STATE-OF-THE-ART OF SURFACE RECYCLING

R. A. Jimenez, University of Arizona

The present knowledge and practice of asphaltic surface recycling is presented. A review of the available information has shown the practicability of restoring the desirable characteristics of pavement surfaces through the use of heater planer or scarifier processes. Also discussed are specifications for recycling agents and for construction procedures.

This report is concerned with a specific portion of the National Seminar on Asphalt Pavement Recycling. As indicated by the title, this presentation covers the topic of surface recycling as a review of the experiences and recommendations of those who have been involved in surface recycling principally in a restoration mode. Although some phases of present procedures of surface recycling have been performed, some 40 (1) or less years ago, the total process may still be considered as an art. Webster (2) defines an art as being a "skill in performance obtained by experience". However, the contributions of science to the successes of recycling cannot be disregarded.

The oil embargo of 1973 and other shortages in the highway construction industry gave an impetus and urgency to the reuse of materials in existing asphaltic roads for reconstruction or restoration of the roadway. Since the restoration processes are relatively new and have been practiced by various people over the country, a new jargon has developed and will be defined and summarized in the presentations of this seminar.

In general, recycling of pavement materials involves its transfer or moving to a processing area and then being returned to a/the roadway; thus completing a circuit. Recycling is practiced principally for economical reasons based on cost and availability of materials for making and processing pavement layers. Although not always so, recycling is concerned with the maintenance and restoration of an existing facility. (Asphaltic concrete from abandoned parking lots and roadways is being stockpiled for recycling into future pavements.)

The title of this presentation, Surface Recycling, indicates that the process involves reusing only the surface (top 1.91 to 2.54 cm [3/4 to 1 in.]), that its purpose is to restore or improve the road's surface condition, and that the recycling circuit (hauling distance) is very short. Some of the reasons for surface recycling are as follows:

1. To correct or eliminate surface deformations of rutting or shoving,
2. To correct or eliminate a slippery surface,
3. In correcting the above, to maintain the original elevation of the surface, and
4. To minimize reflection cracking to an overlay.

In the process of surface recycling, heat may or may not be used for breaking up the surface; new materials or modifying agents may be added; and the construction may be a continuous one-phased or a multiphased one.

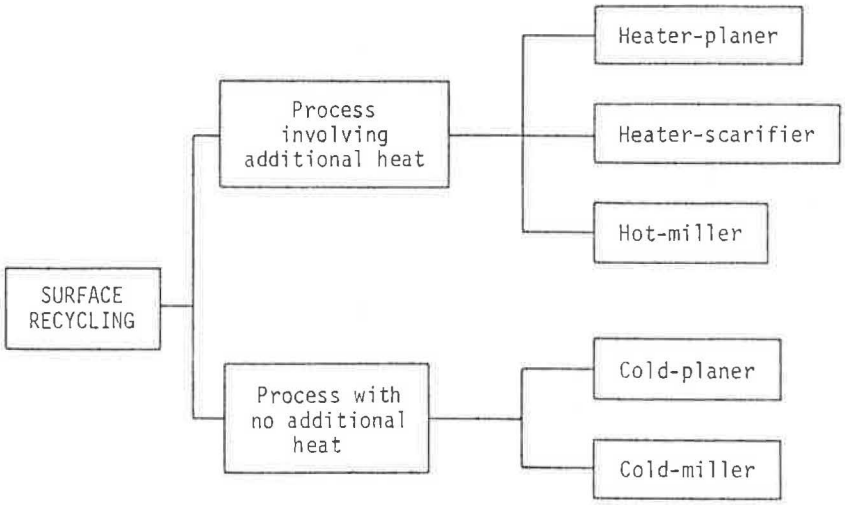
Prior to selecting a surface recycling-restoration program, preliminary investigations must be performed to establish the causes of the surface deficiencies and to show that surface recycling is a viable remedy. Subsurface weaknesses or failures in a pavement will appear on the surface as cracks or deformations. Shear failures of surfaces, bases, or subgrades will eventually appear as ruts at the surface. Fatigue or shrinkage weaknesses or failures in the pavement system will result in cracking of the surface. It is generally accepted that recycling for restoration of only the top 2.54 cm (1 in.) of the surface will not serve for a significant period of time before the existing failures recur. However, under certain conditions of age and moderate surface cracking, recycling of the pavement surface prior to an overlay is justified. The breaking-up of the old pavement surface destroys the crack pattern; the softening (low modulus of elasticity) of the recycled material will serve as a strain-attenuating layer; and the strengthening effect of the overlay; all contribute to minimize reflection cracking of the new surface course.

The design and construction of the recycled surface must be considered as carefully as for a new overlay. Thought must be given as to the effects of additives and construction procedures on the stability and bleeding characteristics of the recycled course, especially where more liquid is added to the recycled material.

Methods and Construction Procedures

There are two basic processes in use for the recycling of asphaltic pavement surfaces; one utilizes the heating of the pavement and the other does not. Figure 1 (1) presents a visual description of the

Figure 1. Basic surface recycling procedures.



processes and subdivisions for each.

From the third column of Figure 1, it is noted that the names of the processes are obtained from the type of equipment used. Accordingly, in defining the process using heat (1,3,5),

1. The heater-planer is a device that heats the pavement surface and then shears up to 2.54 cm (1 in.) of the hot material with a steel blade or plate,
2. The heater-scarifier is a device that heats the pavement surface and rips the surface up to a depth of 2.54 cm (1 in.) by raking spring loaded steel points over the hot materials, and
3. The hot-miller is a device(s) by which the pavement surface is heated and then miller or ground up to a depth of 5.08 cm (2 in.) with a rotating drum that has cutting tips mounted over the cylindrical surface.

