MEANS FOR TREATING BITUMINOUS PAVEMENT

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This invention relates to the treating of bituminous pavements in place by the application of penetrative radiant energy thereto.

The construction of roadways and pavements has continued at increasingly greater rates as the importance and general appeal of transportation by motor vehicle has increased. Ordinarily, such roads are formed of a mixture of aggregates and a binder to hold the aggregate in position thereby forming a solid pavement placed on a base course such as broken stone. Such pavements are commonly known as Portland cement concrete or as bituminous concrete, depending upon the type of binder which is employed. Bituminous concrete pavements are also known as asphalt pavements because of the binder used therein. Various types of asphalts have been used for pavements. Originally, most asphalt was Trinidad Lake asphalt. In recent years, however, petroleum asphalts formed from the fractionation of crude oils or derived from tars have been used in progressively larger amounts for paving purposes.

Asphalt is a mixture of various hydrocarbons which have varying properties of viscosity and the like. The properties of the asphalt result from the properties of its constituents. Some asphalts are volatile, for example, become fluid and tacky on hot summer days due to the fact that they contain a higher percentage of fluid hydrocarbons than other asphalts. Broadly speaking, an asphalt pavement should be of sufficiently low viscosity to remain firm on the hottest days. It should have sufficient ductility to avoid cracking on the coldest day of winter. Naturally, the particular properties desired in an asphalt for paving purposes vary with the climate of the place where the pavement is laid.

The various fractions that make up an asphalt have varying volatilities, the lighter fractions being more volatile. Over a prolonged period of time, the more volatile fractions of the asphalt tend to become separated from the remainder of the asphalt by oxidation or evaporation, thus leaving a relatively hard and brittle residual asphalitic material. The asphalt then lacks essential ductility and begins to crack and break, leading to rapid disintegration from water penetration and traffic. The initial deterioration ordinarily takes place at the surface which is exposed to the atmosphere, and such zone of deterioration extends only a short distance into the asphalt. Once the surface begins to suffer severe deterioration, however, creating fissures and openings extending into the pavement, the entire pavement is subject to attack and its service life rapidly approaches an end point. The amount and severity of traffic, the prevailing climate, the base, the subgrade, and the composition of the asphalt surface material when placed all affect the length of life of the pavement.

Asphalt paving is almost universally placed in position while it is hot or semi-hot. Ordinarily, it is placed continuously by mechanical spreaders or pavers. Hot asphalt is delivered to trucks from an asphalt plant and transported to the paver while the entire mix is maintained at an elevated temperature of at least several hundred degrees. The pavement is placed while hot but rapidly cools as the paving machine stops laying and where the vertical face of the pavement was exposed. In like manner where several plurality of courses are laid side by side, failure to place them substantially simultaneously results in longitudinal joints or fissures. Due to operating limitations, it is difficult or impossible to form separately placed sections of asphalt paving into a unitary sheet free of joints and fissures at the adjoining faces, even though some reduction may be made. These fissures, themselves, constitute weak places in the overall paving complex and invite destruction of the pavement.

As indicated above, numerous factors affect the life of the pavement. In some cases, as with well-laid Trinidad Lake asphalt not subjected to unduly heavy service, the pavement may remain serviceable for as much as fifty years after originally being placed. In other cases, deterioration takes place in shorter periods of time. I have discovered that the life of asphalt paving can be effectively increased and prolonged by selectively subjecting the asphalt to penetrative radiant energy. Such exposure is beneficial in making the asphalt workable and receptive to further treatment with other substances. I preferentially employ means generating radiant energy having wave lengths of about two to six microns and prefer that such energy have a wave length predominately of about three microns.

In asphalt or bituminous pavement can be treated and reconditioned by removing it from the base, reducing it in size and then mixing the particles with a reconditioning agent. The asphalt and aggregate is then ready to be relaid by conventional methods. This process is described in my Patent 2,701,213. Heretofore, it had been necessary to break up the asphalt for effective use of a reconditioning agent. Application of reconditioning agents directly to the surface of a pavement in place produced little or no effect within any practicable length of time.

