

NEW MEXICO ENGINEERING RESEARCH INST ALBUQUERQUE
HEATING TECHNIQUES FOR ASPHALT/AGGREGATE MIXTURES. (U)
DEC 79 V CASSINO F2960

F29601-76-C-0015

MMERI-AP-33

AFESC/ESL-TR-80-02

NL

1 OF 1

20
A045 455

[illegible]

END
DATE
FILMED
7-80
DTIC

14

② LEVEL II

ESL-TR-80-02

HEATING TECHNIQUES FOR ASPHALT/ AGGREGATE MIXTURES

V. CASSINO
NEW MEXICO ENGINEERING RESEARCH INSTITUTE
UNIVERSITY OF NEW MEXICO
BOX 25, UNIVERSITY STATION
ALBUQUERQUE, NEW MEXICO 87131

DECEMBER 1979

FINAL REPORT
MARCH 1979 - NOVEMBER 1979

DTIC
ELECTE
S JUN 11 1980 D
B

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED



AFESC

ENGINEERING AND SERVICES LABORATORY
AIR FORCE ENGINEERING AND SERVICES CENTER
TYNDALL AIR FORCE BASE, FLORIDA 32403

80 6 11 034

ADA 085355

DDC FILE COPY

NOTICE

Please do not request copies of this report from
HQ AFESC/RD (Engineering and Services Laboratory).
Additional copies may be purchased from:

National Technical Information Service
5285 Port Royal Road
Springfield, Virginia 22161

Federal Government agencies and their contractors
registered with Defense Technical Information Center
should direct requests for copies of this report to:

Defense Technical Information Center
Cameron Station
Alexandria, Virginia 22314

18 M L C 2 / E S 1 11 - 9 13

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER BSL-TR-80-02	2. GOVT ACCESSION NO AC 80 30.5	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) HEATING TECHNIQUES FOR ASPHALT/AGGREGATE MIXTURES		5. TYPE OF REPORT & PERIOD COVERED Final Report March - November 1979
7. AUTHOR(s) V. Cassino		6. PERFORMING ORG. REPORT NUMBER NMRI-AP-33
9. PERFORMING ORGANIZATION NAME AND ADDRESS New Mexico Engineering Research Institute University of New Mexico, Box 25, University Sta. Albuquerque, New Mexico 87131		8. CONTRACT OR GRANT NUMBER F29601-76-C-0015
11. CONTROLLING OFFICE NAME AND ADDRESS HQ AFESC/RDCR Tyndall AFB, FL 32403		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 101
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office) HQ AFESC/RDCR Tyndall AFB, FL 32403		12. REPORT DATE December 1979
		13. NUMBER OF PAGES 34
		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION DOWNGRADING SCHEDULE
16. DISTRIBUTION STATEMENT (of this Report) Approved for public release; distribution unlimited		
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)		
18. SUPPLEMENTARY NOTES Available in DTIC		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) Asphalt Solar Asphalt Heating Rapid Heating Asphalt Mixtures Microwave		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) This report investigates conventional and recently developed equipment and methods used in the heating and mixing of asphalt/aggregate mixtures. Recommendations are made for techniques to be developed which will meet the rapid repair time that is specified. Microwave, solar, and conventional heating equipment is examined to determine the most feasible method to pursue for rapid heating and fuel conservation.		

PREFACE

This report documents work performed during the period March through November 1979 by the University of New Mexico under contract F29601-76-C-0015 with HQ AFESC/RDCR, Tyndall Air Force Base, Florida 32403. Captain Thomas Bretz managed the program.

This report has been reviewed by the Public Affairs Office (PA) and is releasable to the National Technical Information Service (NTIS). At NTIS it will be available to the general public, including foreign nations.

This technical report has been reviewed and is approved for publication.

Thomas E. Bretz Jr.
THOMAS E. BRETZ JR, Capt, USAF
Project Officer

Robert E. Boyer
ROBERT E. BOYER, Lt Col, USAF
Chief, Engineering Research Div.

George D. Ballentine
GEORGE D. BALLENTINE, Lt Col, USAF
Director, Engineering and Services
Laboratory

DTIC
ELECTE
S JUN 11 1980 D
B

ACCESSORY for	
NTIS	Write Section ☒
DDC	Buff Section ☐
UNANNOUNCED	☐
JUSTIFICATION	
BY	
DISTRIBUTION/AVAILABILITY CODES	
Dist.	AVAIL. and/or SPECIAL
A	

TABLE OF CONTENTS

Section	Title	Page
I	INTRODUCTION	1
	Background	1
	Objective	1
II	DEFINITIONS	3
	Asphalt	3
	Asphalt Cement	3
	Aggregates	4
	Plant-Mix Hot-Laid Bituminous Surfaces	4
III	CONVENTIONAL EQUIPMENT IN USE	7
	Asphalt Heaters	7
	Asphalt Plants	8
IV	LITERATURE SEARCH	9
	Microwave-Powered Units	9
	Solar Systems	10
	Conventional Systems	12
V	FEASIBILITY STUDY	15
	Energy Source Requirements	15
	Capacity I	15
	Capacity II	16
	Total Costs	18
	Life-Cycle Costs	19
VI	TECHNIQUE RECOMMENDATIONS	21
	Capacity I	21
	AC	21
	AC/Agg Mixture	21
	Capacity II	24
VII	CONCLUSIONS	29
	Discussion	29
	Recommendations	31
	Summary	32
	REFERENCES	33

LIST OF FIGURES

Figure	Title	Page
1	Solar-Microwave Asphalt Storage Tank	22
2	Asphalt-Mobile®	23
3	Microwave Pavement Heater	25
4	Heating of Paving by Microwaves and Hot Gas	26
5	Solar-Heat Pipe Concept	30

LIST OF TABLES

Table	Title	Page
1	Energy Source Requirements	17
2	Total Costs (Excluding Labor)	18
3	Life-Cycle Costs	19
4	Times Required by Conventional Equipment	20
5	Proposed Cost of Equipment	27

SECTION I INTRODUCTION

BACKGROUND

The investigation of the rapid heating of asphalt and asphalt mixtures is a continuing effort to research materials and techniques to improve the Air Force rapid runway repair capabilities.

The limitations of asphalt paving are mainly time constraints. Asphalt and its constituent materials must be heated to provide a quality paving material, and the time needed for heating can be of long duration. If the time necessary to bring the materials to mixing temperature could be shortened, then asphalt mixtures could possibly meet the time criteria specified by the Air Force.

This present work reports an investigation of possible methods for the rapid heating of asphalt mixtures. This investigation was conducted by the Engineering Research Institute of the University of New Mexico (NMERI).

OBJECTIVE

The objective of this study was to evaluate all techniques, methods, and materials for rapid heating against the criteria established by the Air Force for rapid runway repair.

As a guide for analysis of the methods, two capacities were established as goals. The first was equipment capable of heating a minimum of six 55-gallon drums of hard asphalt and six drums of asphalt/aggregate mix to 330°F (165°C) in 30 minutes or less. The second capacity was equipment and methods for heating and mixing 12 cubic yards of asphalt/aggregate mixture to 330°F (165°C) in 30 minutes or less.