As indicated earlier, this presentation is concerned principally with the restoration mode of recycling in which the material will be reused in the same pavement layer.

Cold Process

The cold-planing and cold-milling processes are used to remove surface material that is deteriorated or causes surface roughness or slipperiness. Although this material can be recycled for use in another layer of another pavement, it is not generally returned to reconstruct the original surface. It is to be pointed out that the material has not been reused for restoration principally because of the cold process itself.

Heated Process

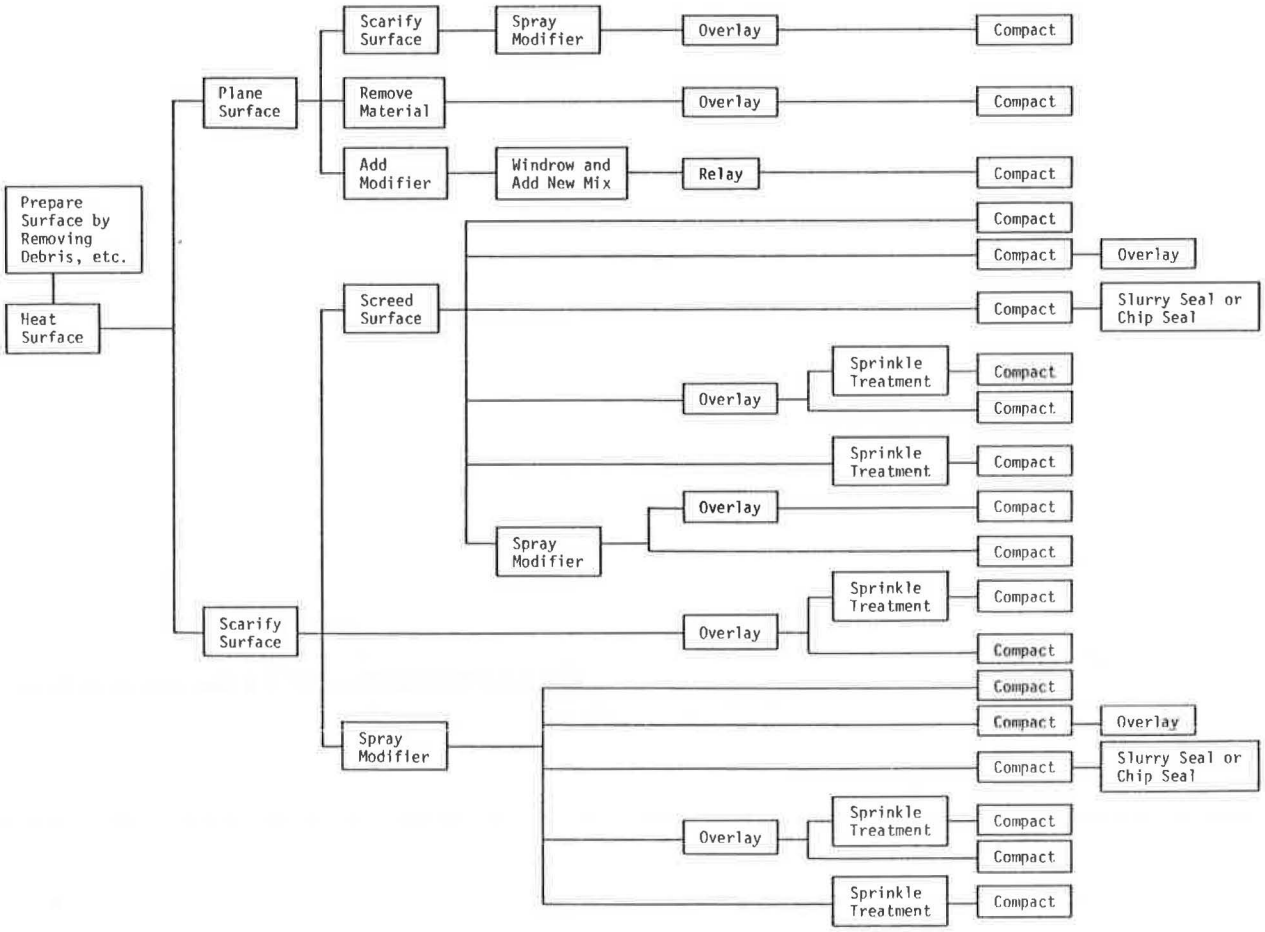
The several operations using a heated process of surface recycling are involved mainly with the reuse of the material in the surface. However, a form of the heated process is used for removal of surface material and for reuse elsewhere. Figure 2 shows the possible variations in the techniques available for surface recycling as suggested by Reference 3. It was not intended to give the objectives of the operations shown in Figure 2. The following paragraphs will describe procedures (1,3,4,6,7,8,9,10) that have been used to restore surface deficiencies by recycling or reclaiming methods.

To Correct a Slippery Surface. The pavement surface may have low skid resistance due to characteristics of the aggregate or to a bleeding or flushed condition. Analysis of the pavement and its surface material should guide in the selection of one of the procedures from the following:

1. a. The surface is heated and scarified,
   b. The surface material may be mixed for uniformity,
   c. A liquid recycling agent is sprayed, if needed,
   d. The recycled mixture is compacted,
   e. Skid resistant aggregate is spread,
   f. The aggregate and pavement is heated, and
   g. Steel wheel rolled to embed aggregate to proper depth.
2. a. The treatment of item (1) may be modified by adding and mixing new asphaltic mixture to the scarified material, and then spreading and compacting.
3. a. If the problem is a polished or nontextured surface,
   b. Skid resistant aggregate is spread over the surface,
   c. The aggregate and pavement is heated, and
   d. Steel wheel rolled to embed the aggregate.
4. a. The treatment of item (3) has been suggested for a flushed pavement surface; however, one must recognize that deformation may be imminent in such a situation.
5. a. If the existing material is not suitable for recycling into a surface course, then it must be planed and hauled away for possible reuse in some other location.
   b. The planed surface is then overlaid with a new mixture.