I have discovered that, concentrated highly penetrative radiant energy applied to the pavement in place, the pavement may be treated in place rather than separately from the base course as has heretofore been believed necessary and required by previous methods known to me. It has previously been proposed to subject asphalt pavements to flames of high temperature to make the asphalt workable. Equipment designed pursuant to these proposals has usually embodied a hood formed of metal sheets and a burner beneath the hood. The burner produces a long flame generating a high temperature of several thousand degrees Fahrenheit. The result is usually to burn or carbonize the surface of the asphalt without making the asphalt workable or receptive for further treatment. Asphalt is a notoriously poor conductor of heat, and the result of surface heating has been largely superficial.

I have discovered that a penetrative radiant energy penetrates into an asphalt pavement, apparently changes the properties of the asphalt and permits the pavement to be laid and treated to maintain a continuous surface free of fissures and surface defects. For example, exposure of a pavement to penetrative radiant energy permits a well-known liquid reconditioning agent, such as that set forth in my Patent 2,701,213, to actively work upon it even if it be a bit of little or no use. I term this effect “breaking the skin tension of the asphalt.” The exact chemical and physical process is unknown to me, but I have deter-
mined that exposure of the bituminous pavement to highly penetrative radiant energy makes the asphalt highly receptive to the liquid reconditioning agent and permits it to be effectively used on a long existing pavement to recondition the pavement and restore its surface integrity without the labor and expense of lifting the pavement and then relaying it. In some cases an exposure of ten or fifteen seconds to the penetrative radiant energy is sufficient to produce satisfactory results. In other cases where an old pavement is being treated, as much as ninety seconds may be required. Ordinarily, an exposure of about forty-five seconds is sufficient to permit the reconditioning agent and treatment and reclamation of the pavement to make it suitable for substantially immediate use.

In this form of my invention I subject the bituminous pavement to a source of concentrated highly penetrative radiant energy and then apply to the pavement a liquid reconditioning agent such as is described in my United States Patent 2,701,213, for example. Following application of the reconditioning agent, I compact the pavement, making it suitable for substantially immediate use. I preferably subject the pavement to a source of radiant energy having a wave length of from two to six microns, spaced a short distance above the pavement and directed downwardly towards it and then apply the reconditioning agent and mechanically work the surface of the pavement for intimate admixture of the reconditioning agent and bituminous pavement. I further preferably level and smooth the pavement before compacting the pavement and then use. In some instances, the leveling and smoothing process may leave the pavement in condition for use without further compaction. I preferably provide carriage means having penetrative radiant energy generating means suspended therefrom. I preferably provide reconditioning applicator means for application of the reconditioner to the heated pavement. I further preferably provide rake means for working the surface and tamper means and screed means for leveling and smoothing the surface. I preferably mount the carriage upon a plurality of pneumatic tires arranged rearwardly of the tamper and screed means and arranged to roll across every portion of the pavement previously treated by the apparatus.

In another application of my invention, I selectively apply highly penetrative radiant energy to a newly laid pavement. I direct the energy toward the side elevation or slope of a course of asphalt paving just prior to placing a second course abutting the first course. The application of such energy breaks the skin tension of the asphalt and maintains it in workable condition, making it receptive to the course laid abutting thereto. The two courses when so placed become a single unitary structure free of fissures and maintaining surface integrity without a break.

Other details, objects and advantages of my invention will become apparent as the following description of certain present preferred embodiments thereof proceeds.

In the accompanying drawings I have illustrated certain present preferred embodiments of my invention in which:

FIGURE 1 is a plan view of pavement treating apparatus embodying my invention showing the carriage and prime mover;
FIGURE 2 is a side view of the apparatus shown in FIGURE 1;
FIGURE 3 is a plan view of the rake, tamper and screed mechanism employed with the apparatus of FIGURE 1;
FIGURE 4 is a partial sectional view taken along line IV—IV of FIGURE 3;
FIGURE 5 is an end view of the apparatus shown in FIGURE 3 looking at the rake end of the mechanism;
FIGURE 6 is a sectional view taken along line VI—VI of FIGURE 3;
FIGURE 7 is a plan view of the radiant energy generator means with some details of construction omitted;
FIGURE 8 is a side view of the mechanism shown in FIGURE 7;

FIGURE 9 is a sectional view of the reconditioner applicator;
FIGURE 10 is a side view of paving apparatus embodying another form of the invention;
FIGURE 11 is a fragmentary sectional view of the apparatus shown in FIGURE 10 taken along line XI—XI of FIGURE 10; and
FIGURE 12 is an elevational view in section of one of the radiant energy generators shown in FIGURE 7.