SECTION II
DEFINITIONS
(Reference 1)

ASPHALT

Asphalt is a dark brown cementitious material, solid, semisolid, or liquid in consistency. Its predominating constituents are bitumens that occur in nature as such or are obtained as residue in refining petroleum.

ASPHALT CEMENT

Asphalt cement (AC), the basic material of the asphalt family, is refined from crude oil; at temperatures below 100°F (38°C), it is solid or semisolid. To be useful in paving or maintenance operations, it must be fluid enough to coat the aggregate. This can be accomplished in three different ways: (a) by heating in a storage tank and asphalt kettle or pressure distributor, (b) by dissolving in a petroleum solvent (liquid asphalts), and (c) by combining with water and an emulsifying agent (emulsion).

Asphalt cements have been classified in a number of grades using either a penetration test or the viscosity test. The paving grades of asphalt cements range from a rock-hard (may be powdered) material to a soft flux. The penetration grade asphalts (fine grades ranging from 0 to 300) are classified by a standard penetration test. Penetration is determined by measuring the distance that a standard needle penetrates the surface of an asphalt sample under given conditions of time, temperature, and load. Recently, asphalts have been classified by determining the viscosity of the original asphalt and the viscosity of the asphalt after it has been aged in a thin-film oven test. Determining viscosity of the "aged residue" has

Reference

1. *Maintenance and Repair of Surface Areas*, AFR-25-8, Directorate of Civil Engineering, Department of the Air Force, Washington, D.C., March 1977, The definitions in this section are taken from this reference.

resulted in grade classifications ranging from AR 10 to AR 160. The AR classification has been adopted for use in the western area of the United States. The tabulation below roughly compares the two classifications:

Penetration Grades	Viscosity Grades	
	AC (Original Asphalt)	AR (Aged Residue)
200-300	2.5	10
120-150	5	20
85-100	10	40
60-70	20	80
40-50	40	160

Standard specifications for viscosity-graded asphalt cements are contained in American Association of State Highway and Transportation Officials (AASHTO) Designation M226-73.

AGGREGATES

Aggregates (Agg) must carry the load of traffic and provide the necessary resistance to wear. Aggregates include materials that may or may not require any preparation other than screening, such as sand, gravel, and rock, as well as materials that require both crushing and screening, such as limestone and granite. In no case may the aggregate particles be coated with films that prevent the bitumen from coating and sticking. The load-bearing capacity of the pavement is dependent on the interlocking of the aggregate surfaces and the cementing action of the bitumen.

PLANT-MIX HOT-LAID BITUMINOUS SURFACES

Hot-mix bituminous concrete is composed of well-graded mineral aggregates, mineral filler, and bituminous material (AC or tar, depending on the

desired mixture). The hot-mix method of preparing bituminous paving mixtures provides a uniform film coating of the aggregates and allows accurate control of the aggregate sizes; hence this process is considered the best method. Also, this type of surface may receive traffic as soon as the material has reached air temperature. Well-proportioned and well-compacted hot-mix surfaces have a high stability and high resistance to the abrasive action of traffic. When obtainable in small quantities, hot-mix material is ideal for patching and pothole repair.

SECTION III
CONVENTIONAL EQUIPMENT IN USE
(Reference 2)

ASPHALT HEATERS

Asphalt heating equipment is of the following principal types:

1. Tank heaters. These heat the asphalt by circulating steam or hot oil through coils in the tank.
2. Combination tank heater and booster. The tank may heat the asphalt to pumping viscosity only; then the amount of asphalt required for immediate use may be heated to the desired viscosity by the booster. This effects savings in heating costs and raises the asphalt to the higher use temperatures in the minimum possible time.
3. Asphalt kettles. These are used for maintenance and repair. Asphalt kettles range in size from 75 to 225 gallons. They are heated indirectly with a heat transfer fluid and require several hours to bring the mixture to pouring temperature. Fuel oil, gas, and electricity are all used in various types of asphalt heating equipment.

Asphalt is usually shipped in insulated tank cars equipped with coils for heating. Insulated cars may be used so that, if loaded with hot asphalt at the refinery, unloading may be accomplished with little or no heating. Transport trucks with tanks are another common means of transportation; they use the same methods of heating as the tank cars. Some of the large storage tanks have a capacity of more than 10,000 gallons.

Asphalt is also transported in bulk in barges and ships. Steel drums of 50- to 55-gallon capacity are also used when small quantities are desired.

Reference

2. *The Asphalt Handbook*, The Asphalt Institute, College Park, Maryland, 1963.
All material in this section is taken from this source.

ASPHALT PLANTS

Asphalt batch plants for plant-mix hot-laid asphalt pavements range in size from small patching units to large drum mixers with an output of 705 tons per hour. These plants consist of a storage tank, aggregate bins, dryers, weigh hoppers, dust collectors, and mixers.

SECTION IV

LITERATURE SEARCH

A study was made to locate all methods available to assure the necessary heat for heating and mixing asphalt. Among the heating techniques investigated were the microwave process, infrared, solar energy, conventional fuel oil, gas, and electrical systems.

MICROWAVE-POWERED UNITS

In an attempt to provide rapid maintenance of asphalt pavements, Bossio, Spooner, and Granger (Reference 3) used a mobile 2.5-kW microwave power source to heat the pavement. The heat was applied on the pavement to seal cracks and prevent water infiltration which causes road heave during freeze/thaw cycles. Pavement cannot be preheated by existing heat-applying techniques (flames, hot rollers) because heat penetration is limited by the low thermal conduction of bituminous mixtures. With the use of microwave power at 2450 kHz, bituminous mixtures were found to readily absorb microwave power to a depth of 5 inches without overheating the surface layer of the asphalt pavement. The material was heated on both sides of the road cracks to the maximum permissible surface temperature of 302°F (150°C). The underlying material could be loosened and remixed in situ to a depth of 4 to 5 inches. Compaction followed the remixing.

The speed of the road crack repair was 4 feet per hour with a 2.5-kW microwave power supply. Increasing the speed of the road repair would require much higher output from a mobile microwave power unit.

In another research effort, Boyko, et al., (Reference 4) of the Syracuse University Research Corporation (SURC) designed, fabricated, and tested a

References

3. Bossio, R. G., Spooner, J., Granger, J., "Asphalt Road Maintenance with a Mobile Microwave Power Unit," *Journal of Microwave Power*, 9(4), 1974.
4. Boyko, L. L., Lederer, E. H., Sawyer, R. G., *Microwave Heating for Road Maintenance*, SURC-TR-76-052, Syracuse University Research Corporation, Syracuse, New York, 1976.

high-power microwave generator for curing monomers in rapid repairing of bridge decks and highway pavements. Alternative uses of the equipment included the use of microwave power to patch existing asphalt. Experimental testing was not sufficient to give any data for analysis of the use of microwave power in asphalt road maintenance. However, a recommendation is made for pursuing research in this use of microwaves since it is believed that it has considerable merit, especially in cold weather. Asphalt is similar to synthetic polymers in its microwave absorption characteristics. The microwave power unit used by SURC consisted of 20-kW microwave power operating at 2450 kHz. The power supply was a 50-kW generator.

