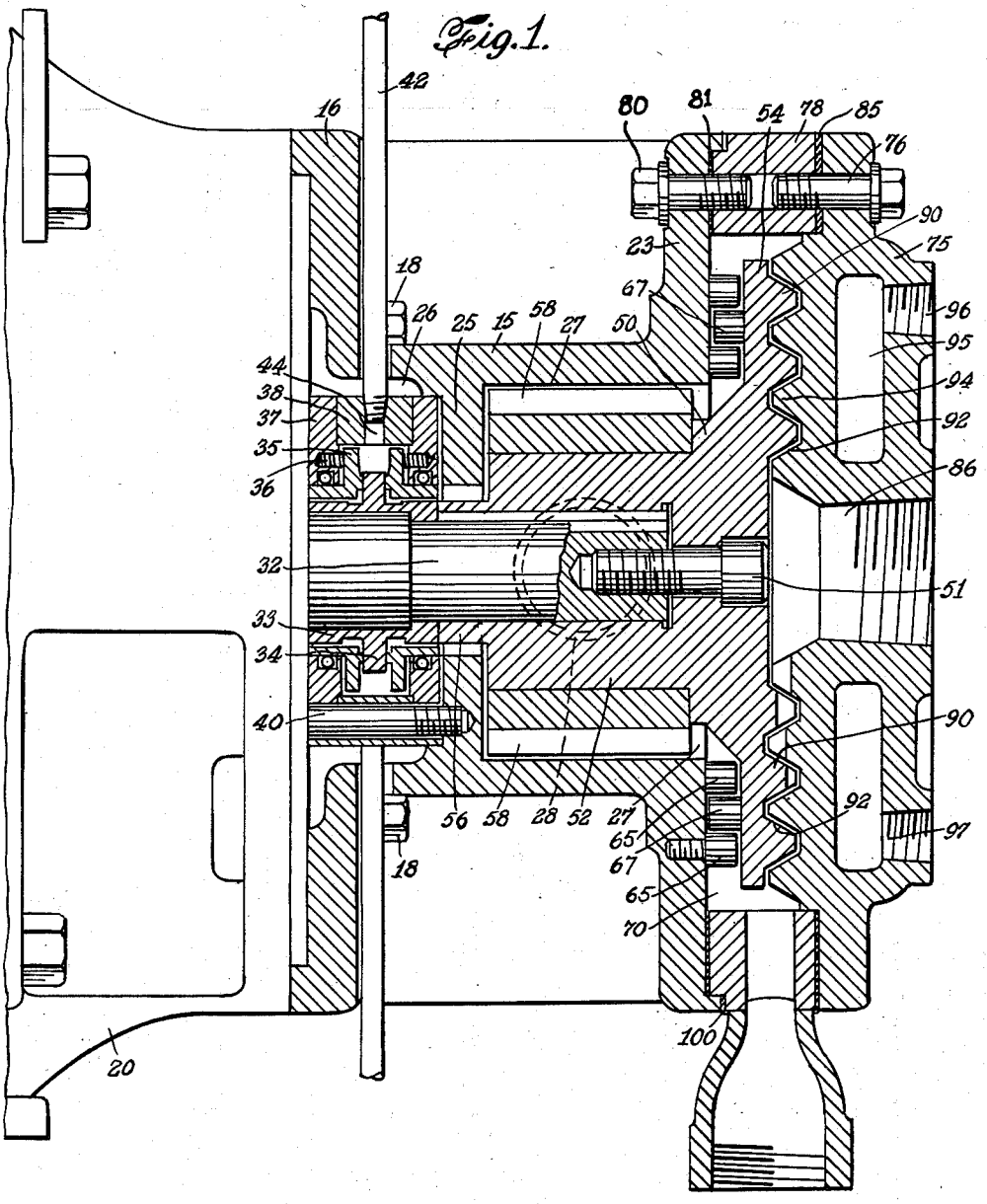
July 14, 1953 D. D. FORBES 2,645,464

DISPERSING APPARATUS

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Fig. 1.




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DISPERSING APPARATUS

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Fig. 2.

