization for other applications such as dilution to fuel, etc., are not attractive; as previously indicated, recovery of asphalt with No. 2 oil to produce an equivalent No. 6 fuel oil can be accomplished directly from the roofing waste. If the product is primarily for reuse in the production of new roofing, the asphalt must be recovered at a cost less than or equal to that of purchased and delivered fresh asphalt. That this economics requirement can be met by proposed solvent extraction systems is not at all clear.

Estimates for the solvent extraction system costs, assuming a 40 ton/day roofing waste feed rate and 288 day/year operation (11,538 TPY), are:

Capital Cost: $1,600,000
$139/annual ton

Operating Cost: $750,000
$65.00/ton

Recovery:	113,765 MMBtu/yr $6.59/MMBtu	or:	712,000 gal asphalt/yr $1.05/gal

5.6 - Thermal Extraction of Asphalt from Roofing Waste

U. S. Patent 4,330,340 describes a process for extracting excess asphalt, asphalt saturated pulp and asphalt coated aggregate from job site waste. The method describes dumping roofing waste into a kettle of hot, fresh asphalt maintained at 500°F. Asphalt saturated pulp is claimed to float to the top. Aggregate sinks to the bottom and excess asphalt is claimed to mix with the asphalt which comprises the heating bath. A brief communication with the inventor suggested that this process has never been demonstrated. Experience and judgement suggest that very little asphalt would be recovered by this process. The patent states that the processing of shingle waste will be a net consumer of asphalt; this is apparently because some roofing components may soak up or become coated with additional asphalt from the bath. Since shingles contain about 2/3 of the asphalt in all roofing waste it seems obvious that such a process would recover little, if any, asphalt on a national average basis. Thermal extraction of asphalt was rated very low because it seemed clear that it would be a far less efficient process than others such as solvent extraction.

5.7 - Hydraulic Extraction of Asphalt from Roofing Waste

Recovery of the asphalt in fresh roofing waste using a water process was demonstrated on laboratory scale by Bird and Son nearly 40 years ago. This was a cumbersome process involving hammermilling, screening to separate dislodged mineral granules, water soaking, and prolonged violent agitation. Much of the asphalt remained with the felts and dislodged granules. Free asphalt was obtained with its combined mineral filler and was regarded as waste to be discarded because of the low value of asphalt in the 1940's. Today's "free" asphalt contains much higher filler contents which would increase the difficulty of separation by this process because of the much higher viscosity caused by the increased filler loading. This process was never tried with weathered roofing. The low recovery efficiency of free asphalt and the likely need for an additional solvent extraction step to separate asphalt from filler ranked this process quite low.

The use of Canadian tar sands water separation processes was also considered. This sort of process involves hot, chemically modified water to "float" bitumen from sand particles. The asphalts in roofing and especially in weathered, worn out roofing are extremely viscous whereas tar sands bitumen is rather soft. The softening point of weathered asphalts is usually well above the boiling point of water. Asphalt must be flowable for the process to succeed and for this reason the concept was rated low.

5.8 - Recycle Roofing Scrap as Filler in New Shingles

A prime ingredient of new asphalt roofing shingles is filled coating consisting of blown asphalt and filler (finely ground rock, sand or limestone) in quantities of about 100 pounds/square - 40 to 50 percent of the shingle weight. The use of finely chopped asphalt roofing scrap, which already contains sufficient asphalt, has potential for significant reuse in filled coatings for new shingles.

This concept is not new; the idea of recycling roofing scrap has been historically considered and even partially developed by the industry. U. S. Patent No. 2,368,371 (January 30, 1945), now expired, describes a process for comminuting factory roofing waste and incorporating the material in the molten asphalt to be applied to new shingles in process. The recycling was not implemented because of perceived adverse effects on shingle quality. Until rather recently, asphalt shingles incorporated organic felt bases. It was reasoned that organic felt fibers deteriorate rapidly when exposed to the weather, and that incorporation of felt fibers in the exposed layers of the filled coating could lead to more rapid degradation and decreased life of the shingles. However, with the advent of fiber glass shingles, there is less concern as to weather resistance. Fiber glass base shingles already constitute a majority of production and are expected to totally replace felt base shingles in the future (a major industry change). Therefore, the concept of roofing scrap recycling merits reinvestigation.

The recycling of roofing waste as filler for new shingles appears suited only for factory scrap. Job-site roofing waste would be expected to consist largely of felt base shingles for the next decade or so. There is the possibility of some asbestos and coal tar in field waste; neither of these materials is compatible with new shingle production. The effects that aging and weathering of the waste roofing materials might have on filled coating quality are largely unknown and probably represent unacceptable risk.

Factory scrap, on the other hand, is of known or identifiable composition, and would require minimum preparation. In the case of scrap tabs (a large proportion of shingle production waste), the material is available in an advantageously reduced size. The factory scrap is unweathered (relatively fresh) and collectible as clean material. Finally, the quantities available at the factory are compatible with a conservative recycled material addition. A five percent production scrap rate provides an equivalent 10 pounds per square of material substitution or at least 10 percent of the filled coating requirements. An acceptable filled coating mixture for new shingles might consist of 10 percent recycled shingles, 45 percent virgin coating, and 45 percent virgin filler material.

Figure 5.8 indicates the method and equipment for incorporating recycled factory scrap into production filled coatings. A recycling rate of one ton per hour has been assumed with the recycled material substituting for 10 percent of the filled coating. It is anticipated that the factory scrap would have to be reduced by chopping and crushing to no greater than 1/4-inch size. The prepared material would be transferred to storage for subsequent heating and delivery to an existing filled coating mixer. Virtually 100 percent of the roofing waste feedstock is recycled.