Referring to FIGURES 1 and 2, the carriage is indicated generally at 1. It is carried by a carriage 2 and is supported from a truck 3. At its opposite end, it is supported from a tank and wheel assembly 3 which is further described below. The carriage is pivoted to draw bar 4 of the truck by pin 5 at its leading end. At its rearward end, it engages a forwardly projecting plate 6 of assembly 3 between plates 7 and 8 of the carriage, thereby permitting relative movement between carriage 1 and assembly 3 only in a horizontal plane. A pin 9 fixed in plate 6 is also fitted within an elongated slot 10 in plate 7. A corresponding slot is formed in plate 8, thereby limiting relative horizontal movement of the components to a path dictated by the configuration of slot 10. The assembly 3 carries a storage tank 11 for a liquid bituminous reconditioning agent such as is described in my prior Patent 2,701,213. Tank 11 may be divided into two compartments, one for the reconditioning agent and one for water which may be applied to the rear tires to prevent them from sticking to the heated treatment. The assembly is supported by a shaft 12 which is mounted on the bottom surface of plate 6. Three A frames 13, 14 and 15 are mounted upon shaft 12. Each A frame carries three pneumatic tires 13a, 14a and 15a, respectively. The tires are arranged in staggered and overlapping relationship to cover the entire width of the machine. Thus, every portion of the pavement over which the machine passes will have at least one of the pneumatic tires 13a, 14a or 15a roll across it. Pin 9 is connected to piston rod 16 of the hydraulic cylinder 17, permitting the pivot point of carriage 1 to be assembly 3 to be adjustably moved to either side of the center of carriage 1. Additional hydraulic cylinders 17a and 17b permit the angle of assembly 3 and carriage 1 to be selectively adjusted for making turns and the like.

A radiant energy generator assembly indicated at 18 is mounted beneath the forward end of carriage 1. It is suspended from four links 19 which are pivotally attached to the underside of the carriage and to the upper side of generator assembly 18. Two hydraulic pistons 20 are connected at one end to carriage 1 by pins 21. The piston rods are connected to flexible cables 22 which pass over sheaves 23 and are connected to the generator assembly 18. Operation of the piston permits the assembly to be lifted above the pavement for transportation. Casters 18a are provided to support the assembly when it is lowered to the pavement.

The generator assembly is shown in somewhat greater detail in FIGURES 7 and 8. It comprises a rectangular frame 24 fabricated from a number of channels. Vertical plates 25 are welded to frame 24 extending between the two sides of frame 24 in parallel relationship. Flat plates 26 welded to the bottom of vertical plates 25 form slides for the generators themselves. The generators produce a radiant energy having wave lengths of two to six microns and concentrated at about three microns. An illustrative type of generator is shown in United States Patent 2,775,294 which shows a burner having a chamber formed of a housing and a perforated grid-like closure member having a plurality of passages therethrough. Fuel is supplied to the chamber with a burner having a slightly pressurized and passes outwardly from the housing through the perforations and is combusted adjacent to said perforate member. As indicated in FIGURE 7, there are seven rows of generators generally indicated at 30, 31, 32, 33, 34, 35 and 36 from front to rear, respectively,
extending between the sides of the generator assembly, eight generators being positioned in each row. The generators are indicated at 27 in FIGURE 8. They are placed side by side in frames 28 which rest upon plates 26 and are also fastened to backing plates 29. The frames of rows 30 and 36 are fixed in position relative to frame 24, but the remaining groups of generators are free to slide from side to side.