To Correct a Deformed Surface. The reasons for the rutting, shoving, or bumps must be established. Structural failures cannot be remedied with correction of only the upper 2.54 cm (1 in.) of the pavement surface. The following descriptions are related to possible treatments:

Figure 2. Surface recycling procedures using heat.



1. a. For a limited area of bumps or humps, the surface can be planed or heater-scarified,
   b. The excess material is used to fill the low or depressed areas,
   c. If necessary, liquid recycling agent is added,
   d. Then the planed and filled areas are compacted.
2. a. For the deficiencies or deterioration within a thin (3.81 cm [1 1/2 in.]) surface course, the layer can be removed by heater scarification or planing,
   b. Then a new surface is laid.
3. a. Under certain conditions the upper 2.54 cm (1-1 1/2 in.) of the surface can be heater scarified and mixed,
   b. If necessary, a liquid recycling agent is added,
   c. New asphaltic paving material is mixed with the old loose mixture, and
   d. Then the screeded and vibrated layer is compacted, forming a new layer generally less than 6.35 cm (2 1/2 in.).
4. a. If the existing material is not suitable for recycling into a surface course, then it must be removed for possible reuse elsewhere, and
   b. Then a new surfacing material must be laid.

To Correct for a Cracked Surface. An asphaltic pavement surface may be cracked for a variety of reasons. These reasons or causes can be generalized as due to shrinkage of the surface course, reflection of underlying cracks, failure by flexural fatigue, or construction shortcomings. Restoration of the surface generally requires recycling a position of the top course plus the addition of added asphaltic concrete or an overlay as described in one of the following methods.

1. a. The pavement surface is heater scarified,
   b. A liquid recycling agent is added,
   c. New asphaltic concrete is mixed with the reclaimed material,
   d. The new mixture is spread and compacted.
2. a. The pavement surface is heater scarified,
   b. A liquid recycling agent is added,
   c. The reclaimed material is spread and compacted,
   d. A new plant-mix overlay is spread and compacted.
3. a. The pavement surface is heater scarified,
   b. The scarified material is compacted,
   c. A liquid recycling agent is added,
   d. If needed, a flush or tack coat is added,
   e. A new plant-mix overlay is spread and compacted.

The original plus recent thinking on the successes of the above procedures is that (a) scarification breaks up the regularity of the surface crack pattern, (b) the recycled material plus the asphalt softening agent serves as a strain-attenuating layer to minimize relfection cracking, and (c) the recycled and new layer adds strength to the pavement by preventing surface water infiltration into the subsoils.

In addition to correcting surface failures described above, it is apparent that the processes of surface recycling and reclaiming can also be used for the purposes shown below.

1. To maintain curb height while repairing surface failures,
2. To maintain overhead clearance at overpasses while repairing surface failures,
3. To maintain, instead of adding to, the dead load on bridges while repairing surface failures.

Construction Equipment

A great variety of equipment for surface recycling has been used over the past years. For low volume farm-to-market roads constructed with liquid asphalts, the surface was planed or scarified and then recompacted to restore the surface smoothness. As can be imagined, blades, and disc or spring harrows could have been used. Development of some present day equipment has been regionalized and by people such as Cutler (6), Jackson (15), Payne (16) and Moench (17) for heater-planer scarifiers. Photographs of the various types of heater-scarifiers are shown in Figure 3. It is apparent from the size of these units that their operation and maintenance are quite involved and specialized. These units must be capable of heating the surface to a specific depth and within a certain range of temperature.

Controlled heating is necessary to soften the pavement for scarifying or planing without damage to the asphalt for reuse. Penetration of the heat into the pavement is tied to the speed of travel of the heater or heaters in tandem so as to leave a finite temperature gradient to the depth desired. Also, the heating of the surface must be such so as to minimize burning emissions and meet air pollution standards. In scarifying 1.90 to 2.54 cm (3/4 to 1 in.) of surface, a general requirement is that the temperature of the mixture behind the scarifier should range between 107-138°C (225-280°F) (9,12).

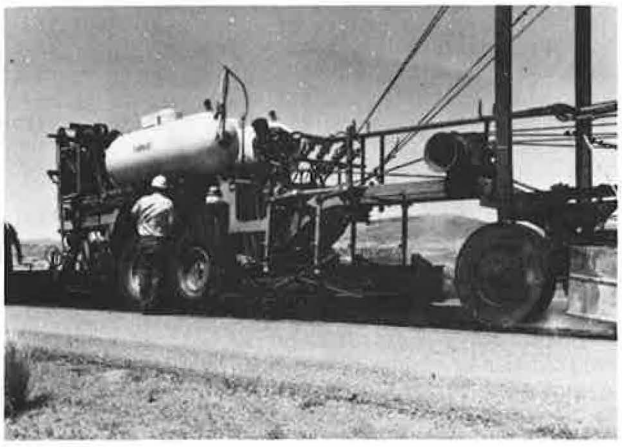
There are several methods used for heating the pavement surface. The fuel used may be a liquified petroleum gas (LPG) or diesel oil and the heating may be from an open flame or from a radiant tube for indirect heating.

A recent publication by V. Servas (22) describes a process developed by Wirtgen GmbH in West Germany for surface remixing. The procedure is similar to the U. S. practice except that the surface material is heated to temperatures between 140-160°C (284-320°F) and up to 8.0 cm (3.1 in.) can be heated and scarified. The pavement is preheated with a gas-fired, infra-red heater unit.