The capital and operating costs for the additional requipment needed to utilize the factory scrap in this reuse concept at a capacity of one ton/hour, 6000 hours/year (6000 TPY) are:

Capital Cost: $200,000
$33.33/annual ton

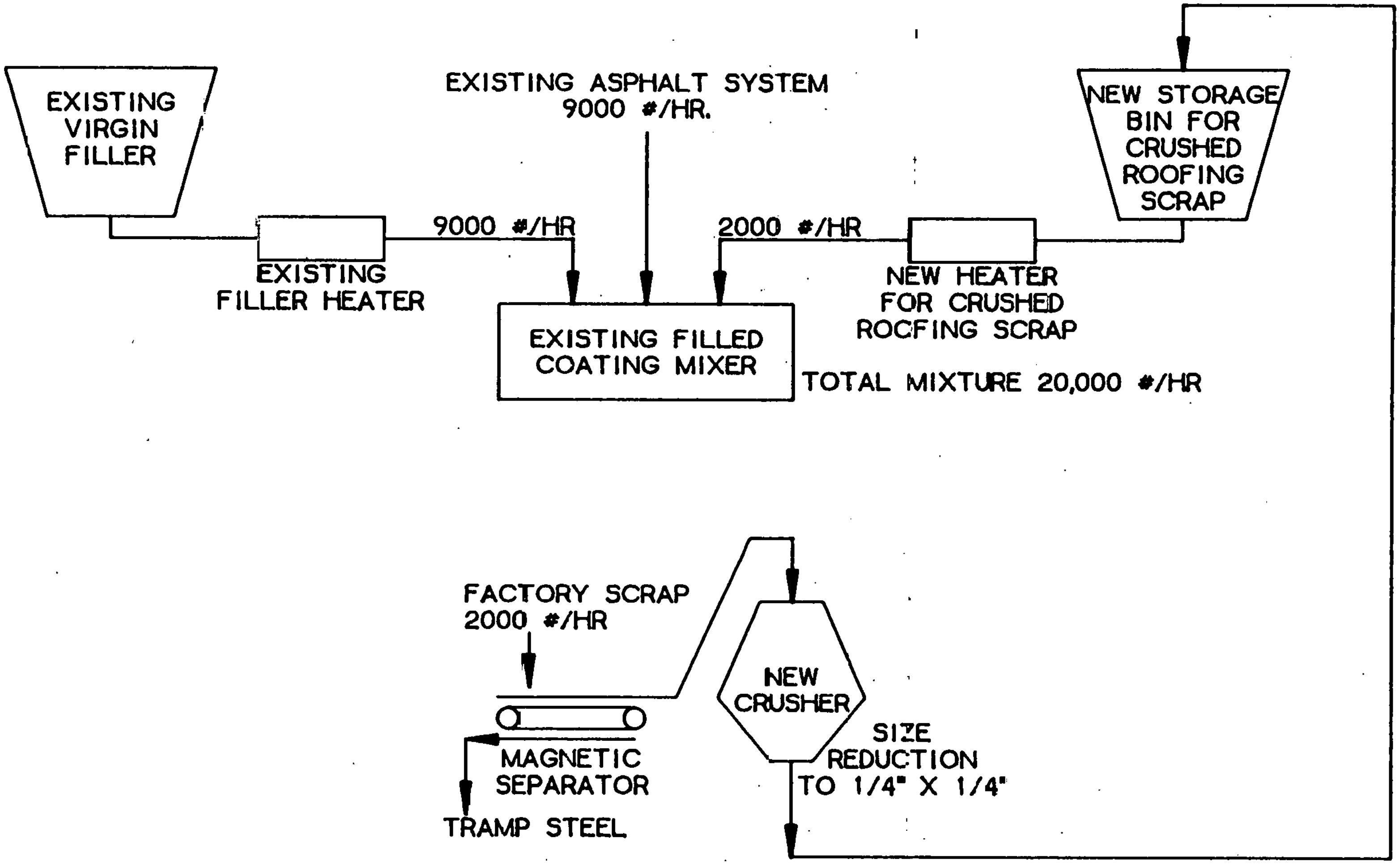
Operating Cost: $35,000/yr
$5.83/ton

Recovery: 70,000 MMBtu/yr
$0.50/MMBtu.

5.9 - Develop Paving Mixes Containing Roofing Scrap

The largest single use consumption of asphalt is for bituminous paving material. The "blacktop" or "asphalt paving" consists of 5-10 percent asphalt plus rock aggregate and filler material. Bituminous paving consumes between 18,000,000 and 26,000,000 tons asphalt annually in the United States.(10) Problems with cost and availability of asphalt over the last decade prompted a number of asphalt paving conservation developments including pavement recycling and substitution of extenders such as rubber from scrap tires.

The production of roofing material is the second largest use of asphalt in the United States. It has been estimated in the present study that United States asphalt roofing product waste includes about 2,100,000 tons asphalt annually, or about one-tenth of all paving asphalt requirements. Theoretically, paving mixes might accommodate all the nation's roofing waste.



USE OF FACTORY ROOFING WASTE AS A FILLER IN MANUFACTURING NEW SHINGLES

FIGURE 5.8

Asphalt paving compositions containing shingle scrap have been produced and applied by Tri-County Asphalt, a New Jersey paving contractor, according to U. S. Patent No. 4,325,641. The patent is oriented toward a means for processing the shingle scrap, not toward the use of scrap in paving per se, nor toward any specific compositions. According to interviews with Tri-County Asphalt and one roofing manufacturer who supplied waste roofing, only clean factory glass fiber base shingle scrap, specifically the tabs or cut out pieces (about 1/4 x 5 x 0.015 inches) from shingle product, have been used successfully. Job-site waste has not been considered because of the inclusion of nails and other non-shingle material and the lack of processing equipment for chopping up large pieces of scrap. The paving mix contains about 1 percent by weight of shingle tabs.