Jeppson¹ gives details of a much higher microwave power system with a 600-kW microwave power unit. This equipment is being developed by the Microdry Corporation of San Ramon, California, and a demonstration of the unit will be given when it is completed. Scrimsher² details the results of a prototype unit constructed by the Microdry Corporation and demonstrated to the California Department of Transportation. This unit, operating at 915 MHz had 50-kW power output ducted to a 3.5- by 4-foot enclosed chamber. In the study, salvaged asphalt concrete and various emulsion mixtures were heated, and measurements of the heat rise were taken. Results from these studies indicate that considerably greater power would be required for rapid road repair.

SOLAR SYSTEMS

The U.S. Department of Transportation has, through its Demonstration Project No. 52, promoted the use of solar energy. The promotion is intended

Footnotes

¹A status report on the application of microwave energy in the maintenance and rehabilitation of highways for Microdry pavement heating systems, from M. R. Jeppson of Microdry Corporation to G. D. Love, U. S. Department of Transportation.

²Memorandum on microwave pavement heater, by T. Scrimsher of California Department of Transportation, Sacramento, California, November 20, 1978.

to help address the national energy problem by providing alternative ways of combating the rising cost of conventional energy sources, the depletion of fossil fuels, and the diminishing funds for highway construction and maintenance. Various states have responded with solar energy research in a variety of projects including the heating of asphalt and emulsions by solar energy systems. Among the states responding are Arizona, Oklahoma, Texas, and Virginia.

Parker, Wiebelt, and Henderson (Reference 5) designed a solar-heater asphalt storage system for the Oklahoma Department of Transportation which consisted of a 10,000-gallon storage tank, 6 solar panels, and associated pumps, piping, auxiliary heat, and controls. Emulsions need to be stored at temperatures between 65 and 140°F (18 and 60°C). Results indicate that by using single-glazed collectors the maximum temperature of operation was never exceeded. This system uses ethylene glycol as a heat exchange fluid. This effort resulted in a Federal Highway Technology Sharing Report (Reference 6).

The Virginia Department of Transportation used electric heaters to maintain asphalt at 140°F (60°C). The asphalt was pumped through the solar-heated copper tubes when the collector's temperatures rose 10°F (6°C) above the temperature of the tank. When the collector and tank temperatures were equal, the solar unit automatically shut down.

Hoffman and Hauskins (Reference 7) developed a solar-powered heat system for the Arizona Department of Transportation. This system was for heating emulsion for road maintenance. The system consisted of eight solar

References

5. Parker, J. D., Wiebelt, J. A., Henderson, J. B., *The Use of Solar Energy in the Heating of Asphalt in Storage Tanks*, Oklahoma State University, Stillwater, Oklahoma, June 1978.
6. Parker, J. D., Wiebelt, J. A., Henderson, J. B., *A Solar-Heated Asphalt Storage Tank*, Technology Sharing Report FHWA-TS-78-207, Office of Research and Development, U. S. Department of Transportation, Washington, D.C., 1978.
7. Hoffman, G., Hauskins, J., Jr., "Solar Energy Provides Heat for Asphalt Emulsion Tank," *Arizona Professional Engineer*, Volume 30, No. 5, November 1978.

collectors with a light oil as a heat exchanging fluid. The tank had a 8300-gallon capacity, and the temperature limits were set at 75°F (23°C) minimum and 160°F (71°C) maximum. The only energy other than solar employed for the first year of operation was electricity for the circulation pump. The backup heater was never turned on.

Hauskins and Ong³ have prepared, as a Federal Highway Demonstration Project 52, a solar power asphalt storage system to be constructed at Gray Mountain, Arizona. The 8000-gallon tank has 16 parallel-flow flat-plate collectors with a heat transfer fluid of low-oxidation-potential oil. The design is intended to be capable of maintaining asphalt at a storage temperature of 150°F (66°C) and also to be able to raise the temperature (with proper notice) to provide hot cutback asphalt at a temperature of 225°F (107°C) for direct use in roadway maintenance operations.

CONVENTIONAL SYSTEMS

The conventional systems that use gas, electricity, or hot oil to heat the asphalt and the aggregates are generally too slow for consideration for rapid heating techniques (Reference 8). The usual time for large storage tanks is 24 hours to bring the asphalt to the mix temperature of 330°F (165°C). The conductive heat must be slow to prevent oxidation of the asphalt; oxidation is detrimental to the adhesive properties needed for paving mixes.

There is drum melting equipment on the market which can handle from 4 to 20 drums depending on the size of the heating tunnel. The rate of melting is 1 hour. Additional time is needed to bring the temperature to 330°F (165°C). Among the electrical heaters that could be considered for drum

Reference

8. Abraham, H., *Manufactured Products*, Volume 3 of *Asphalt & Allied Substances*, 6th Edition, Van Nostrand Press, Princeton, New Jersey, 1960-1963.

Footnote

³"Gray Mountain Solar Project," by J. Hauskins, and B. Ong. A proposal submitted to the U. S. Department of Transportation, Federal Highway Administration, Region Nine, Arizona Division.

heaters are band, strip, immersion, and circulation heaters. All would either be slow or cause oxidation if placed in direct contact with the asphalt.

The asphalt storage tanks which are an integral part of asphalt plants usually have a rate of heat rise varying from 10 to 15°F per hour depending on whether hot oil or electric heat elements are used.

A technique where the asphalt is maintained at 250°F (121°C) and can be rapidly brought to 330°F (165°C) meets the criteria for rapid runway repair. Connell (Reference 9) describes one of the newer mobile batch plants which could be adapted to rapid runway repair. The asphalt tank of 350 gallons can be heated to mixing temperature. The asphalt can be kept at a reduced temperature for storage and returned to mix temperature for paving purposes.

Chi (Reference 10) has described another conventional technique, the heat pipe, which can be used with numerous heat sources. The heat pipe is effective as a high-performance heat transmission device. Among the many outstanding advantages of using the heat pipe are the following: constructional simplicity, exceptional flexibility, accessibility to control, and ability to transport heat at a high rate over considerable distances with an extremely small temperature drop. Moreover, heat pipes require no external pumping power.

Feldman⁴ has used the heat pipe technique with solar collectors to demonstrate its effectiveness as a water heater. This method could also be used as primary source of heat for asphalt cement.

References

9. Connell, C. A., "Maritime Province Solves Winter Patching Problem," *Public Works Magazine*, Volume 110, No. 8, Stroudsburg, Pennsylvania, August 1979.
10. Chi, S. W., *Heat Pipe Theory and Practice*, Hemisphere Publishing Co., Washington, D.C., 1976.

Footnote

⁴"Description of a Cost-Effective Heat Pipe Solar Water Heater," paper by K. T. Feldman, Mechanical Engineering Department, University of New Mexico, Albuquerque, New Mexico, August 1978.

SECTION V
FEASIBILITY STUDY

ENERGY SOURCE REQUIREMENTS

For the feasibility study, it was assumed that the asphalt cement was Penetration Grade 85-100, Viscosity Grade AC-10, AR-40. This grade of asphalt is typical of that used in airfield pavements. The aggregate used in the asphalt mix was assumed to meet the specifications as defined in AFM 88-6 (Reference 11).