Costs of Surface Recycling

In some cases, certain operations of surface recycling may be subcontracted to specialists for heater-planing or scarification only. As a

Figure 3. Heater scarification in Arizona.



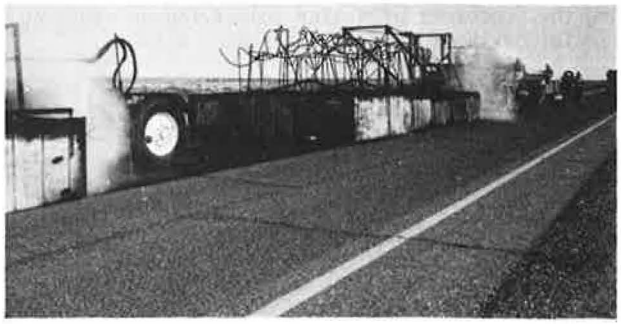


Table 1. Ranges of unit costs for surface recycling.

Item	Cost $/m	Comments	(Ref.)
Heater-planing	0.18 - 1.07	Removal of 1.9 cm	(12,18,19)
Heater-scarifying	0.30 - 0.95	1.9 cm. + additive, + compaction	(12,18)
a. plus 0.95 cm chip seal	0.95 - 1.67	Complete	(12,18)
b. plus 5.08 cm asphaltic concrete	3.09 - 4.76	Complete	(12,18)
Cold-milling	0.42 - 1.43	Removal of 2.54 cm	(18)
a. plus 90 kg asphaltic concrete	2.38 - 3.57	Complete	(18)

2.54 cm = 1 in.

0.84 m^2 = 1 yd^2

0.45 kg = 1 lb

consequence, and along with all the variables that affect bid prices, there is a wide range in the unit cost for surface recycling. The listings in Table 1 range in unit costs for various items in surface recycling.

The unit costs shown in the table were obtained from references dated 1980 and serve for immediate comparisons. The range in cost for a particular item, as shown, is based on difference in surfacings. The low cost operation would most likely be for a fine grained or soft surface; while the high unit cost would be for an old, hard, and 1.90 cm (3/4 in.) aggregate asphaltic concrete. According to Reid (19), one of the most important factors affecting cost of heater scarification is the depth of surface heating required in one pass of the equipment and meeting controls on temperature and air pollution at the same time.

Specifications for Surface Recycling

It appears that it has been the practice for specifications to be developed by promoters of specialized equipment to perform a particular operation or function. In some cases through ignorance or on purpose certain aspects required for an improved product have been omitted from the specifications. This does not imply that the specifications are not adequate, especially since a certain amount of flexibility should be afforded the contractor to incorporate more efficient methods or products.

In the Appendix, two specifications for surface recycling have been reproduced. One is that recommended by the Asphalt Recycling and Reclaiming Association and the other is one that was developed by the Arizona Department of Transportation following 12 years (10) of experience in surface restoration.

A review of the two recent specifications shows there are some variations in the methods for controlling the processes of heater scarifying or remixing. Examples of these differences are as follows:

1. One requires the heating unit to have a minimum rating of 10,584 MJ's (10 million BTU's) per hour and an hourly production of scarified material to be between 840-1,260 m^2 (1,000-1,500 yd^2); the other one does not set limits on heating capability or production rates,
2. One requires the pavement surface to be heated and remixed to a depth of 1.5 to 2.0 cm (0.6 to 0.8 in.); the other one controls the amount of scarification on the basis of 44 kg/m^2 (9 lbs/ft^2) to represent a scarification depth of between 1.90 to 2.54 cm (3/4 to 1 in.),
3. One does not mention weather or calendar restrictions; the other one does on the basis of project elevation.

Other than the three items listed above, the two specifications have much in common.

Recycling Agents

It is generally accepted that the asphalt on the surface of a pavement will age the most rapidly and to the greatest extent as compared to some lower location in the layer. This is to be expected since the highest temperatures and the most amount of air occur on the surface. In order to recycle the top 1.90-2.54 cm (3/4-1 in.) of the pavement for reuse as a surface cover, the asphalt must be returned or changed to have properties of an original asphalt. This transformation has been effected by incorporating liquid additives to the mixture being recycled. These additives have been called by various names such as asphalt-softening agent, asphalt rejuvenator, and recycling oil, and have been typed as being an asphalt emulsion, high penetration asphalt, or one of several proprietary materials.

A prototype specification was discussed by Kari (20) at the 1980 Annual Meeting of AAPT. Since at present there are no standards for specifying these materials, the basics of the Kari, et al., report will be discussed.

First, this class of material will be called "recycling agent" and defined as "A hydrocarbon product with physical characteristics selected to restore aged asphalt to the requirements of current asphalt specifications".

And secondly, specification tests and values are to be based on functional needs of:

1. Grade and consistency - viscosity
2. Handling and shipping - flash point
3. Volatility - oven weight change
4. Compatibility and solvency - saturates
5. Durability - viscosity ratio
6. Accounting - specific gravity

Table 2 (20) presents the suggested specification grades and test values for recycling agents. It is noted the recycling agents (RA) are graded from RA 5 to RA 500 on the basis of viscosity at 60°C (140°F).

Table 2. Proposed specifications for hot mix recycling agents.[a]

Test	ASTM Test Method	RA 5 min.	RA 5 max.	RA 25 min.	RA 25 max.	RA 75 min.	RA 75 max.	RA 250 min.	RA 250 max.	RA 500 min.	RA 500 max.
Viscosity @ 140°F, cSt	D2170 or 2171	200	800	1000	4000	5000	10000	15000	35000	40000	60000
Flash point, COC, °F	D92	400	-	425	-	450	-	450	-	450	-
Saturates, wt. %	D2007	-	30	-	30	-	30	-	30	-	30
Residue from RTF-C oven test @ 325°F	D2872[b]										
Viscosity ratio[c]	-	-	3	-	3	-	3	-	3	-	3
RTF-C oven weight change, ± %	D2872[b]	-	4	-	3	-	2	-	2	-	2
Specific gravity	D70 or D1298	Report		Report		Report		Report		Report	

[a]The final acceptance of recycling agents meeting this specification is subject to the compliance of the reconstituted asphalt blends with current asphalt specifications.