In order to make truly significant utilization of the roofing waste resource, the reuse concept must accommodate job-site or field scrap containing nails, assorted demolition trash, and perhaps asbestos and coal tar roofing material ingredients. It is assumed that demolition debris can be adequately removed in preprocessing. Nail removal should be adequately accomplished by magnetic separation following hammermilling or other size reduction. The degree to which the roofing scrap must be purified of nails will depend on paving application. A surface course would probably have to be absolutely nail-free. However, nails could likely be tolerated in the base course of paved areas. A pure surface course would effectively seal base course nails from moisture and traffic.

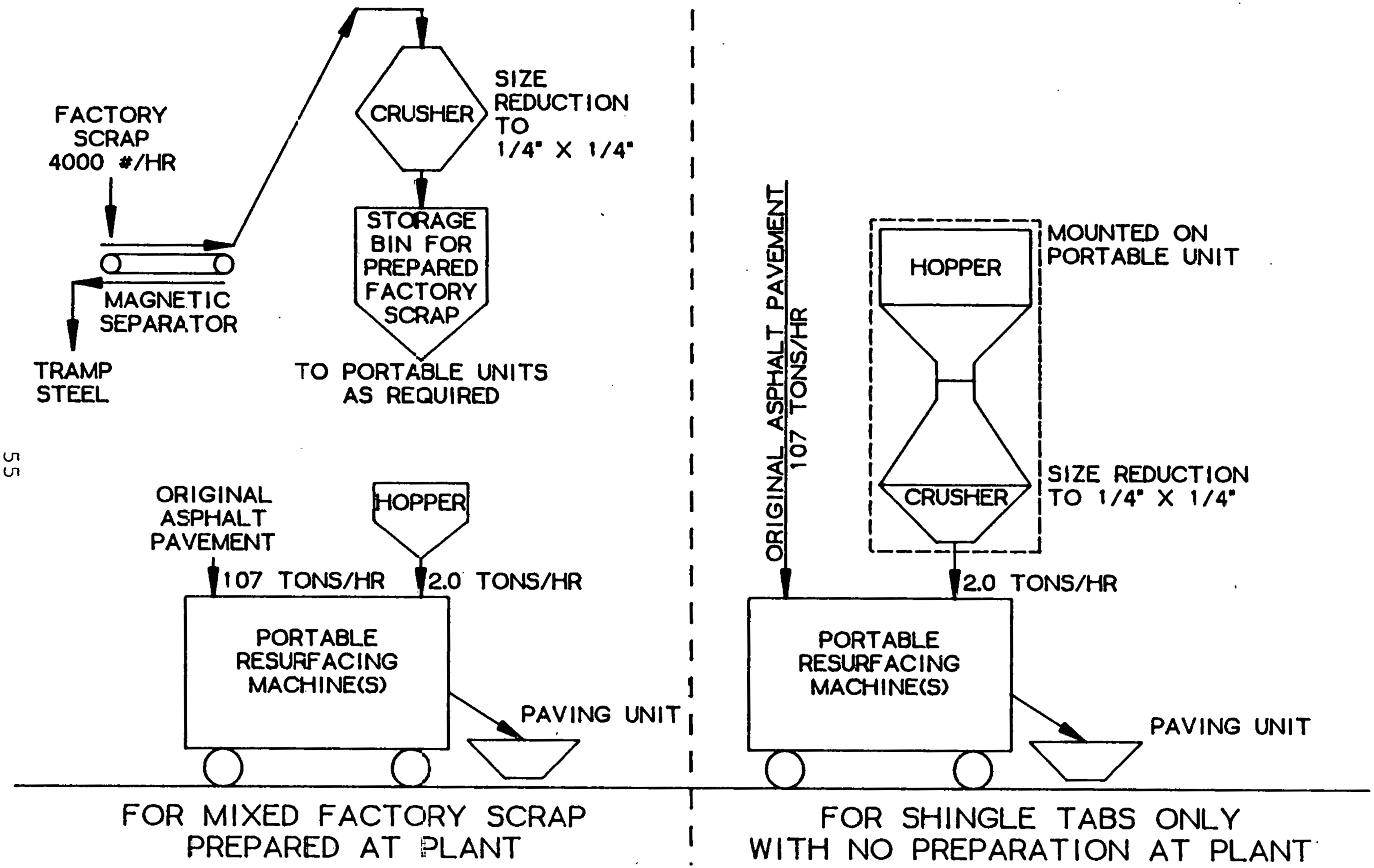
Asbestos represents only a small portion of roofing scrap and would remain in the bound state at temperatures of asphalt heating and application; the asbestos would not be subject to the EPA Part 61 of Title 40, Code of Federal Regulations, the National Emission Standards for Hazardous Air Pollutants, and should present no problem in paving mix. The presence of coal tar, even in small quantities, presents a potential problem. Coal tar is not ordinarily compatible with asphalt and it might be necessary to perform simple chemical tests and reject to landfill any batches of roofing waste with coal tar components. However, the degree of incompatibility of <u>weathered</u> coal tar products from reroofing is not known; there is a reason to believe that the aging and environmental factors alter the characteristics of coal tar. Further research on this item may be warranted.

For purposes of process evaluation, a ratio of 1 part roofing asphalt to 10 parts paving asphalt has been assumed. With paving mix and asphalt roofing assumed to contain respectively 7 percent and 37 percent asphalt, the weight of total roofing waste in the new paving mixture would be 1.9 percent. Figure 5.9 presents the equipment and flow for utilizing clean factory scrap in asphalt recycling operations. Two cases are presented. In one case, shingle tabs (only) are delivered directly to a hopper-fed shredder/crusher mounted directly on a resurfacing machine for size reduction to 1/4inch. No at-factory preparation of the waste is involved. In the other case, mixed clean factory scrap is prepared and comminuted to 1/4-inch size at the factory for delivery as a product to the paving customer. A small in-house preparation effort could supply scrap product for several such paving operations even if they were continuous.