One of the generators is illustrated in greater detail in FIGURE 12. It comprises a housing 136 which may conveniently be a steel casting. Fuel gas is supplied to the burner under pressure through a line 131. The gas passes through an orifice or nozzle 132 at the end of line 131 and into a mixing tube 133. The gas is aspirated into the mixing tube with the gas at 134. The fuel-air mixture is mixed in tube 133 and passes unburned into chamber 135 where it is under a slight pressure developed by the velocity of the entering gas.BUFFLES may optionally be provided near the end of tube 133 to aid in even distribution of the fuel-air mixture within chamber 135. A perforate closure member 136 is provided which forms a lower surface of the generator and closes the chamber 135. Member 136 may conveniently be a perforate plate with a large number of small holes throughout, or it may be a perforate metallic member such as one or more layers of fine stainless steel wire mesh or gauze. The pressure within chamber 135 forces the unburned gas outwardly from the chamber through the perforations. The gas is combusted adjacent the perforated member bringing the perforate member to a high temperature and developing a radiant energy which penetrates deeply into the asphalt.

Two plates 27 are welded between vertical plates 25 above the middle row of generators 33. A double-acting hydraulic cylinder 38 is mounted on plates 37 and has a piston therein with rods 39 and 40 projecting from opposite ends of the piston. A pair of bars 41 and 42 are fastened above the generator assembly and extend generally longitudi- nally to end adjacent each side of the generators. The bars 41 and 42 in each pair are pivotally connected at one end to each other and to piston rods 39 and 40 by pin and clevis mountings. The free ends of the bars are placed between dual rollers 43 which are rotatably mounted on posts 44 which are fastened to backing plates 29 of the first and last rows of generators 30 and 36. The rollers 43 are slotted around their circumference to receive the bars. Additional rollers 45 are mounted upon the intermediate rows of generators 31, 32, 34 and 35, on bars 41 and 42 and against the outside of one end of the bars 41 and 42. The center row of generators 32 is equipped with posts 46 standing upwardly and termi- nating in the pins through the clevises on the end of piston rods 39 and 40. A slot 47 is cut in the lower flange of the channels forming the side members of the generator frame 24 to receive the posts 46 when the piston rod is fully extended.

A tool supporting sled, indicated generally at 48 (FIG- URE 2), rests upon and is drawn along the pavement behind the generator assembly by pull rods 49. Rods 49 are connected both to the sled and to the carriage by universal joints permitting the sled to freely follow the contour of the pavement. Hydraulic cylinders 49a are formed integral with rods 49 to vary their length to pro- vide a steering effect for tool sled 48. Lift means comprising hydraulic cylinders 50, and cables 51 passing over sheaves 52 are provided to lift the sled clear of the ground. A西 nsider 53 is attached to the forward edge of the sled and is shown in somewhat greater detail in FIGURE 9. It comprises a pipe 54 having holes drilled therein in which bristles 55 are fitted to form a brush extending across the width of the mechanism. Pipe 54 is packed with felt 58. A fluid supply pipe 56 is fitted with pipe 54 and within a passage 57 extending along the length of felt 58. The liquid reconditioner is de- livered to pipe 56 from tank 11 then into passage 57 through conduit means which have been omitted from the drawings for purposes of clarity. The liquid then passes along passage 57 and is dispersed through felt 58 to produce a flow of liquid into bristles 55 which is evenly distributed along the entire length of the pipe. The fluid is ordinarily pumped through the supply conduit to pipe 56 under pressure, and the supply is cut off when it is desired to stop the flow of liquid reconditioner. How- ever, the liquid within the applicator 53 may be forced to continue to run through bristles 55 for a further period of time. The entire applicator, comprising pipes 54 and 56, may, therefore, be arranged for axial rotation through an angle of approximately 180°, thereby placing the openings in the upward position.