The quantities that are needed to be heated were treated as the desired factors in the study. The desired quantities in Capacity I were 350 gallons of AC and 4400 pounds of AC/Agg mixture. For Capacity II, 36,000 pounds of AC/Agg was the desired amount.

Capacity I

Converting the six 55-gallon drums of asphalt cement at a specific gravity of 1.04 gives the weight of 2860 pounds. The amount of energy necessary to raise the AC from 40 to 330°F (4 to 165°C) is 414,700 Btu. This amount was determined using the equation $Q = Mc_p \Delta T$

where Q = Energy in Btu
 M = Mass in pounds
 c_p = Specific heat
 c_p asphalt = 0.5 Btu/lb °F
 ΔT = Change in temperature Fahrenheit

$$Q = 2860 \left(\frac{0.5 \text{ Btu}}{1 \text{ lb } ^\circ\text{F}} \right) 290 = 414,700 \text{ Btu}$$

Reference

11. AFM 88-6, Chapter 9, "Bituminous Pavements, Standard Practice," Department of the Air Force, Washington, D.C., June 1979.

For the other requirement of six 55-gallon drums of AC/Agg mix, a 6-percent AC content and a dry, loose aggregate mix blend was assumed. A theoretical unit weight of 110 lb/ft³ of loose AC/Agg mix gives the weight of 4840 pounds.

$$\begin{aligned}
 \text{AC} & (0.06)(4840) = 290 \text{ lb} \\
 \text{Aggregate} & (0.94)(4840) = 4550 \text{ lb} \\
 Q_{\text{AC}} & = \frac{290 (0.5 \text{ Btu})}{(1 \text{ lb } ^\circ\text{F})} (290) = 42,050 \text{ Btu} \\
 Q_{\text{Agg}} & = \frac{4550 (0.2 \text{ Btu})}{(1 \text{ lb } ^\circ\text{F})} (290) = 263,900 \text{ Btu}
 \end{aligned}$$

where the c_p of rock = 0.2 Btu/lb $^\circ\text{F}$

A total of 305,950 BTUs are necessary to heat the AC/Agg mix to 330°F (165°C).

Capacity II

For the 36,000 pounds of AC/Agg mix at 6-percent AC content, the Btu of energy necessary to raise the temperature from 40 to 330°F (4 to 165°C) were found as follows:

$$\begin{aligned}
 \text{AC} & (0.06)(36000) = 2,160 \text{ lb} \\
 \text{Aggregate} & (0.94)(36000) = 33,840 \text{ lb} \\
 Q_{\text{AC}} & = \frac{2160 (0.5 \text{ Btu})}{(1 \text{ lb } ^\circ\text{F})} 290 = 313,200 \text{ Btu} \\
 Q_{\text{Agg}} & = \frac{33840 (0.2 \text{ Btu})}{(1 \text{ lb } ^\circ\text{F})} 290 = 1,962,720 \text{ Btu}
 \end{aligned}$$

Total energy required is 2,275,920 Btu.

Converting the Btu and allowing for the specified time period of 30 minutes gives the energy requirements in watts.

$$1 \text{ Btu} = 1.0551 \times 10^3 \text{ Joules}$$

$$1 \text{ watt} = 1 \text{ Joule/second}$$

Capacity I

$$\text{AC} = \frac{(414,700)(1.0551 \times 10^3)}{(60)(30)} = 243,083 \text{ watts}$$

$$\text{AC/Agg} = \frac{(305,950)(1.0551 \times 10^3)}{(60)(30)} = 179,338 \text{ watts}$$

Capacity II

$$\text{AC/Agg} = \frac{(2,276,920)(1.0551 \times 10^3)}{(60)(30)} = 1,334,655 \text{ watts}$$

Table 1 summarizes the energy requirements.

TABLE 1. ENERGY SOURCE REQUIREMENTS

	Btu	Watts
<u>Capacity I</u>		
Six 55-gal drums of AC	414,700	243,083
Six 55-gal drums of AC/Agg	305,950	179,338
<u>Capacity II</u>		
12 yd ³ AC/Agg	2,276,920	1,334,655

TOTAL COSTS

The total costs for materials, energy, and equipment (neglecting labor costs) are summarized in Table 2. Costs are as of December 1979; they can be inflated by 15 percent per annum at current inflation rates. Equipment costs are taken from the Green Guide (Reference 12) and from the manufacturers current costs of construction equipment.

The total costs are presented in Table 2.

TABLE 2. TOTAL COSTS (EXCLUDING LABOR)^a
(as of December 1979)

Category	Equipment	Energy	Materials		Total Costs (excluding labor)
		No. 2 Fuel Oil	AC	Aggregate	
Cost Per Unit		9.74 per million Btu	0.90/gal	8.50/yd ³	
Capacity I					
Six 55-gal Drums A/C	6-drum Melter 10,000.00	4.00	297.00		10,301.00
	400-gal Asphalt Kettle 5000.00	4.00	297.00		5,301.00
4400 lb AC/Agg	4000-lb Batch plant 300,000.00	13.00	29.00	17.00	300,059.00
Capacity II					
36000 lb AC/Agg	Continuous Drum Mixer 50 TPH 500,000.00	22.00	231.00	128.00	500,381.00

^aAll costs in dollars.

Reference

12. *Green Guide*, Volume 1, Equipment Guide Book Co., Palo Alto, California.

LIFE-CYCLE COSTS

Life-cycle cost (LCC) is defined by the following equation:

$$LCC = AC + FC + OMC$$

where AC = Acquisition cost
 FC = Total fuel cost over system lifetime
 OMC = Operation and maintenance cost over
 system lifetime.

Over a 10-year period, the average cost of replenishing the energy source will be 15 percent per annum. The costs of materials and replacement of asphalt will be inflated by 15 percent per year. The aggregate will not have to be replaced. The operation and maintenance costs of the equipment are included in the 15-percent replacement costs. The life-cycle costs for conventional equipment are given in Table 3.

TABLE 3. LIFE-CYCLE COSTS^a (EXCLUDING LABOR)
 (as of December 1979)

Category	Equipment AC and OMC	Energy, No. 2 Fuel Oil	Materials		Life-Cycle Costs over a 10-year Period
			AC	Agg	
Capacity I					
330 gal AC	6,175.00	101.00	9,096.00		15,372.00
4400 lb AC/Agg	55,000.00	745.00	910.00	17.00	56,672.00
Capacity II					
36000 lb AC/Agg	96,000.00	5,545.00	4,048.00	127.50	105,720.00

^aCosts in dollars.

None of the equipment listed in the feasibility study can meet the time requirements for the rapid heating of asphalt mixtures. To meet these requirements all of the equipment would have to be modified or developed. The times required by the conventional equipment are listed in Table 4.