Figure 5.10 indicates processes and equipment for preparation of job-site roofing waste at some location convenient to existing hot mix operations. The product of the processed scrap is a 1/4-inch addition ready for delivery to, and mixing at, the hot mix site. In both the example processes, the energy resource represented by the asphalt contained in the roofing waste is recovered for reuse at very nearly 100 percent.

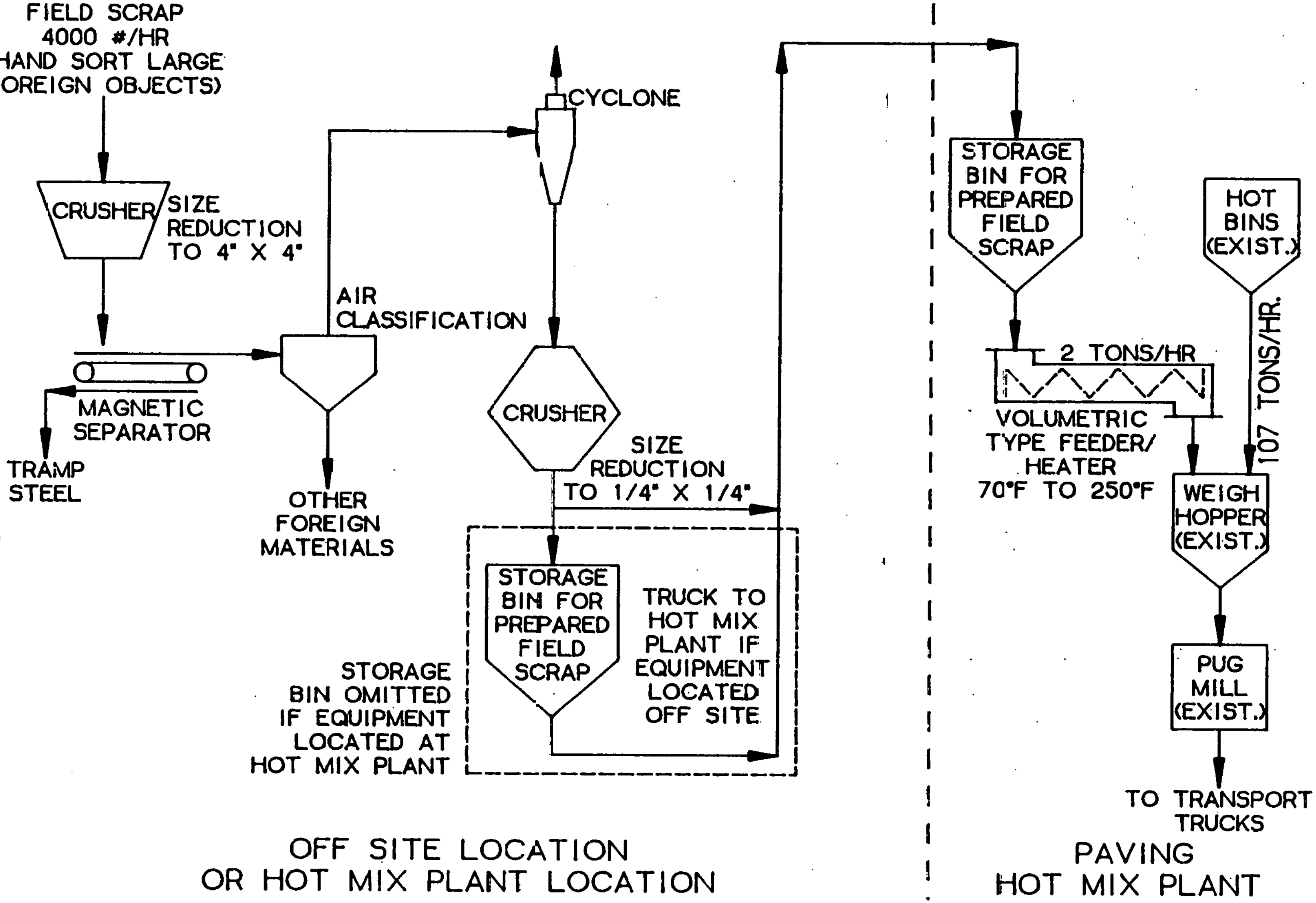
Estimates of capital and operating costs for the indicated preparation of factory and field scrap normalized to 4000 lb/hr roofing waste, 6000 hr/yr (12,000 TPY) are:

	Factory Scrap		**Job Site**
	Tabs Only	**Mixed Scrap**	**Roofing Waste**
Capital Cost:	$115,000 $9.58/annual ton	$250,000 $20.83/annual ton	$650,000 $54.17/annual ton
Operating Cost:	$ 32,000/yr $2.67/ton	$160,000/yr $13.33/ton	$235,000 $19.58/ton
Recovery:	151,000 MMBtu/yr $0.21/MMBtu	151,000/MMBtu/yr $1.06/MMBtu	151,000 MMBtu/yr $1.56/MMBtu



USE OF FACTORY ROOFING WASTE IN PAVING MIXES

FIGURE 5.9



USE OF FIELD ROOFING WASTE IN PAVING MIXES
(2 TONS/HR RATE)

FIGURE 5.10

5.10 - Develop New Products Made from Roofing Scrap

Roofing scrap has been the subject of product development efforts for decades. The concept is to recover roofing waste so as to utilize the substance as raw material for a new product. Roofing manufacturers and other firms have devoted considerable time and expense in efforts to convert factory waste to a valuable by product. Their commercial successes have been very limited. Interviews conducted as part of this study confirmed that research and development is still underway at several manufacturers, indicating continued interest in a profitable alternative to landfill disposal of factory scrap. None of the interviews indicated any efforts to find or develop uses for job-site roofing waste.

In a previous section, the collection and processing of asphalt roofing waste to provide an extender for commercial paving mixes was examined. Some other product uses, both current and historical, are discussed below.