Four reciprocating rakes 59, 60, 61 and 62 are provided, each rake being made up of a number of elements. They are mounted on sled 48 behind applicator 53. The rake indicated generally at 59 is formed of a frame comprising two opposed angles 63 (FIGURES 4 and 5). Three hollow tubes 64 extend between the angles and are welded thereto. Two of the tubes are at the same elevation and the third tube is directly below the rearward tube of the upper pair. The tubes are aligned with tubes 65 which are conventionally mounted with tubes 64 but extend through angles 63 and terminate at side walls 66 of the tool supporting sled. The tubes 65 are tapped to receive bolts 67 extending through side wall 66 and hold- ing tubes 65 in place. Three rake sections indicated gen- erally at 68, 69 and 70 are provided. Each rake section consists of a T-shaped bar 71 upon which tubes 72 are welded. A backing plate 73 is attached on the rear surface of the vertical section of the T-shaped section. The rake sections float within the rake assembly of angle 63 and hollow tubes 64. The angles and tubes are reciprocated on tubes 65 in a manner described below. Reciprocation of that assembly carries the rake sections 68, 69 and 70 in the same motion, the angles forcing the rake sections to reciprocate also. The weight of the rake sections holds them downwardly and causes the tines to dig into the pavement. Each rake section is individually free to rise within the assembly as indicated by dotted line in FIGURE 4, however, the bars 64 keep the rake in proper alignment. A bar 74 extends across the upper section of the rake assembly connecting the upper flanges of angles 63. The construction and mounting of rakes 60, 61 and 62 are identical to that of rake 59.

A hydraulic motor 75 is mounted on top of sled 48. It drives a shaft 76 on which a pulley 77 is mounted. Belt 78 is placed thereon and drives pulley 79 mounted on camshaft 80. The camshaft is equipped with circular cams 81 and 81a which are 180° out of phase. Cam 81 has a follower 82 connected to link 83, pivotally mounted at 84a and projecting downwardly through an opening in the top of sled 48. Link 83 is connected to a link 84 which is also connected at pivot 85 to a lug 86 projecting upwardly from bar 74. In like manner, cam 81a is connected through a link mechanism to the corresponding bar of rake 62. Rake 59 carries two upwardly projecting posts 87 on which rollers 88 are mounted. The rollers engage one end of levers 89 pivoted to side walls 66 of the sled at pins 90 which are supported from the side walls. Levers 89 in like fashion engage similar rollers associated with rake 60. Reciprocation of rake 59 causes an opposite reciprocation of rake 60. In like manner, rakes 61 and 62 are connected through levers for oppo- site reciprocation. Other means may be provided in place of the rakes such as a rotating screw which will work and intermix the surface material with the liquid re- conditioner.

A plurality of radiant energy generators are arranged extending between the side walls of the sled 48 rearwardly of the rakes and are indicated generally at 91. They may be of the same construction as previously described.
A hydraulic motor 92 mounted on the top of sled 48 drives a shaft 93 on which a belt pulley 96 is mounted. The associated belt 95 drives pulley 96 on camshaft 97. Two circular cams 98 are provided on camshaft 97 having followers 99. The cams are in phase. The followers 100 extend downwardly and, through a linkage, carry a tamper 101, which projects outwardly through slots 103 formed in the side walls 66 of sled 48. A screeed 104 is pivotally attached to the side walls 66 at 105 at the forward end of the sled. The forward end of the screeed is pivotally attached to piston 106 of hydraulic cylinder 107 which is fixed to sled 48. A series of radiant energy generators 108, similar to those previously described, are placed between side walls 66 above the screeed.

As has been previously indicated, screeed 48 is generally formed of a plurality of plates. A plurality of stiffening members 109 are placed strategically within the structure and are welded as necessary to provide a sufficiently strong and durable structure. A bolt 110 is provided near the lower rear end of the sled to pull the side walls against the associated supporting members and extend to serve as a function at the forward end of sled 48.

Several tanks of liquefied petroleum gas 111 are mounted on carriage 1. They provide fuel for the various radiant energy generators which have previously been described. Pipes are provided connecting the generators and gas source. These are of conventional design and have been omitted from the drawings for purposes of illustration. Various hydraulic pistons and motors have also been described. They are powered from a hydraulic pump through control valves on the truck which supplies hydraulic fluid under pressure to the hydraulic operating devices. The valves and connecting pipes, and pumps, have been omitted from the drawings.

Another form of the invention is illustrated in FIGURE 10. A self-propelled asphalt paver or spreader of well-known design is indicated generally at 112. It includes a main frame 113 which is mounted, for example, on endless track 114. It is provided at its front end with a hopper 115 to receive hot asphalt delivered to the paver by truck from an asphalt plant. A screeed arm 116 is pivoted to the main frame 113 at pivot point 117 on each side of the machine and extends rearwardly therefrom. The screeed is indicated generally in FIGURE 12, and is formed on the rear of the machine being pivoted to each screeed arm 116 at pivot point 119. The angle of the screeed may be changed by rotation of a screw 120. Screw 120 is attached to the screeed at either end and is threaded through the corresponding screeed arm 116, a handwheel 121 being provided to rotate the screw.