[b]The use of ASTM D1754 has not been studied in the context of this specification, however, it may be applicable. In cases of dispute the reference method shall be ASTM D2872.

[c]$\text{Viscosity Ratio} = \frac{\text{RTF-C Viscosity at 140°F, cSt}}{\text{Original Viscosity at 140°F, cSt}}$

The amount and grade of the recycling agent to be used for a particular pavement depends on the characteristics of the asphalt that one would require for new construction; that is, whether one would specify high or low viscosity of the asphalt. In order to determine the quantity of a recycling agent required, the pavement asphalt must be recovered and blended with varying amounts of the agent. Following the blending, the viscosity measurements would be made to pinpoint the amount of agent needed to give the desired viscosity for the new binder. Manufacturers of recycling agents have developed charts for obtaining the amount of recycling agent needed to obtain a specific viscosity or penetration value once the viscosity or penetration of the recovered asphalt is known. Kari, et al., (21) presented such charts and discussed the roll of recycling agents in hot-mix recycling.

Summary

The review for this state-of-the-art presentation has shown a lack of professional reports in the literature. Most of the information has been obtained from personal correspondence and promotional brochures. However, it seems evident that at the present the state-of-the-art of surface recycling is in transition into a well defined procedure that involves pavement evaluation, material evaluation, material proportioning, and construction controls.

Surface recycling has been used principally for conservation of materials and energy, and for reducing cost for correcting or minimizing pavement surface deficiencies of skid resistance, deformation, and cracking.

Future improvements to the present processes will most likely be in the equipment used.

References

1. Recycling Materials for Highways. National Cooperative Highway Research Program, Synthesis of Highway Practice No. 54, Transportation Research Board, 1978.
2. Webster's Seventh New Collegiate Dictionary. G. & C. Merriam Company, 1972.
3. Interim Guidelines for Recycling Pavement Materials, Draft Copy. NCHRP Project 1-17, Texas Transportation Institute, November 1978.
4. Model Specifications. Asphalt Recycling and Reclaiming Association, 2nd edition, 1978.
5. Vyce, John M., and Nittinger, Robert J. Milling and Planing of Flexible Pavement. HRR No. 647, Transportation Research Board, 1977.
6. Sales Information. Cutler Repaving, Inc., Lawrence, Kansas, 1980.
7. Experimental Asphalt Recycling Project Debuts in Minnesota. Construction Bulletin, September 1979.
8. Burgin, E. D. Heater-Scarifying with Rejuvenation. Rocky Mountain Construction, January 1978.
9. McGee, James A. Recycling of Existing Bituminous Pavements. Presented at the Asphalt Recycling and Reclaiming Association meeting held in Boston, October 1978.
10. Peters, Rowan J. Surface Recycling--Quality Control. Presented at the Asphalt Recycling and Reclaiming Association meeting held in Palm Springs, 1980.
11. Coutts, Mick; and Sensibaugh, Paul. Scarified and Rejuvenator Cut Recycled Runway Cost. Rural and Urban Roads, March 1980.
12. Sales Information. The Tanner Companies, Phoenix, Arizona, 1980.
13. Specifications for Recap Runway 30-12, Slurry Seal Concrete Ramp, Shafter Airport, Cawelo,

California. Public Works Department, Kern County, California, 1968.
14. Specification 4060701. Arizona Department of Transportation, 1980.
15. Jim Jackson--Contractor. Little Rock, Arkansas.
16. G. J. Payne, Carson, California.
17. F. Moench, Asphalt Equipment Company, Albuquerque, New Mexico.
18. Epps, J. A.; Terrel, R. L.; Little, D. N.; and Holmgreen, R. J. Guidelines for Recycling Asphalt Pavements. Preprint of paper presented at the Annual Meeting of AAPT, February 1980.
19. Reid, Kirk. Personal communications. Copper State Asphalt Heaters, Inc., Tucson, Arizona, 1980.
20. Kari, W. J.; Andersen, W. E.; Davidson, D. D. David, H. L.; Doty, R. N.; Escobar, S. S.; Kline, D. L.; and Stone, T. K. Prototype Specifications for Recycling Agents Used in Hot-Mix Recycling. Preprint of paper presented at the Annual Meeting of AAPT, February 1980.
21. Kari, W. J.; Santucci, L. E.; and Coyne, L. D. Hot Mix Recycling of Asphalt Pavements. Preprint of paper presented at the Annual Meeting of AAPT, February 1980.
22. Servas, V. P. Remixing. Civil Engineering (British), June 1980.

Appendix

A. Exerpts of a 1968 General Specification Covering Heater Scarification (13).

1. LOCATION

The work covered by these specifications is located on runway 30-12 and east apron and taxiway, Shafter Airport, Cawelo, California.

2. SCOPE OF WORK

A. Runway and Connecting Taxiway

The work to be done consists, in general, of heating, mixing and adding asphalt rejuvenating agent to existing surfacing and of surfacing with 3/16" minimum thickness slurry seal, as shown.