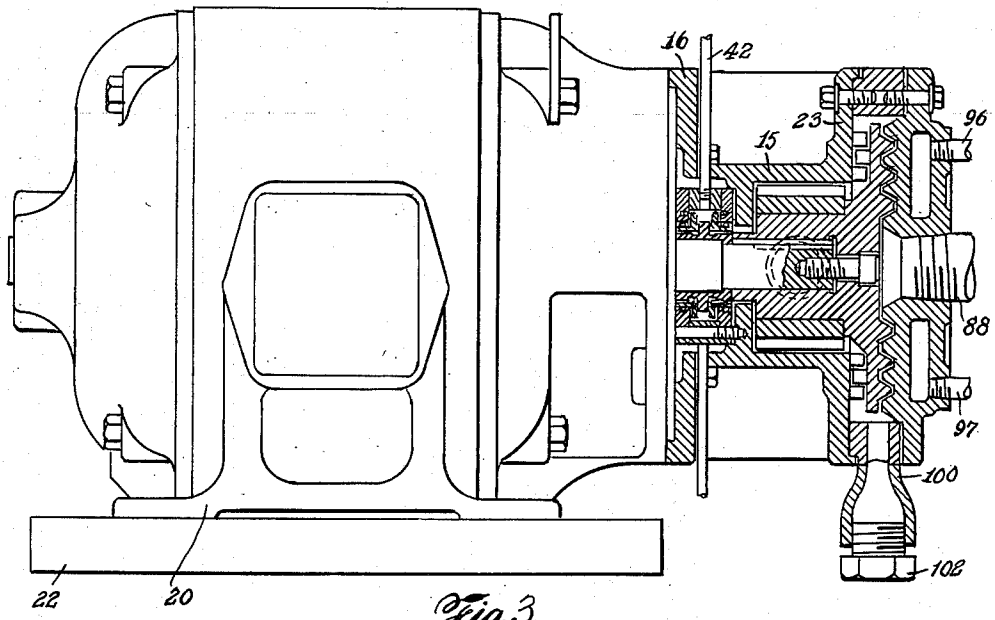
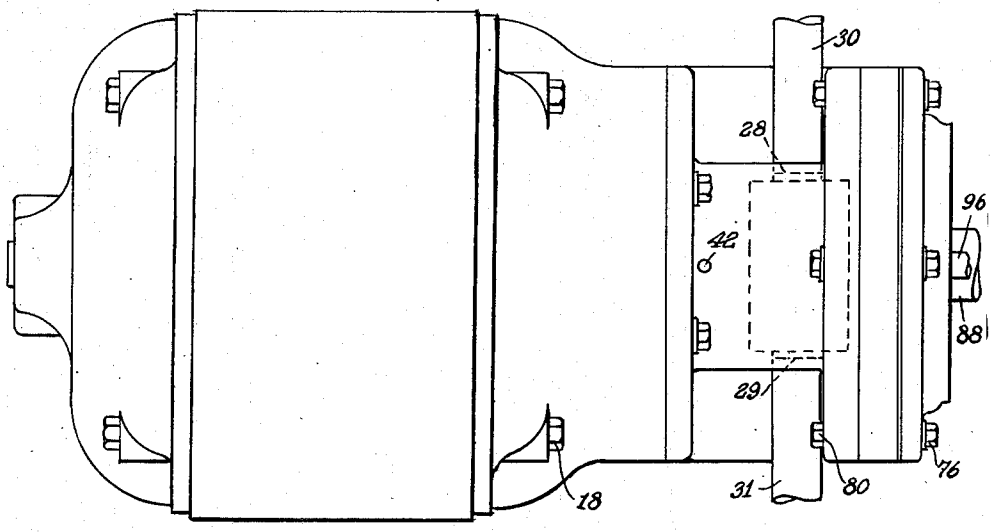



Fig. 3.




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DISPERSING APPARATUS

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Fig. 4.