Asphalt deposited in hopper 115 is moved rearwardly within the machine and is then placed on the pavement base 122 in advance of the screeed leaving a leveled and compacted layer of asphalt 123 rearwardly of the paver. Various constructions of pavers have been advocated and used, and it is not necessary to describe them further here. The thickness of the deposited asphalt may be regulated by altering the angle between screeed 116 and screeed arm 116, or, alternatively, pivot point 117 may be adjusted up and down vertically. Brackets 124 are provided extending horizontally from screeed arm 116. The brackets are necessary practice is to lay one course on the base and then to place a succeeding course abutting the edge of the first course. FIGURE 11 shows a small portion of a paver traveling on base 122 along the abutting unfinished edge 127 of a previously laid course 128. The edge 127 has a slope and is exposed to the air from the time it is laid. The assembly of structure 125 and generators 126 is adjusted by chains 124 to be above slope 127 as the paver moves along the side of asphalt course 125 in position to direct penetrative radiant energy at the exposed face 127 as well as spreading some energy on the upper face of course 125 and on the upper face of pavement base 122. The generators 126 are supplied with a source of fuel which may be mounted on the paver in some convenient location and connected by means of flexible pipes or the like. After the several courses have been laid, they are compacted by rollers to lock seamlessly the edges of the pavement and secure a uniform surface. The rolling aids in the removal of discontinuities and tends to force the aggregate in the paving material into closely packed relationship.

In operation of the first described embodiment of the invention, the radiant energy generators on assembly 126 are placed in operation, and operation of the rollers and tamper is commenced, and the apparatus is slowly advanced over the pavement which is to be reconditioned. Exposure of the surface to the generators for a period of perhaps forty seconds is ordinarily adequate to break the skin tension. Following this period, generators 126 are turned off and asphalt is allowed to cool and harden. The rollers manipulate the surface asphalt, thoroughly mixing the surface asphalt and the conditioner for complete penetration of the asphalt. The generator assembly 126 is then turned on, and the paver moves forward. Following application of penetrative radiant energy to the asphalt, the reconditioned asphalt is transported by a paver traveling in the same or opposite direction. Tamper 100 recovers up and down and tamps some of the asphalt beneath it. Frequency happens that the loose asphalt will not entirely be tamped under, in which pipes and tamper also serve as a strike-off and will generally carry surplus asphalt forward. The tamper thus tends to level the surface and redistribute excesses into low areas, creating a more uniform surface without localized high or low spots. Screed 104 is heated from above by generators 108. The screed serves as a flat float and tends to further level and smooth the surface. The screed is adjustable about its pivot 105 and the amount of pressure which it applies can be controlled by adjustment of hydraulic cylinder 107. Following passage of sled 48, pneumatic tires 13a, 14a and 15a pass over the asphalt and tends to compact it in place to form a uniformly compacted surface.

Hydraulic cylinder 38 may be controlled through conventional valve means to move the generator assemblies selectively to either side. Thus, on a curve where the central section tends to form a chord across the arc described by the front and rear wheels, the generators may be moved outwardly more closely approximating the curve described by the wheels. Frequently, it may be desired to use the apparatus adjacent a curb. In such a case, the generators may be adjusted toward the curb with greater precision, thereby applying energy to the pavement along an exact line closer to the curb than the apparatus as a whole can be operated.

Further correction for curves can be made by operation of hydraulic cylinder 17, offsetting the carriage from the central pivot 9. A carriage can in this manner be moved outwardly away from the chord between the front and rear wheels. The rear is provided by hydraulic cylinders 17a and 17b.

Use of generator assemblies 91 and 108 is optional. Where a simple dressing of the surface is required, entirely satisfactory results may be obtained using solely the main generator assembly. Where, however, greater leveling and smoothing are necessary, or where the asphalt has badly deteriorated, it may be necessary to supply additional penetrative radiant energy to keep and maintain the asphalt at workable condition.