B. Taxiway and Apron

3. INSPECTION OF SITE

4. GENERAL REQUIREMENTS

5. SUPERINTENDENCE

6. EQUIPMENT

a. All equipment, tools and machines used shall be subject to the approval of the engineer as determined by their effectiveness in performance of operations to be accomplished, and shall be maintained in a satisfactory working condition while in use. Equipment not specifically meeting these specifications and rejected by the engineer shall be removed from the job site and replaced with suitable types.

b. The asphalt heater-scarifier shall be a self-contained machine specifically designed to reprocess upper layers of bituminous pavements. The machine shall be self-propelled, capable of operating at speeds of 0 to 70 fpm and consists of an insulated combustion chamber adjustable in width from 8' to 12' with ports permitting fuel and air injection for proper combustion. The heater shall have a minimum output of heat of 10,500,000 BTU per hour. The scarifier attachment shall be divided into sufficient sections individually controlled to conform with the existing pavement cross section, including inverted sections, and shall provide satisfactory protective devices to insure that no damage will be done to manholes, water valves or other existing structures. The scarifier shall be adjustable and consist of at least two rows of spring loaded rakes. Spacing of teeth shall be on 1-1/2 inch centers and the two rows shall be adjusted to provide maximum scarifying effect without ridging. The Contractor will be required to furnish a minimum of one 12-ton, 3-wheel roller or tandem roller; surface shall be rolled immediately following application of asphalt rejuvenating agent. Following the steel rolling, the area shall be thoroughly rolled with a rubber-tired roller.

c. Slurry seal shown on the plans shall be done in accordance with the State of California, Department of Public Works, Division of Highways "Standard Specifications" dated January 1964, Section 37, Bituminous Seals, Part 37-2, Slurry Seal, with the following exception: Only continuous pugmill mixer type equipment shall be used. Transit mix, or rotating drum mixers will not be used. Items 37-2.07 and 37-2.08 shall not apply.

7. GENERAL

The work will consist of preheating and scarifying existing asphalt surfacing in one operation which will be followed immediately with the addition of an asphalt rejuvenating agent and slurry seal application.

8. PREPARATION

Immediately before heating, the pavement shall be thoroughly cleaned of all dirt, debris, and loose material.

9. MATERIALS

The asphalt rejuvenating agent shall conform to the requirements for asphalt rejuvenating agent set forth in these special provisions.

a. The asphalt rejuvenating agent shall be composed of a petroleum resin oil base uniformly emulsified with water and shall conform to the following requirements:

Test procedure AASHO Designation: T59 to be modified by using distilled water in place of 2 per cent sodium oleate solution.

A test report shall be furnished in duplicate by the vendor at the time of shipment of each lot

of asphalt rejuvenating agent. The report shall show the shipment number, date of shipment, contract number or purchase order number, quantity, and the results of the specified tests.

Before spreading, the asphalt rejuvenating agent will be cut back with water at the approximate rate of 33 per cent of water by volume, of the combined mixture. The asphalt rejuvenating agent mixture shall be spread at the rate of from 0.10 to 0.15 gallon per square yard of surface covered. The exact rate of application will be determined by the Engineer.

10. APPLICATION

a. The existing pavement shall be evenly heated and scarified to a depth of from 0.05 to 0.07 foot by a single continuously moving surface heater scarifier. The surface shall be left in an evenly spread condition and aggregate shall not be pulverized, spalled or broken. The minimum temperature of the scarified material shall not be less that 225°F. when measured three minutes following reprocessing. At least 90% of the aggregate shall be remixed by turning or tumbling. Following the scarifying operation, a cationic oil and resin emulsion, asphalt rejuvenating agent, shall be applied at the rate of .10 to .15 gallon per sq. yd. by a pressure distributor while the remixed material is still hot enough to cause demulsification. Overlapping applications of asphalt rejuvenating agent and leaking of the pressure distributor spraybar will not be allowed.

b. The spreading of slurry seal as specified in these special provisions shall follow after surface is rolled to engineer's satisfaction.

11. AIR TRAFFIC CONTROL

12. CLEAN UP

Upon completion of the job, the site shall be cleaned of any paving material, oil matter, and debris caused or left over in the process of this work.

13. GENERAL SPECIFICATIONS

This Contractor shall provide the Engineer with sieve analysis reports of the aggregate and emulsion weigh slips.

14. TRAFFIC CONTROL

This Contractor shall work in close cooperation with the Airport manager. Runways 30-12 shall be "X"'d out or closed as per plan for the duration of application and curing time of this project.

B. Asphalt Heater-Scarifying or Remixing (4).

SCOPE

This item shall be part of a multi-step process of asphalt surface rehabilitation that consists of softening the existing flexible pavement with heat and thoroughly stirring, spinning or tumbling the mixture; applying an asphalt rejuvenating agent; and installing a surface treatment or overlay.

The operation shall be planned so as to be safe for persons and property adjacent to the work, including the traveling public (the route may or may not be kept open to traffic during construction).

The contractor shall take such additional precautions as he deems reasonable for the safety of his operation.

EQUIPMENT

The equipment for heating and scarifying shall be of a type that has operated successfully on similar work completed prior to the award of this contract or equipment proven through test results.

The heating unit shall have a minimum rating of 10,000,000 BTU's per hour. The hourly production of heated and scarified material shall be between 1000-1500 square yards per hour. The heater scarifier may be equipped with a leveling device to provide for an even distribution of loose material. The scarifier shall be of a type to insure continuous and undiminished pavement contact without damaging manholes and valve boxes. Overhanging trees shall be trimmed in advance to a 9' minimum clearance. Parkway trees may be protected from heat damage by individual shielding and water spray or any combination the contractor deems practical.

SURFACE PREPARATION

The pavement surface to be heater scarified shall be first cleaned of trash, debris, earth or other deleterious substances present in sufficient quantity to interfere with the work to be performed.