- Industrial flooring planks or blocks have been produced of a bituminous composition containing roofing scrap mixed with other ingredients such as asphalt and fillers in proprietary recipes. The masticated mixture is rolled or extruded to its final thickness, which may range from one-half inch to one and one-half inches, and is then cut to the desired length and width dimensions. Products made in this manner were formerly specified for flooring in U.S. Post Offices. Manufacturers of the planks reported that this market has greatly diminished. Some planks or blocks are sold for use as roof walkway tiles and some as bridge deck underlay tiles. Interviews with manufacturers indicated that there was little opportunity for increasing the use of roofing scrap in these types of products primarily because of a recent government edict that these flooring products no longer be used in certain sizes of post offices.

- A current, continuing use for factory roofing scrap involves the incorporation in asphalt expansion joint material, a protection board for waterproofing, a protection course for railroad bridges call VIBRAFLEX and a roof traffic pad called WHITE WALK. All these products are manufactured by W. R. Meadows, Inc. Their representative declined to offer information about the quantity of roofing waste used annually in the manufacturing of these four products. The volume was described only as "significant". Only clean, factory waste is used and these items have been manufactured for about 50 years. The outlook for increasing sales was described as good.

- A scrap shingle reclaiming process was used by Bird and Son, Inc., many years ago. The manual process involved dipping a scrap, whole shingle into a bath of asphalt; placing the shingle on a powdered mica covered workbench; sprinkling colored granules on the hot asphalt surface; then embedding the granules into the asphalt with a wooden rolling pin. This process was discontinued in the early 1950's.

- Research at Bird and Son in the 1940's developed a process for separating factory shingle scrap into its original constituents by a process involving hammermilling, violent agitation in water, flotation and drying. This process produced no commercial products. Rag fibers used in the production of the base felt were recovered in a clean, fluffy state. These did make an acceptable stuffing for dolls, but the size of the market did not justify a commerical installation. The hammermilled shingles were used as a molding compound to produce papermill roll end plugs. However, these were not cost competitive with wooden plugs in use at that time.

- Shingle scrap, and only the small cut-out pieces, has been used as a residential driveway surfacing material. This has been a non-commercial use. Such driveways may be seen in many parts of the country close to roofing factories. These driveways have probably been surfaced by roofing factory employees who make good use of a free material. It is observed that such driveways are highly serviceable. However, texture of the driveway is unconventional and the color of the driveway is variegated according to the colors of the shingle scrap and whether each piece falls colored side up or black side up.

In order to be of national significance in utilizing the roofing waste resource, any new product development must address the use of job-site scrap. The limited successes using factory scrap suggest that the potential for expanding similar applications to job-site waste should be studied. As previously discussed, field scrap is contaminated with nails and very likely other demolition debris. The roofing material after metal and debris removal is of varying composition, primarily felt base as opposed to modern fiberglass base, and may include undesirable components such as coal tar or asbestos. Furthermore, the old roofing will be weathered, probably brittle, and of variable and degraded quality relative to new asphalt roofing physical and chemical properties. Ideally, the new product application for roofing waste material would be such that composition factors would not be of primary significance.

For purposes of this study, three representative new product applications for asphalt roofing waste were selected for general evaluation. The applications were chosen to reflect diverse customers for the roofing waste product.

A. <u>Light-Duty Surfacing</u> - The incorporation of roofing waste in bituminous commercial (traffic duty) paving mixes was discussed earlier; a new mix ratio of a few percent asphalt roofing scrap with existing paving compositions would be expected to have little effect on pavement quality. The use of asphalt roofing waste alone in paving would be relegated to light duty, such as driveways, paths or shed flooring. The typical customer for such a product would be the homeowner. Widespread marketing of the product for such applications would suggest distribution and retail sale through hardware stores, lumber yards, home improvement centers, etc. The material could be provided in a convenient package such as a 50-pound bag.

To be successfully marketed the product must compete with other surfacing materials. For example, ready mix concrete for surfacing an area 8 x 20 ft. (a driveway perhaps) for a strength of 3000 - 4000 psi (2 to 3 inch depth) would cost about $80 delivered. A roofing waste product covering only one inch thick would require some 29, 50-pound bags of material. Even if the waste product covering properties were equivalent, the product would have to retail for substantially less than 5.5 cents/pound.

While no attempt has been made to provide a commercial market distribution plan, it has been assumed that product marketing would involve a distributor and retailer. Table 5.1 presents earnings statements for the retailer, distributor and manufacturer based on the following assumptions:

- Distributors and retailers labor and overhead averages 20 percent of their purchase price
- All three entities pay a 49 percent of net profit tax rate

- Manufacturing costs average 65 percent of selling price. (This is considered to be a very optimistic assumption.)

- All parties will accept a 10 percent net profit ratio after taxes.

The resulting pricing of "driveway mix" indicates a maximum production cost of $0.63 per 50-pound bag, or 1.3 cents per pound, which must cover the producers cost of:

- Constructing and equipping the resource recovery plant
- Acquiring roofing scrap
- Buying bags
- Filling and warehousing bags
- All labor and overhead
- Order handling, shipping and billing.

Table 5.1

Pricing of 50-pound Bag Roofing Scrap Driveway Mix

Retail Outlet Earnings Statement

Selling price	$ 2.50
Less purchase cost from distributor	1.68
Retail gross profit	0.82
Less labor and overhead at 20 percent	0.34
Net profit	0.48
Less income tax at 49 percent	0.23
Net earnings	$ 0.25
Percent net earnings on sales	10%

Distributor Earnings Statement

Selling price	$ 1.68
Less purchase cost from manufacturer	1.00
Wholesale gross profit	0.68
Less shipping cost for 20 miles	0.15
Less labor and overhead at 20 percent	0.20
Net profit	0.33
Less income tax at 49 percent	0.16
Net earnings	$ 0.17
Percent net earnings on sales	10%

Manufacturers Earnings Statement

Selling price	$ 1.00
Less factory cost	0.65
Gross profit	0.35
Less shipping cost for 20 miles	0.15
Net profit	0.20
Less income tax at 49 percent	0.10
Net earnings	$ 0.10
Percent net earnings on sales	10%

It is difficult to say whether or not such a product would have significant demand at 5 cents per pound for a one-inch surface. If the consumer perceived that an equal thickness compared to concrete (2 or 3 inches) was needed, the maximum competitive price of the roofing waste surfacing material would be reduced proportionally, eliminating the possibility of profitable production.