Following passage of the above described apparatus
over an asphalt surface and reconditioning of the surface as indicated, the asphalt will cool quickly to ambient temperature. It is then suited for and may be opened to traffic. The elapsed time from completion of treatment to passage of traffic is, at most, a matter of a few minutes.

The apparatus shown in FIGURES 10 and 11 is employed in treating pavements preliminarily to placing an additional course of paving material abutting the material which has already been placed. As the paving machine there illustrated advances to lay the new course, the generators 126 are placed in operation directing penetrative radiant energy of the type described at the sloping face 127 of the previously laid pavement, breaking its skin tension and making it workable and receptive to the application of new paving material. The newly deposited material is rolled for compaction and becomes united with the previously laid material and forms a single unitary structure free of fissures and other defects.

Hereinbefore, it was recognized that such fissures and defects could be avoided by placing adjoining courses substantially simultaneously, requiring use of a multiplicity of paving machines. Despite such precautions, the accelerated deterioration and unworkability caused by cold weather severely limited the time of the year when asphalt paving could be placed. For example, one state highway department previously permitted paving only between May 15 and October 15 when the prevailing temperature was above 40°F. Using my invention, the same department permits paving to begin a month earlier and to continue a month longer, thus increasing the allowable paving season from six to eight months—a clear gain of at least one-third more paving time per year. The operation is also completely freed of the prevailing temperature thus resulting in a further gain in paving time.

Use of the invention removes the necessity for employing a plurality of pavers traveling on substantially concurrent parallel courses thus reducing the number of machines required. In addition to the increase in availability of paving machines, there seems no reason why, after further experience, use of asphalt pavers cannot be extended to a year round basis except for particular days in the middle of winter which may force a temporary shutdown.

From the foregoing, it will be seen that I have invented novel and useful means for treating bituminous pavements and of substantially extending their service life. While I have illustrated and described certain preferred embodiments of my invention herein, it is to be understood that I do not limit myself thereto and that the invention may be otherwise variously practiced within the scope of the following claims.

I claim:
1. Paving apparatus comprising penetrative radiant energy generating means and pavement shaping means, said generating means being suspended from said apparatus a predetermined distance above a pavement surface, said generating means comprising an enclosure having a perforate member forming a lower surface thereof, and means to supply fuel under pressure to said enclosure whereby the fuel burns in the course of passage through said perforate member and generates penetrative radiant energy which is directed against the pavement surface, said shaping means being arranged to follow said generating means and to shape the pavement to a desired contour and finish.

2. Bituminous material paving apparatus comprising generating means which supply radiant energy which penetrates deeply into said bituminous material, and pavement shaping means, said generating means being positioned a determined distance above the pavement and movable therealong to limit exposure of the pavement to said radiant energy to prevent scorching of the pavement, said generating means comprising an enclosed chamber having a perforate lower surface, means to supply fuel to said chamber, which fuel is combusted adjacent to said perforate member whereby the perforate member is heated and generates said radiant energy, said shaping means being disposed to treat the pavement surface after exposure to said generating means and to shape the pavement to a desired contour and finish.

3. Bituminous material paving apparatus comprising penetrative radiant energy generating means and pavement shaping means arranged to be applied to said pavement after exposure to said generating means, said generating means being supported at a distance above the pavement and movable along the pavement whereby exposure of the pavement to the generating means and scorching of the pavement is eliminated, said generating means comprising an enclosed chamber having a lower surface formed of a perforate member, means to supply fuel to said generating means under pressure and pass it from within the chamber outwardly through the perforations of said perforate member while combusting the fuel adjacent said perforate member, whereby the temperature of the pavement is generated and directed downwardly to the pavement, said shaping means being disposed to treat the pavement surface after exposure to said generating means and to shape it to a desired contour and finish.

4. Bituminous material paving apparatus comprising penetrative radiant energy generating means, said generating means being supported at a distance from the pavement and being movable along the surface whereby exposure of the pavement to generated energy is limited and scorching of the pavement avoided, said generating means comprising an enclosed chamber having a perforate member forming a lower surface of said generating means, and means to supply fuel to said generating means and pass it outwards through said perforate member while combusting the fuel adjacent said perforate member thereby heating said perforate member to a high temperature whereby penetrative radiant energy is generated and directed against a portion of previously placed bituminous material, said bituminous material placing means being disposed to place additional bituminous material adjacent the section exposed to said penetrative radiant energy, said pavement shaping means being disposed to shape the newly placed bituminous material to a desired contour and finish.