HEATING AND SCARIFYING

The pavement surface shall be evenly heated and remixed to a depth of between 0.5 to 0.7 foot (.0155 to .0127m) by a continuously moving surface heater scarifier machine. At least 90% of the aggregate shall be remixed by spinning or tumbling. Heater material shall have a temperature in a range between 220 degrees - 260 degrees Fahrenheit measured immediately behind the heater scarifier. The remixed layer shall be uniformly and evenly heated throughout. No uncontrolled heating, causing differential softening of the upper surface will be permitted. The asphalt binder shall not be carbonized in excess of .10 of one percent. The scarified material shall be left in an evenly spread condition. Aggregates shall not be pulverized, spalled or broken. Width of scarified surface shall be sufficient to accommodate subsequent processing.

NOTE: When the surface to be scarified is to have an overlay of new pavement placed thereon, the scarified material adjacent to any concrete structure can be shaved or graded to provide a uniform cross-slope. The excess material may be distributed and compacted as a leveling course over the adjoining scarified surface or removed from job site depending upon the finished grade design contour. Excess material or oversized aggregate dislodged by the planing or remix operation too large to be covered by the overlay, shall be removed and disposed of by the contractor at his expense.

ALTERNATE

A standard header or gutter cut should be normally performed prior to heater scarifying. The excess

material is loaded and hauled to a site for reuse off the project. In the event a 1" or greater depth of cut is required, the planing or removal operation should be scheduled first as the speed of performing it is generally slower than heater scarifying.

LEVELING DEVICE

Following the heater scarifier and before overlay installation, a leveling device reduces ridge buildup present from heavy scarification of soft mixtures. Material processed by the leveling device should be monitored to assure leveling of grooved and loose stike-off.

ALTERNATE - SCREED DEVICE (for special situations)

Following scarification and before compaction, if a surface treatment has been specified, an oscillating or vibratory device shall spread and distribute the loosened mix. Rolling may be required to compact oversized aggregate and finish the mat closing the voids.

Contractor shall furnish the services of a registered professional engineering laboratory specializing in asphalt technology. Abson recovery tests shall be made on representative cores prior to construction to obtain asphalt penetration (ASTM D-5) and to determine results of treating binder with variable types of additive. No work shall be undertaken until the laboratory report has been approved by the Engineer.

The cost of testing and preparation of reports shall be included in the cost per square yard for heating and remixing surface. The number of cores required shall not exceed 1 per 10,000 square yards of treated pavement.

Contractor shall minimize the escaping of particulant into the air by either the machine or burning of pavement during the heater remix operation. The machine shall be operated to conform with standards of the Air Pollution Control District.

ASPHALT PRIMER

An asphalt primer shall be applied at the rate of .1 to .25 gallon per square yard by a pressure distributor at the end of each work shift. The primer may be scheduled to be applied in one continuous operation to obtain uniformity and prevent overlapping.

PRIMER ALTERNATIVES

Primer--Type 1

The asphalt rejuvenating primer shall be composed of a petroleum resin oil base uniformly emulsified with water and shall conform to the following requirements:

Specification Designation	Test Method	Requirements
Viscosity, S.S.F. at 77°F, Seconds	AASHTO T59	15-40
Sieve Test % Max.*	ASTM D244-60 (Mod)	60
Particle Charge Test	Calif. 343A	Positive
Tests on Residue from ASTM D244-60 (Mod)		
Viscosity, cs. 140°F	ASTM D445	100-200
Asphaltenes % Max.	ASTM D2006-65-T	0.75
Ratio N+A1 / P+A2	ASTM D2006-65-T	0.3-0.5

*Test procedure identical with AASHTO T59 except that distilled water shall be used in place of 2% oleate solution.

Primer--Type 2

The asphalt primer shall be composed of asphalt cement uniformly emulsified with water and shall conform to the following requirements:

Specification Designation	Test Method	Requirements
Viscosity, S.F. at 77°F, Seconds	AASHTO T59	20-100
Residue, % by wt.		57-62
Tests on Residue per 77°F 100g 5 sec.	AASHTO T49	100-200
Ductility 77°F cm	AASHTO T51	40+

Primer--Type 3

The asphalt rejuvenating primer shall be composed of a 50/50 blend of petroleum resin oils and asphalt emulsified with water and shall conform to the following requirements:

Specification Designation	Test Method	Requirements
Viscosity, S.F. at 77°F Seconds	AASHTO T59	12-25
Residue, % by wt.	Calif. 351	50-65
Particle Charge Test	Calif. 343A	Positive
Viscosity, cp, 275°F	ASTM D445	20-65
Asphaltenes, % Max.	Calif. 352	9-13

DISTRIBUTOR

The distributor should also comply with specifications. While spraying, the pressure should be high enough to give the desired application through uniform spread along with constant straight edged spray fans at each nozzle. The spray bar should be at a constant height to prevent streaking.

ROLLERS

The use of self-propelled smooth tread pneumatic tire rollers is recommended on surface treatments so that the aggregate is imbedded firmly into the asphalt without crushing the particles. In general there are three types of rollers which may be used to compact heater scarified treatments. A pneumatic tired roller or steel wheel roller should be in a range of 10-12 tons overall.

The vibro roller is a unique tool which is capable of achieving very high density with only a few passes over the surface. The vibrating effort of the roller is controlled and produces density without causing horizontal displacement. The steel wheel and vibro roller may be used effectively on surface of uniform grade without abrupt breaks at the quarter point or crown. If a surface is distorted, a satisfactory result is obtained by specifying the pneumatic tire roller.

The multi-step process should be kept as close together as practical to insure the maximum benefit is achieved from each phase for complete integration and to permit easy traffic arrangement.

MEASUREMENT AND PAYMENT

Heater Scarified - Heating and scarifying treatment will be measured by the square yard or square meter and shall include all work completed and accepted.