B. <u>Molding Compound</u> - Research in the 1940's successfully developed a shingle scrap molding compound. This technical success was a commercial failure for at least two reasons.

1. The sponsor apparently sought only in-house uses for the material and did not pursue any potential sales outlets.

2. The designated end use, paper mill roll-end plugs, was satisfied at lower cost by wooden end plugs.

This near 40 year old venture demonstrated that roofing waste can be processed to make a flowable, handleable large granular material which can be molded at modest heat and pressure to make rather rugged, serviceable articles. Use-limiting qualities of such an article would include the following.

- The only available color is black
- The compound binder is thermoplastic and would have a limited service temperature range
- It is likely that the molded article would transfer black stain to anything it contacted
- The molding compound would be quite abrasive unless rock granules and aggregate were removed.

It was not within the scope of this study to identify specific final products which could be molded from scrap and then sold at a profit. A few suggestions were elicited including:

- Light duty pallet
- Preformed, driveway curbing
- Light duty paving blocks
- Moisture resistant containers

The customer for the roofing waste compound would be the manufacturers of such specialty products.

The process to prepare the molding compound from factory roofing scrap would involve the following steps:

- Segregate each roofing product by type
- Hammermill or otherwise reduce the scrap to suitable size pieces. Note that the scrap feed pieces will vary in size from 1/4 inch by 5 inches by 0.15 inch shingle tabs to 6 inches in diameter by 3 feet long rolls
- Screen the milled pieces to remove dislodged granules and classify by the size of the product
- Recycle oversize pieces to the hammermill
- Blend the milled roofing products to achieve the desired molding compound properties.

Use of field scrap would require at least two added steps:

- Hand sort the scrap to remove trash such as wood, sheet metal and insulation
- Magnetic separation of nails from the milled scrap.

Molding compound must be uniform in composition to assure a controllable process and uniform finished product properties. Uniformity of composition will be difficult, perhaps even impossible, to achieve when dealing with field scrap. Product identification tests, segregation and blending would likely be a necessity.

The market for black (only) thermoplastic molding compound is judged to be small. Current demand is filled by a number of relatively inexpensive modern plastics; the only incentive to utilize the roofing waste product as a substitute would be a tremendously reduced raw material cost. For example, colored, thermoplastic, "utility" grade molding compounds of polyethylene or polystyrene may sell for .35 cents - .45 cents per pound. These are "engineered" plastics whose color and properties are duplicated from batch to batch. The plastics are non-staining; i.e., roofing waste is not. Roofing waste is also quite abrasive to molds comparable to commercial molding compounds.

C. Binder for Densified Refuse-Derived Fuel - Roofing waste combined with refuse derived fuel (RDF) may offer a low cost fuel product which would enhance the utility of both roofing and municipal waste. The product concept would be a fuel briquet or rod in which the asphalt in roofing waste serves as a binder for the other ingredients. The product would be a stable, shippable, relatively dry fuel of higher Btu value than much RDF or densified RDF. The quantity of asphalt required to bind such a product would be about 10 percent by weight.(11) Thus, about 540 pounds of roofing waste might be combined with about 1,460 pounds of RDF to produce one ton of densified RDF.

The process envisioned here would involve milling roofing waste to a particle size to be determined. Screening might be used to separate mineral aggregate and rocks which could be landfilled. The roofing waste particles would then be blended with RDF to produce an extruding compound. Conventional briquetting molds or single screw extruders would process the blended waste.

The customer for the product in this application is the public or private entity engaged in resource recovery from municipal solid waste. This same entity would most likely be the roofing waste processor and additive producer. Since RDF facilities are classically located and operated in conjunction with municipal solid waste landfilling, a collection system for roofing waste would involve only its segregation upon arrival at the landfill.

This roofing waste product application was not included in the original project plan and actually grew out of contacts made during the latter part of this study. The potential viability of this reuse concept requires much additional evaluation in conjunction with municipal solid waste resource recovery researchers.

Each of the above new product reuse applications for roofing waste derive from collecting and processing asphalt roofing scrap to a form nominally the same as that prepared for addition to commercial paving mix, discussed in a previous section. For comparison purposes, it is assumed that capital and operating costs, and recovery potential, are the same as estimated for paving mix addition.

6.0 - COMPARISON AND SELECTION OF REUSE ALTERNATIVES

Ten candidate concepts for reusing asphalt roofing waste have been studied. A comparison of these reuse alternatives should include their relative technical viability, cost effectiveness, likelihood of commercial implementation, and energy recovery impact. Evaluating and weighing the relative importance of these factors is necessarily judgemental, particularly the extent to which the U. S. roofing waste energy resource might be recovered.

Information presented in discussion of the reuse concepts relevant to the four comparison factors is summarized in Table 6.1 The attempt has been made to put the concepts on a parity basis as to unit size; in some cases, this was not possible. A brief synopsis of the judgemental results for each of the ten concepts follows.