5. Bituminous material paving apparatus comprising penetrative radiant energy generating means, bituminous material placing means, and pavement shaping means, said generating means being supported in a position a determined distance from the pavement and being movable therealong whereby exposure of the pavement to generated energy is limited and scorching of the pavement is avoided, said generating means comprising an enclosed chamber having a perforate member forming a lower surface thereof, and means to supply fuel to said chamber and combust the same adjacent said perforate member, thereby heating the perforate member to a high temperature for generating penetrative radiant energy which is directed downwardly against at least a portion of the previously placed bituminous material, said bituminous material placing means being disposed to deliver additional bituminous material and place it adjacent the section exposed to said penetrative radiant energy, said pavement shaping means being arranged to contact the bituminous material after placing and to shape it to a desired contour and finish.

6. Bituminous material paving apparatus comprising penetrative radiant energy generating means, bituminous material placing means for pavement shaping means, said generating means being supported at a determined distance above the edge of a previously placed course of bituminous material, and being movable along said edge whereby exposure of the edge to generated energy is limited to prevent scorching of the bituminous material, said generating
means comprising an enclosed chamber having a perforate member forming a lower surface thereof, means to supply fuel to said chamber and pass it outwards through the perforate member while combusting it adjacent said perforate member and heating the same to a high temperature whereby penetrative radiant energy is generated downwardly against the edge of the previously placed course, said bituminous material placing means being disposed to place material for a second course parallel to and abutting said first course, said shaping means being disposed to shape the newly placed material into a desired shape and contour whereby a continuous pavement free of longitudinal faults and fissures is formed.

7. Bituminous material paving apparatus comprising applicator means for a liquid reconditioning agent, penetrative radiant energy generating means, pavement working means, and pavement shaping means, said applicator means having a distribution member whereby a liquid reconditioning agent for bituminous material is supplied across a section of bituminous pavement, said generating means being supported a distance above the pavement and movable therealong subsequent to application of said reconditioning agent whereby exposure of the pavement to generated energy is limited to prevent scorching, said generating means comprising an enclosed chamber having a perforate member forming a lower surface of said chamber, and means to supply fuel to said generating means and pass it outwards through the perforate member while combusting the same adjacent the perforate member whereby penetrative radiant energy is generated and directed downwardly against the paving surface therebelow, said working means being disposed to mechanically work the pavement following exposure to said generated energy for intermixing the conditioning agent with the pavement material, said shaping means being disposed to shape the worked pavement to a desired contour and finish.

8. Bituminous material paving apparatus comprising penetrative radiant energy generating means and pavement shaping means mounted upon a single chassis, said generating means being suspended from said chassis a predetermined distance above a pavement surface, said generating means comprising an enclosed chamber having a perforate member forming a lower surface thereof, and means to supply fuel under pressure to said chamber and pass it outwards through said perforate member while combusting the fuel adjacent said perforate member, said chassis being movable at a determined rate of speed to limit exposure of the pavement surface, generated energy to prevent scorching thereof, said pavement shaping means being positioned on said chassis to follow said generating means and to shape the pavement beneath the shaping means to a desired contour and finish.

9. Bituminous material paving apparatus comprising a chassis movable along a pavement, penetrative radiant energy generating means and pavement shaping means, said generating means being supported at a distance from the pavement and vertically movable whereby adjustment of the chassis speed and the vertical elevation of said generating means limits exposure of the pavement to said energy and prevents scorching of said pavement, said generating means comprising an enclosed chamber having a perforate member forming a lower surface thereof, and means to supply fuel to said chamber under pressure and thereby pass it outwards through the perforations while combusting it adjacent said perforate member and heating said perforate member to a high temperature whereby penetrative radiant energy is generated and directed downwardly against the pavement beneath the generating means, said pavement shaping means being positioned on said chassis to follow said generating means and to shape the pavement beneath the shaping means to a desired contour and finish.

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