TABLE 4. TIMES REQUIRED BY CONVENTIONAL EQUIPMENT

Equipment	Capacity	Energy Source	Time Required, hours
Six 55-gal Drum Heater	330 gal AC	Fuel Oil	2
400-gal Asphalt Kettle	400 gal AC	Fuel Oil	1
Portable Batch Plant	4000 lb AC/Agg mix per batch	Fuel Oil	24
Semi-Portable Batch Plant	50 TPH of AC/Agg Mix	Fuel Oil	24

SECTION VI

TECHNIQUE RECOMMENDATIONS

CAPACITY I

Asphalt cement, in order to keep its cementing properties, must not be overheated or allowed to burn. With the rapidly accelerating use of solar energy many applications are being developed to use this cheap source of energy.

AC

Figure 1 presents a technique which would allow asphalt to be maintained at 250°F (121°C) which is its pumpable viscosity. The solar energy could be collected and transferred with either a heat pipe or a fluid as the transfer agent. The additional 80°F (27°C) necessary for the required temperature could be obtained by using a microwave heater on a 6-inch PVC pipe used for discharge of the asphalt.

Asphalt cannot be heated by microwave heaters in 55-gallon drums because of its mass and packaging. Microwaves are effective to a depth or thickness of about 4 inches. Also, containers made of materials other than metal would have to be used since microwaves do not penetrate metal. It is possible that a hollow-core container could be developed in which a probe emitting microwave power could be used to melt the asphalt. This type of heating would require different packaging of the asphalt and development of special microwave heating equipment.

AC/Agg Mix

The 4400 pounds of AC/Agg mix would require, at 6-percent AC content, 32 gallons of AC and 4135 pounds of Agg. The asphalt mobile as presented in Figure 2 (from Reference 13) would fulfill the requirement for heating stored dry aggregate in the required time. The asphalt cement would be kept in the solar microwave storage tank, raised to 330°F (165°C) with the microwave heater, and maintained with the electric heater on the mobile.

Reference

13. *Asphalt Mobile*, brochure from Daffin Mobile Products Division of Barber-Greene Co., Lancaster, Pennsylvania.

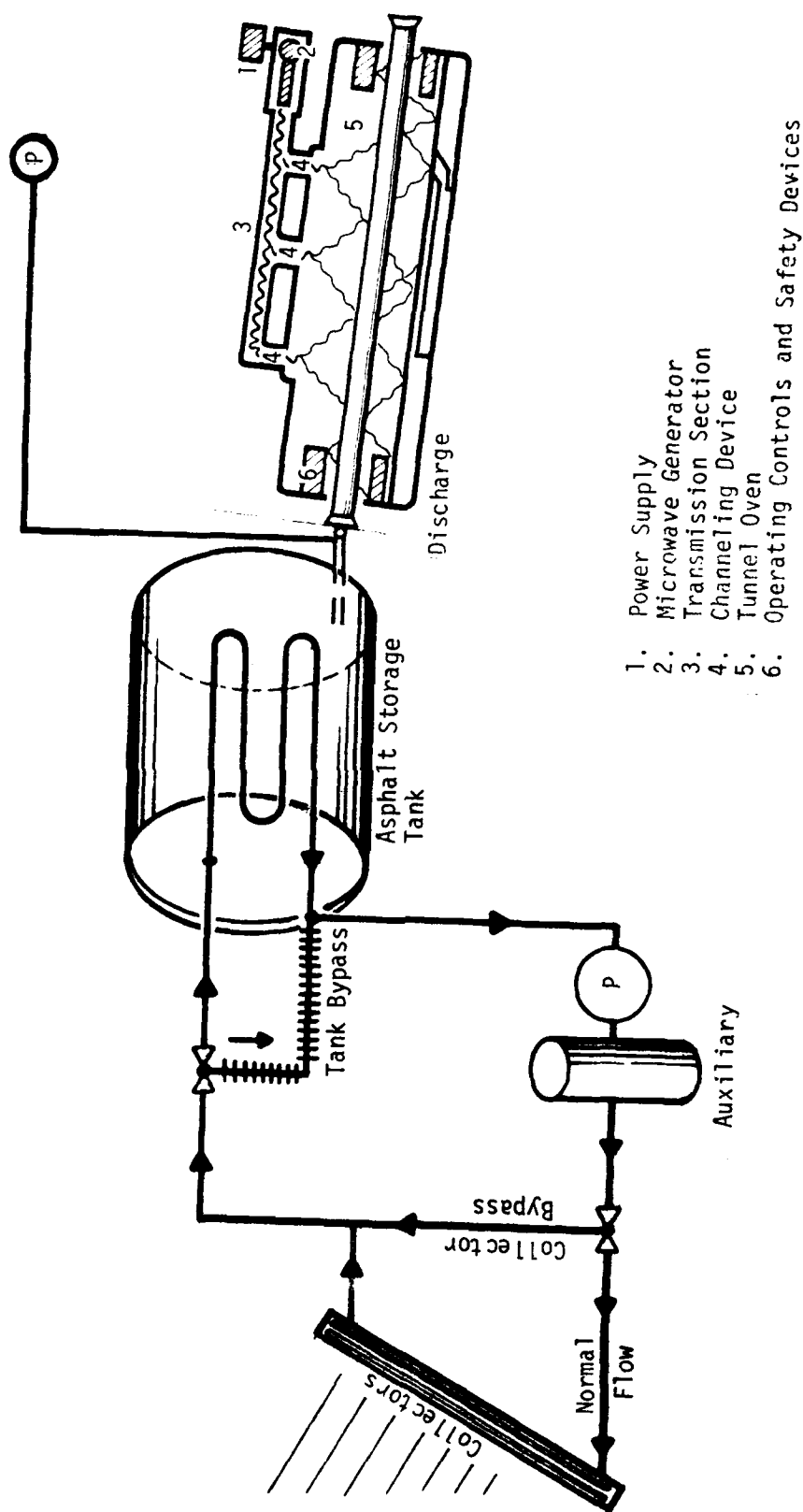


Figure 1. Flow Schematic of Solar-Heated and Microwave-Heated Asphalt Storage System

- | | |
|--------------------|------------------|
| A. Engine | E. Hot Bin |
| B. Generator | F. Bag House |
| C. Bucket Elevator | G. Asphalt Tank |
| D. Heater-Dryer | H. Aggregate Bin |

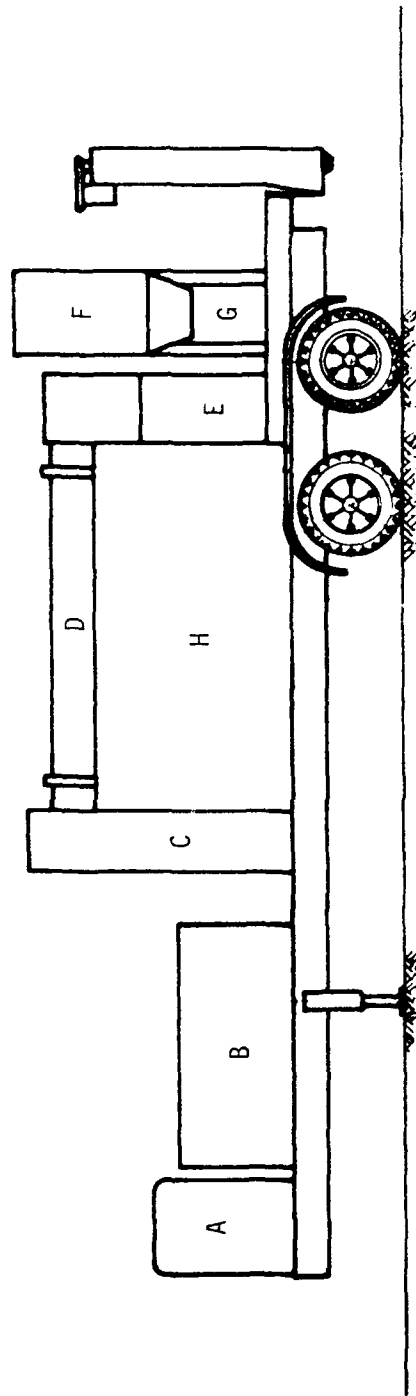


Figure 2. Asphalt-Mobile® (After Reference 13)

CAPACITY II

The method selected here is dependent on the development of equipment which is capable of rapid heating of large quantities without destroying the paving qualities of a hot-mix.