6.1 - Burn Roofing Waste as Fuel - As a fuel substitute, prepared asphalt roofing waste could replace oil or natural gas through construction of a new incinerator or could possibly fuel a retrofitted coal fired system. Both job-site and factory scrap could be utilized, with the resulting heat used to generate steam in existing or new boilers. Considering only the heat producing portion of the system, estimated investment costs are moderate and operating costs are quite low. Energy recovery cost is well below the least expensive purchased fuel costs. Of the two types of systems studied, the pulse hearth appears to be the system of choice. The potential advantages of a fluid bed system would be outweighed by higher costs. Pulse hearth systems for waste incineration are demonstrated and the implementation potential is much higher than for fluidized beds.

6.2 - Convert Asphalt to No. 6 Oil - A relatively low estimated investment cost for this potentially viable concept is somewhat offset by relatively high operating costs. Recovered asphalt from roofing waste would subsitute directly for purchased petroleum fuel at a recovery cost estimated to be slightly lower than the current price of purchased No. 6 oil. There are potential problems with coal tar and other constituents of job-site waste which are not soluble in No. 2 oil, perceived as high technical risk requiring extensive developmental effort.

6.3; 6.4 - Recover Combustibles by Fluid Coking; Pyrolysis - The potential for commercial implementation of these concepts was judged very low. Economical recovery systems would likely have to be extremely large, requiring as feedstock the collected roofing waste from enormous geographical areas. A smaller pyrolysis system, by analogy to tire pyrolysis concepts, would produce only a fraction of the combustibles due to the much lower hydrocarbon content of asphalt roofing waste.

6.5 - Recover Asphalt by Solvent Extraction - High technical viability is offset by high operating costs for this concept. A pilot plant for solvent extraction has been successfully operated using asphalt roofing waste. The goal would be to recover the asphalt from roofing waste to reuse as a substitute for purchased fresh asphalt. Users would be the roofing manufacturer or any other asphalt customer. Unfortunately, the estimated recovery cost of the asphalt is significantly greater than the price of purchased asphalt.

6.6; 6.7 - Recover Asphalt by Thermal Extraction; Hydraulic Extraction - These concepts were considered quite unlikely for asphalt roofing waste recovery and reuse. The concepts may be technically viable, but considerable developmental work would be required without any apparent incentive for development. These extraction processes are estimated to be considerably more costly yet less efficient in asphalt recovery than solvent extraction. Thus, the cost of recovered asphalt would be even further out of line with asphalt prices, perhaps amounting to twice the current purchase price.

6.8 - Recycle Roofing Scrap as Filler - This concept is quite promising to reclaim factory scrap for reuse in new roofing shingle production. In the days of felt-base shingle predominance, reuse of scrap as filler was percieved to threaten shingle quality. With the advent of fiber glass base shingles, the concept deserves reinvestigaton. Capital and operating costs for material recovery are quite low and should be attractive to the roofing manufacturer as an alternative to landfill. The roofing waste asphalt and other materials would directly replace virgin ingredients of filled coating. The impact on energy recovery, however, is quite limited since this concept is applicable only to factory scrap.

TABLE 6.1

COMPARISON OF ASPHALT ROOFING WASTE REUSE ALTERNATIVES

Reuse Concept	Technical Viability	Investment Cost per Annual Ton Scrap capacity ($)	Operating Cost per ton scrap processed ($)	Energy Recovery Cost ($/MMBtu)	Potential for Commercial Implementation	Impact on Energy Resource Recovery
Burn Roofing Waste - Fluidized bed - Pulse hearth	 High Very high	 183 125	 53 29	 3.75 2.32	 Low Moderate	Significant potential impact - factory and job site waste as direct substitute for oil, gas or coal as fuel for boiler or process heat, new facility or perhaps retrofit combustor to existing system.
Convert Asphalt to No. 6 Oil	High*	46	35	3.22	Low	Only modest impact of job-site waste - coal tars present a problem (high risk) - substitute directly for purchased fuel oil.
Fluid Coking to Petroleum Feedstock Pyrolysis to Syncrude	Very Low* High*	High	High	High	Very Low	Impact unlikely - very large units judged impractical for waste collection required, smaller units judged uneconomical.
Asphalt Recovery by Solvent Extraction	High	139	65	6.59	Low	Small impact - recovered asphalt cost appears higher than price of fresh asphalt

TABLE 6.1 (Continued)

Reuse Concept	Technical Viability	Investment Cost per Annual Ton Scrap capacity ($)	Operating Cost per ton scrap processed ($)	Energy Recovery Cost ($/MMBtu)	Potential for Commercial Implementation	Impact on Energy Resource Recovery
Asphalt Recovery by Thermal Extraction	Moderate*					
Asphalt Recovery by Hydraulic Extraction	Moderate*	No Est.	>65	>6.59	Very Low	Impact unlikely - cost of recovered asphalt cost appears higher than price of fresh asphalt.
Recycle Scrap as Filler for New Roofing	Moderate	33	6	0.50	Moderate	Modest potential impact - concept applies <u>only</u> to factory scrap.
Use Scrap in Paving Mixes	Very high	10-54	3-20	0.21-1.56	Moderate	Very high potential impact - factory and job-site waste as direct substitute for virgin paving ingredients theoretical use of all roofing waste.
Use Scrap in New Products						
-Light Duty Surface	High				Very Low	Small impact - appears unprofitable
-Molding Compound	High	10-54	3-20	0.21-1.56	Very Low	Small impact - very low demand (black only)
-Binder for RDF	Unknown*				Unknown	Small impact - limited to MSW facilities producing RDF

*Untested for asphalt roofing waste

6.9 - Roofing Scrap in Paving Mixes - The direct reuse of prepared asphalt roofing waste in commercial paving mixes appears to have very significant potential. Factory waste is currently being reused by one company; the concept could be expanded to utilize job-site waste perhaps with little more than some additional pre-processing and preparation. Capital and operating costs for the roofing waste preparation are low or moderately low even for job-site waste. This reuse concept would substitute both the roofing waste contained asphalt and the non-combustible materials directly for virgin ingredients in extending the paving mix by two percent or so. At this rate, theoretically all roofing waste could be utilized.