The accepted quantities of heating and scarifying treatment will be paid at the contract unit price per square yard for heating and scarifying treatment. Testing and preparing reports prior to treatment of pavement shall be included in the unit price per square yard or square meter. Surface regrading or leveling course constructed as described in the plans and specifications, including all operations of planing and compaction shall be included in the unit price per square yard or square meter and no additional payment will be made.

Alternate - The asphalt pavement adjacent to gutter is to be planed or removed in the form of a wedge 5' to 6' wide to desired depth as a separate operation. The linear feet of cut will be measured and shall include all work to cut, load, haul material for reuse, and sweep surface as directed by the Engineer.

The accepted quantity of gutter cut will be paid at the contract unit price per linear foot for performing all work.

Asphalt Rejuvenating Agent - is paid for by weight and shall be weighed on sealed scales, regularly inspected by State Bureau of Weights and Measures, or may be measured in some other approved manner. A load slip shall be delivered to the Engineer at point of delivery of their material. Asphalt concrete overlay required shall not be paid for under this section.

C. Recycling of Existing Bituminous Surface (14)

DESCRIPTION:

The work under this item consists of recycling the flexible pavement. It shall be accomplished by heating, scarifying, remixing, releveling, compacting and rejuvenating the existing bituminous surfacing material.

EQUIPMENT:

The equipment used to heat and scarify the bituminous surface shall be fueled by liquified petroleum gas. It shall fully meet the standards of the Bureau of Air Pollution Control, Division of Environmental Health Services, Arizona Department of Health Services.

One pneumatic tired compactor shall be furnished to compact the scarified material; however, in addition to the pneumatic tired compactor, the contractor may furnish any other type of compactor. Pneumatic tired and tandem power (steel wheel) compactors shall comply with the requirements of Subsection 406-3.05(F) (2) and (3) respectively of the Standard Specification.

CONSTRUCTION DETAILS:

The work shall generally be accomplished only between the dates hereinafter shown as applicable to the average elevation of the project; however, the beginning date may be moved ahead and the ending date may be extended if, in the opinion of the engineer, weather conditions, surface temperatures and other factors will not have an adverse effect upon the work. At any time the engineer may require that the work cease or that the workday be reduced in the event that weather or other conditions will have an adverse effect upon the work.

Average Elevation of Project, Feet	Beginning and Ending Dates
0 - 3499	February 15 - December 15
3500 - 4999	April 1 - October 31
5000 and Over	May 1 - September 30

Prior to commencing heater-scarifying operations, the existing pavement shall be cleaned of all extraneous material. Power brooming shall be supplemented, when necessary, by hand brooming until all deleterious material has been removed from the existing surface.

The number of heater units utilized shall be determined by the contractor; however, if all heater units are equipped with scarifiers, only the scarifier on the last heater unit of the series shall be utilized for scarification. Multiple heater units shall be utilized in tandem such that the heat emitted and the rate of travel will achieve the specified requirements.

The existing bituminous surface shall be heated not less than six nor more than 12 inches wider than the width of the material to be scarified. The temperature of the scarified material shall be not less than 200 nor more than 300 degrees F. when measured immediately behind the scarifier.

The weight of the existing bituminous surface has been estimated to be approximately 144 pounds per cubic foot. On this basis, a minimum of nine pounds

per square foot of the existing bituminous surface shall be scarified for a depth betwen 3/4 inch and one inch of unscarified material. If tests indicate that the material weighs either less than 137 or more than 151 pounds per cubic foot, the pounds per square foot to be scarified will be adjusted accordingly by the engineer.

If the specified amount is not being scarified after the first full hour of operation, the work shall be stopped and shall be resumed only after adjustments have been made by the contractor which will satisfy the engineer that the requirements can be met.

The scarified material shall then be processed by mechanical equipment equipped with an operating vibratory or oscillating screed capable of producing results approximating those obtained by an asphaltic concrete laydown machine. The equipment shall effectively distribute and level the material to a width no greater than the original width of the material scarified. The equipment may be a separate unit or it may be attached to or be a part of the scarifying equipment. Any equipment deemed to be producing unsatisfactory results will be rejected by the engineer.

The bituminous surface shall be compacted immediately after it has been distributed and leveled and while it is still hot.

Within 30 minutes after compaction, the rejuvenating agent shall be applied; however, no material to which the rejuvenating agent has been applied shall be reheated and rescarified.

If the engineer determines that excessive ravelling has occurred, he may direct the contractor to apply Emulsified Asphalt (Special Type) to the scarified material. The application rate will be specified by the engineer.

ACCEPTABILITY OF SCARIFICATION:

Scarification will be deemed to be acceptable when the moving average of a minimum of three consecutive random tests per hour indicates that the required amount per square foot, based on the weight per cubic foot, of the existing bituminous surface has been scarified.

The amount of material scarified will be determined in accordance with the requirements of Tentative Arizona Test Method 409.

The weight of the existing bituminous surface will be determined in accordance with the requirements of AASHTO T-166 from scarified material compacted in accordance with the requirements of AASHTO T-245, with the exception that the compaction temperature shall be 240±5 degrees F.

METHOD OF MEASUREMENT:

Measurement of this work will be made by the square yard of bituminous surface scarified.

BASIS OF PAYMENT:

Payment for this work will be made at the contract price a square yard for ITEM 4060701 - RECYCLING OF EXISTING BITUMINOUS SURFACE, which price shall be full compensation for the item complete, as herein described and specified.

No adjustment in the contract unit price will be made if tests indicate a weight per cubic foot of the existing bituminous surfacing differing from that shown hereinbefore and the amount of material to be scarified is adjusted accordingly.

Rejuvenating Agent for Bituminous Surface Recycling will be measured and paid for under Item 4012311.

Emulsified Asphalt (Special Type) will be measured and paid for under Item 4030001.