The 600-kW trailer-mounted microwave heater pictured in Figure 3⁵ would meet these requirements if it can be developed. The system would consist of stockpiling a plant-mix hot-laid asphalt in a 4-inch-thick lift 10 feet wide and 90 feet long. This stockpiling would be done on an abandoned apron, taxiway, or any paved area not in use. With the pavement heater moving only at a rate of 3 feet per minute 36,000 pounds of asphalt mixture could be heated to 330°F (165°C). Microwave heating is desirable because of its ability to heat from within. Conventional heating causes the molecules to react from the surface. Figure 4⁶ indicates what the microwave pavement heater may accomplish for the heating of pavements. The heating versus depth at 4 minutes at 20-kW/ft⁶ intensity indicates that much more energy input is necessary.

With the heated mixture at 330°F (165°C), loaders could pick up the material and deposit it into trucks for transporting to the repair area.

In the event that the stockpiled area is destroyed any asphalt pavement will suffice; the younger the pavement, the more likely a desirable remix will occur. This method gives the option of more sources of paving material.

Providing accurate costs for developing this equipment is difficult, but Table 5 gives a summary of a proposed cost schedule based on current knowledge.

Footnotes

⁵This figure is taken from a memorandum on microwave pavement heater, by T. Scrimsher of California Department of Transportation, Sacramento, California, November 20, 1978.

⁶This figure is taken from a status report on the application of microwave energy in the maintenance and rehabilitation of highways for Microdry pavement heating systems from M. R. Jeppson of Microdry Corporation, to G. D. Love, U. S. Department of Transportation.

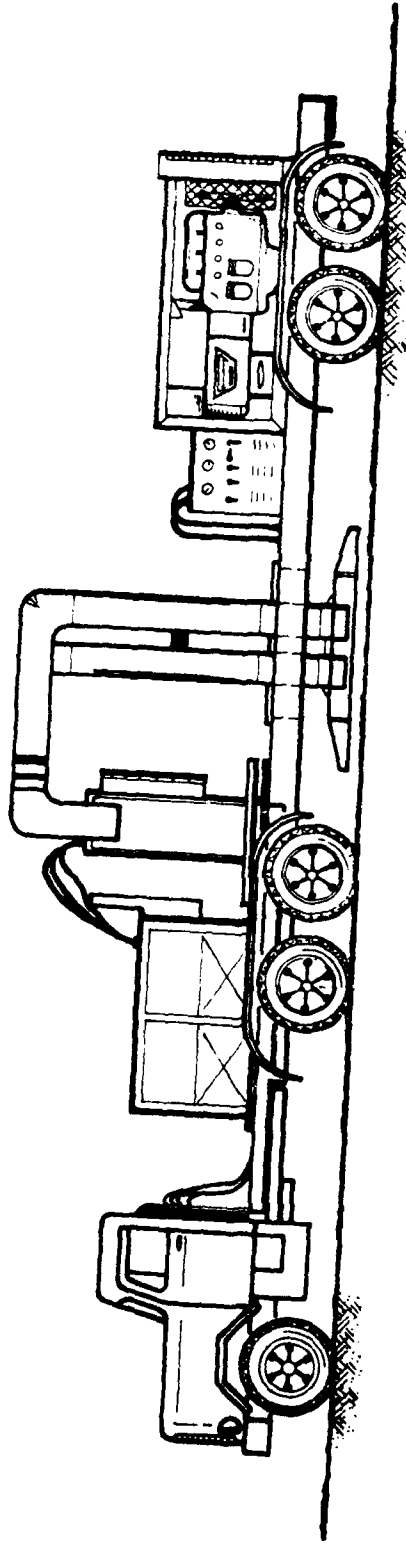


Figure 3. Microwave Pavement Heater
(From Scrimsher, T., Memorandum to
California Department of Transportation)