6.10 - Roofing Scrap for New Products - In evaluating the potential for new products, it was assumed that only preparation costs would be involved, the resulting reduced-size material sold to customers for various applications or final products. Therefore, capital and operating costs are quite low. Three example applications or products were selected for evaluation. A light duty surface ("driveway mix") was estimated to be unprofitable. The sale of the prepared waste as a molding compound to specialty manufacturers was judged to be limited by the restricted color (black only) and possibly by problems of undesirable constituents in job-site waste; energy impact would be quite low. The utilization of roofing waste as a binder for refuse derived fuel is unknown as to technical viability and is limited to utilization at landfills that operate RDF facilities. Collection system complexity for this last application would be minimized since both the roofing waste and the RDF production facility would be at (or near) the landfill site. In each of the new product examples, roofing waste is presumed to substitute for new ingredients substantially different than asphalt or roofing noncombustibles.

The above synopses and Table 6.1 aid in a preliminary elimination of several concepts based on relative merit. Fluid coking and pyrolysis to recover combustibles, and thermal or hydraulic extraction to recover the asphalt, though technically viable, offer no advantages but many disadvantages. Each of the remaining concepts is judged worthy of further study as to the feasibility of commercial implementation despite some relative economic or application limitations.

Of the remaining six concepts, three utilize both the asphalt and the non-combustible materials (i.e., reuse of essentially 100 percent of the roofing waste). Of the new product examples, all would produce at best only a very small impact on resource recovery. The recycle to new shingle concept would undoubtedly utilize only factory scrap, accounting for only 5-6 percent of roofing waste. Only the concept of using asphalt roofing waste in commercial paving mixes has the potential for significantly utilizing the job-site scrap resource in quantity.

In the solvent extraction process, asphalt and possibly other roofing materials are recoverable in a demonstrated process. However, the estimated recovery cost for asphalt from even clean factory scrap is not favorable; recovery appears more expensive than purchase of fresh asphalt. Even if this discrepancy could be offset at least partially by the manufacturer's avoided cost of landfill disposal, implementation is judged of low likelihood. The additional preparation required for field scrap suggests less attractive prospects for the much larger portion of the roofing waste resource.

Two concepts recover the energy content of the asphalt in roofing waste as a substitute for purchased energy. In recovering the asphalt with No. 2 oil to produce an equivalent No. 6 oil, the product substitutes directly for petroleum fuel. The preliminary estimates made in this study indicate the substitute fuel might be produced competitively with fuel oil prices provided the roofing waste could be guaranteed free of coal tar; such a guarantee may be impossible for mixed job-site waste. More attractive is the direct combustion of asphalt roofing waste. Of the two combustion systems studied, the pulse hearth offers the greatest potential. The cost of the recovered heat energy appears to be quite attractive for a wide range of end uses incorporating new or existing boilers or other utilization systems. The environmental impact of roofing waste combustion should not be any greater than for conventional fuel systems.

The comparisons of relative merit of the concepts indicate two are clearly superior with respect to the four primary evaluation factors. Direct combustion of roofing waste and utilization of roofing waste in paving mixes were selected as most worthy of further study. Each was judged high in technical viability. Each has relatively low costs leading to an attractive cost of recovered energy resource. Each was judged to have moderate potential for commercial implementation (none of the concepts was judged high in this regard). Finally, each has the potential to reuse job-site roofing waste thereby having significant impact on energy resource recovery.

An additional factor, time to implementation, addresses how soon resource recovery can get underway. The selected alternatives are among the few for which some commercial demonstration exists, based only on clean factory scrap. Thus, the two selected reuse concepts rank high in considering time to implementation although further development is needed to effectively accommodate the larger job-site roofing waste resource.

For the two selected alternatives, the appropriate next steps in feasibility study, research and development which could lead to demonstration and eventual commercial implementation can be outlined.

Roofing Waste Combustion

- Conduct technical market research and analysis to identify candidate boiler types and roofing waste recovery methods.
- Select at least two boilers for test burning.
- Burn a small quantity of roofing waste to obtain preliminary data for designing commercial scale research.

Roofing Waste Paving Mix

- Analyze various types of roofing waste to provide a basis for laboratory tests.
- Conduct a designed laboratory experiment to identify acceptable paving mixes containing roofing waste.
- Lay several small test pavement sections for traffic evaluation.

7.0 - CONCLUSIONS AND RECOMMENDATIONS

This study has addressed asphalt roofing waste as a recoverable energy resource and has investigated present disposal practices, general methods for collection and acquisition, and potential alternatives for utilization. The asphalt in the nation's asphalt roofing wast represents some 7 x 10^{13} Btu annually, and is almost exclusively disposed of in landfills, currently contributing to an environmental problem. Disposal costs to the roofing manufacturer for factory scrap and to the roofing contractor for job-site roofing waste are increasing. Acquisition of the roofing waste appears only to require an economical alternative to landfilling with collection continuing by present methods, but with a less costly and more convenient destination.

A successful reuse concept must be technially viable, economically attractive, and institutionally implementable. Moreover, to have a significant impact on recovery of the energy resource, the concept must accommodate job-site roofing waste which represents about 94 percent of the total. Of ten reuse concepts studied, two have been identified which are clearly superior in comparison of relative merits. The two concepts judged most worthy of further study and development toward commercial implementation are the direct combustion of asphalt roofing waste (in a conventional incinerator system such as the pulse hearth) and the incorporation of prepared roofing waste in commercial paving mixes. Each of the selected concepts has been demonstrated commercially on a very limited basis, using only clean factory scrap.

It is recommended that additional research and development be undertaken to determine the best technical and economical approaches for extending the selected reuse concepts to job-site roofing waste. The follow on studies should address appropriate sizing and siting of facilities, value and market for the reuse product, and technical development of the processing, conversion and application of the roofing waste energy resource.

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