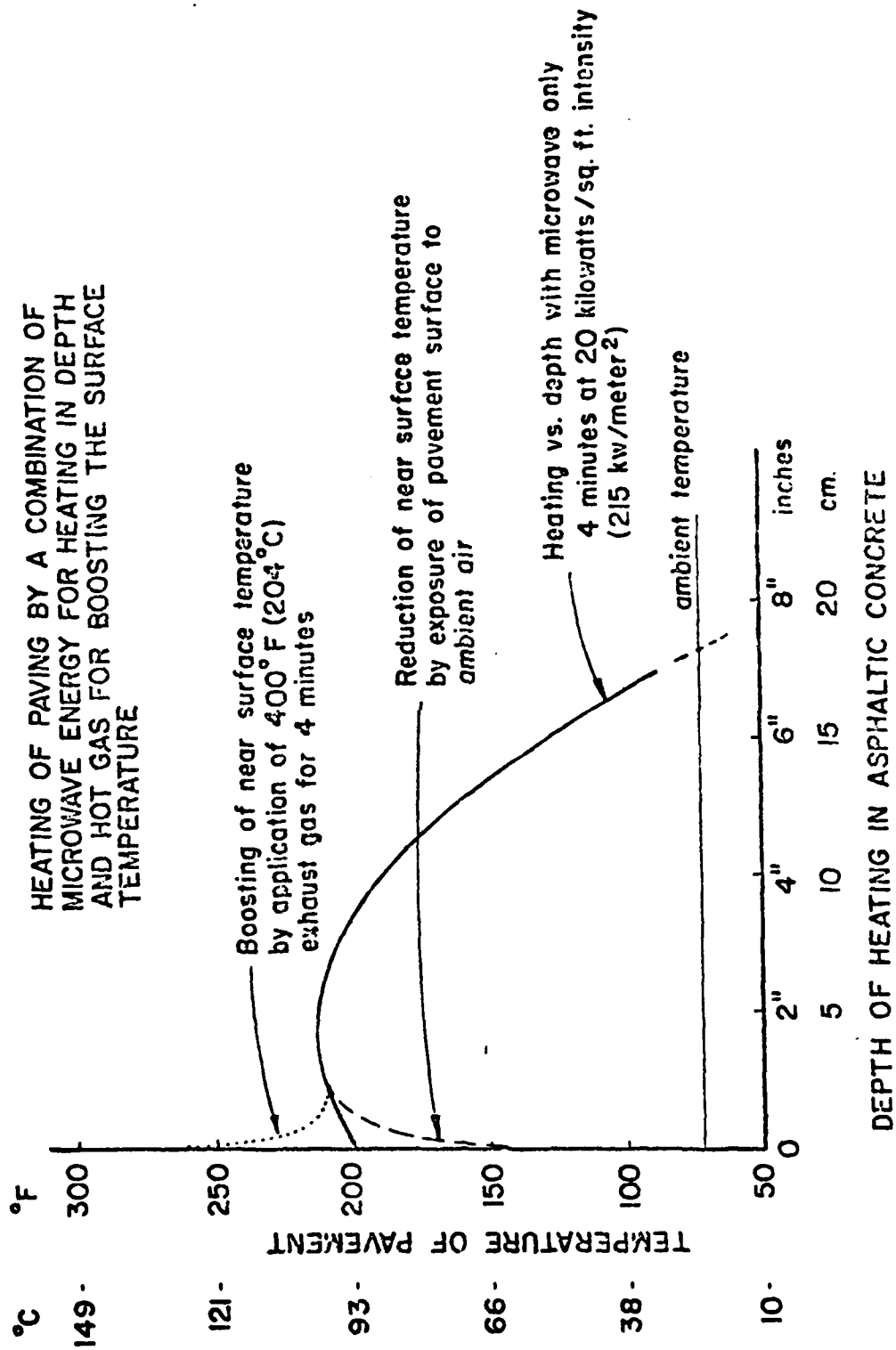


Figure 4. Heating of Paving by Microwaves and Hot Gas
(From Jeppson, M. R., A Status Report to the
U. S. Department of Transportation)

TABLE 5. PROPOSED COST OF EQUIPMENT

	Equipment	Capacity Desired	Temperature, °F	Acquisition Cost, dollars
Capacity I				
330 gal AC	Solar	532,800 Btu/day	250	30,000
	Microwave	200 kW	330	100,000
4400 lb AC/Agg	Mobile Batch Plant	6 tons/h	330	130,000
Capacity II				
36000 lb AC/Agg	Microwave Pave- ment Heater	6 ft/h	330	700,000

SECTION VII

CONCLUSIONS

CAPACITY I

Hard asphalt in six 55-gallon drums at ambient temperature cannot be made sprayable in 30 minutes or less. A different shape of container for the AC mass and nonmetallic drums would be necessary. For the six 55-gallon drums of AC/Agg mixture, no available method is capable of accomplishing the temperature and time objectives. The asphalt mobile would require the asphalt to be close to 330°F (165°C) and dry aggregate in the bins to produce six 55-gallon drums of this mixture within the proposed time limit.

CAPACITY II

There is no method for raising the required 12 cubic yards of AC/Agg mix from ambient temperature to 330°F (165°C) in 30 minutes or less. The material would have to be premixed and stored, and equipment developed to heat the mixture in 30 minutes.

DISCUSSION

Foster (Reference 14) has stated that mixes produced in both drum mixers and conventional plants show that mixing temperatures can be reduced much more than originally thought, and mixes produced in the range of 225°F (107°C) are now being placed and compacted. The Federal Highway Administration eliminated the requirement of a minimum mixing temperature in 1974 but specifies at least 225°F (107°C) at laydown. A 25-percent reduction in mixing temperature will reduce fuel consumption by almost 5 percent.

The Arizona Department of Transportation is developing a solar-heated asphalt tank which will heat and store cutback asphalt at 150°F (65°C) and, when, needed, heat it to 225°F (107°C). With more efficient solar collectors, the asphalt temperature could be raised to 250°F (121°C). If the laydown temperature of 225°F (107°C) minimum were used, the microwave booster heater would not be necessary.

An adjustable solar collector with a heat pipe as shown in Figure 5 would also raise the asphalt to 250°F (121°C). Both of these solar systems would

Reference

14. Foster, C. R., "Reducing the Use of Petroleum Fuels," *Paving Forum*, National Asphalt Pavement Association, Riverdale, Maryland, Fall 1979.

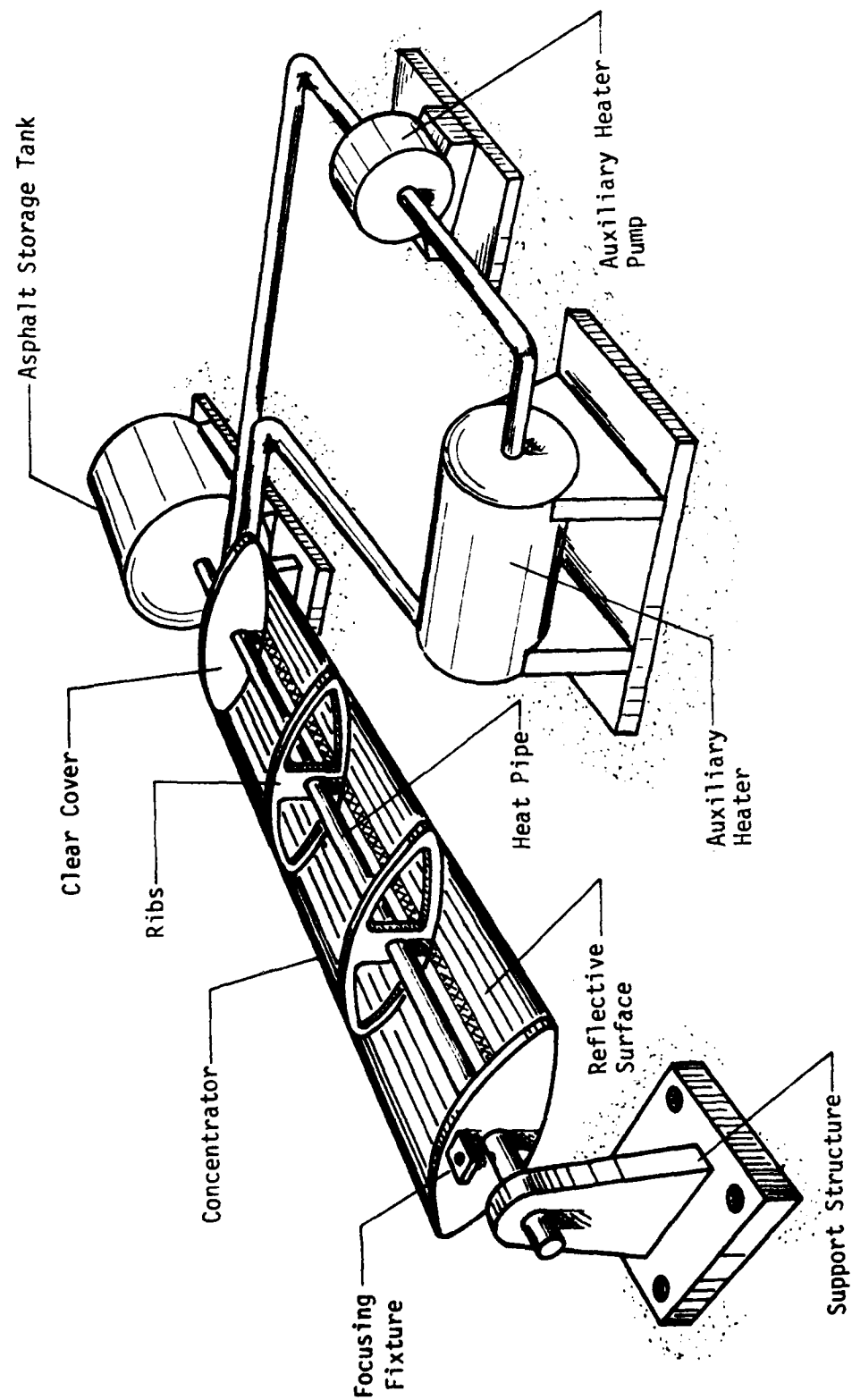


Figure 5. Solar-Heat Pipe Concept

require backup auxiliary heaters to maintain the temperature. Another consideration is that solar radiation varies daily and regionally. This variability makes the booster heater necessary for almost all areas.

The mobile batch plant is already on the market and can easily produce the six 55-gallon drums of AC/Agg mixture for Capacity I.

The microwave pavement heater is an expensive item but is the only one which shows promise not only in meeting the time requirements but also in preserving the material. If the laydown temperature of 225°F (107°C) were observed, considerable savings could be made in the size of the generator and the costs of manufacturing the large piece of equipment. The advantages of microwave heating include its instant startup and shutdown. Its disadvantages are the expensive equipment and maintenance and operation costs.

At the present time it would be desirable to present a feasibility study of these three techniques, but there are no data available since all three systems are under development. No accurate data for energy requirements or operation costs are available.

RECOMMENDATIONS

1. Because the technology of heat conservation is in a state of rapid development, all heating systems should be closely monitored.
2. The promise of solar heating as the best source, not for rapid but for stored heat, is readily applicable to heating asphalt.
3. A microwave pavement heater could be developed. If the temperature for placement of asphalt paving can be lowered, a microwave heater will become more cost-effective.
4. It is felt that a research project using solar and microwave energy for the rapid heating of asphalt mixtures should be developed. The mobile batch plant has recently been placed on the market, and performance and operational data should be collected.

SUMMARY

NMERI is of the opinion that considerable savings in energy and cost can be effected by using solar energy to maintain stored heat in asphalt.

For the AC/Agg mixture required laydown temperatures of 225°F (107°C) would reduce the time of heating and conserve energy.

Research of solar asphalt heating systems which could be used in conjunction with conventional heating in buildings should be carried on. These would be dual-purpose systems used to heat both asphalt and maintenance or storage buildings.

No methods are presently available for heating asphalt and asphalt mixtures in the two capacities from ambient temperature to 330°F (165°C) in 30 minutes or less.

REFERENCES

1. *Maintenance and Repair of Surface Areas*, AFR-85-8, Directorate of Civil Engineering, Department of the Air Force, Washington, D.C., March 1977.
2. *The Asphalt Handbook*, The Asphalt Institute, College Park, Maryland, July 1962 Edition, 1963.
3. Bossio, R. G., Spooner, J., and Granger, J., "Asphalt Road Maintenance with a Mobile Microwave Power Unit," *Journal of Microwave Power*, 9(4), 1974.
4. Boyko, L. L., Lederer, E. H., Sawyer, R. G., *Microwave Heating for Road Maintenance*, SURC-TR-76-052, Syracuse University Research Corporation, Syracuse, New York, 1976.
5. Parker, J. D., Wiebelt, J. A., Henderson, J. B., *The Use of Solar Energy in the Heating of Asphalt in Storage Tanks*, Oklahoma State University, Stillwater, Oklahoma, June 1978.
6. Parker, J. D., Wiebelt, J. A., Henderson, J. B., *A Solar-Heated Asphalt Storage Tank*, Technology Sharing Report FHWA-TS-78-207, Office of Research and Development, U.S. Department of Transportation, Washington, D.C., 1978.
7. Hoffman, G., Hauskins, J., Jr., "Solar Energy Provides Heat for Asphalt Emulsion Tank," *Arizona Professional Engineer*, Volume 30, No. 5, November 1978.
8. Abraham, H., *Manufactured Products*, Volume 3 of *Asphalt and Allied Substances*, 6th Edition, Van Nostrand Press, Princeton, New Jersey, 1960-1963.
9. Connell, C. A., "Maritime Province Solves Winter Patching Problem," *Public Works Magazine*, Volume 110, No. 8, Stroudsburg, Pennsylvania, August 1979.
10. Chi, S. W., *Heat Pipe Theory and Practice*, Hemisphere Publishing Co., Washington, D.C., 1976.
11. AFM 88-6 Chapter 9, "Bituminous Pavements, Standard Practice," Department of Air Force, Washington, D.C., June 1979.
12. *Green Guide*, Volume 1, Equipment Guide Book Co., Palo Alto, California.
13. *Asphalt Mobile*, brochure from Daffin Mobile Products Division of Barber-Greene Co., Lancaster, Pennsylvania.
14. Foster, C. R., "Reducing the Use of Petroleum Fuels," *Paving Forum*, National Asphalt Pavement Association, Riverdale, Maryland, Fall, 1979.

INITIAL DISTRIBUTION

DDC-DDA-2	2
HQ AFSC/DLWM	1
HQ AFSC/SDNE	1
HQ AFSC/DEE	1
HQ AFSC/DEM	1
HQ USAFE/DEMY	2
HQ USAFE/DEM	2
HQ USAFE/EUROPS (DEXD)	2
AFATL/DLJK	1
AFATL/DLOSL (Tech Library)	1
AD/IN	1
USAF TAWC/RX	1
USAF TAWC/THL	1
USAF TAWC/THLA	1
EOARD/LNI	2
Shape Technical Center USRADCO	1
HQ PACAF/DEM	2
HQ TAC/DEE	2
HQ TAC/DRP	1
HQ TAC/DEPX	1
HQ AUL/LSE 71-249	1
HQ SAC/DE	1
HQ SAC/DEE	1
HQ SAC/DEM	1
USN Civil Engineering Laboratory	2
US Naval Construction Battalion Center	1
NAVEODFAC	1
HQ ATC/DED	1
HQ ATC/DEE	1
HQ MAC/DEM	1
HQ AFESC/DEO	1
HQ AFESC/DEMP	2
HQ AFESC/TST	2
HQ AFESC/RDC	2
HQ AFESC/RDCR	5
HQ AFESC/RDCT	2
HQ AFESC/RDCF	2
HQ USAFA/DFEM	1
USAE Waterways Experiment Station/WESGF	2
HQ USAF/LEEX	1
HQ USAF/LEYW	1
HQ USAF/RDPX	1
AFWAL/FIEM	1
AFWAL/FIBE	1
HQ AFLC/DEMG	1
HQ AFLC/DEE	1
AFIT/DET	1
AFIT/LDE	1
AFWAL/MMXE	2
New Mexico Engineering Research Institute	6

END

DATE
FILMED

7-80

DTIC