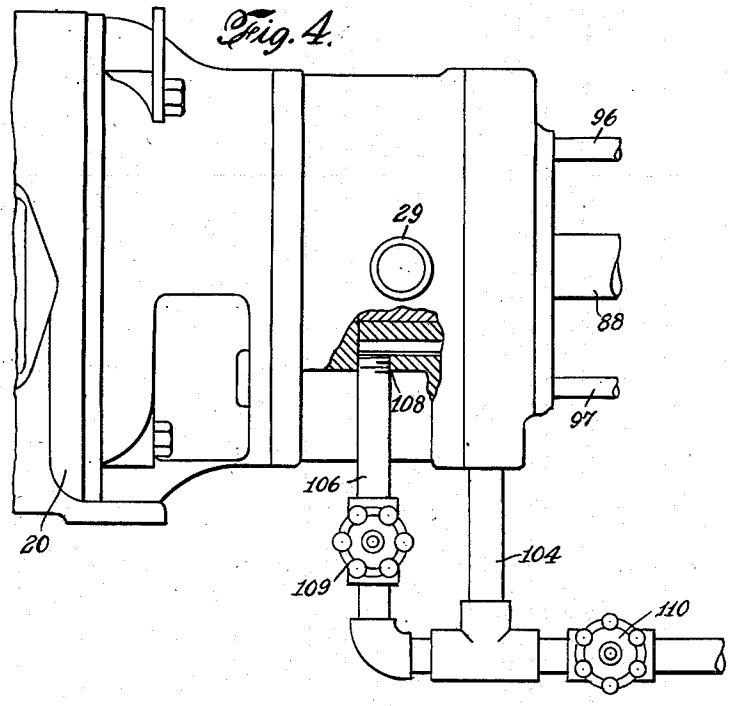
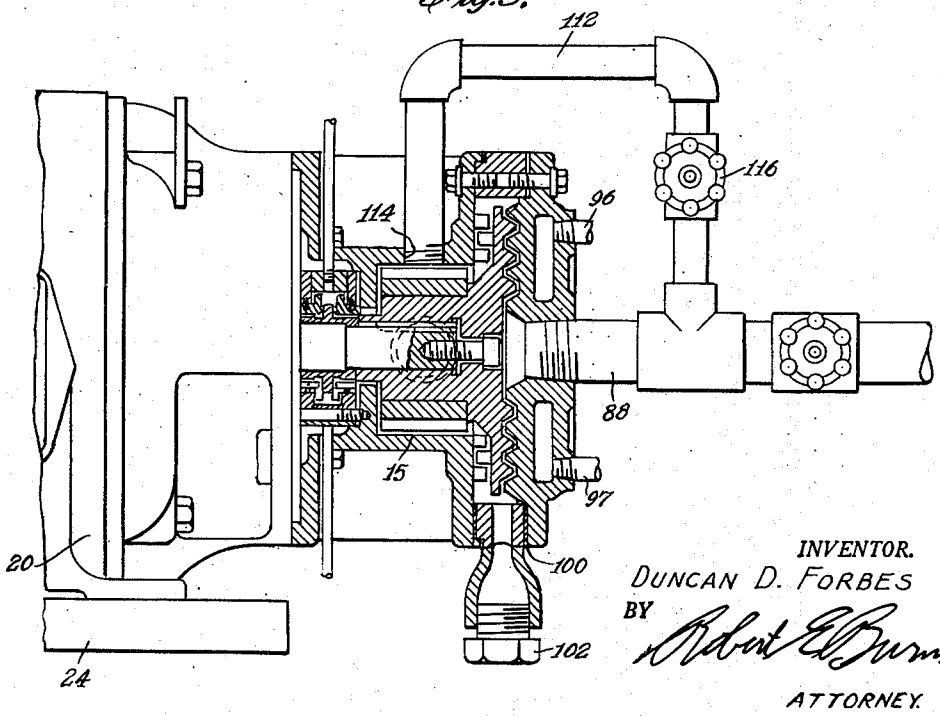



Fig. 5.




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DISPERSING APPARATUS

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Fig. 6.

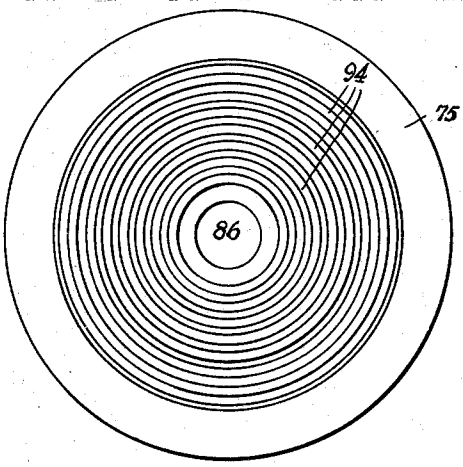



Fig. 7.

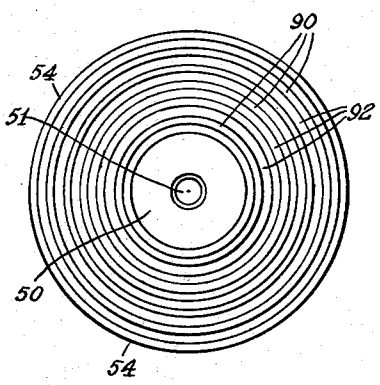



Fig. 8.

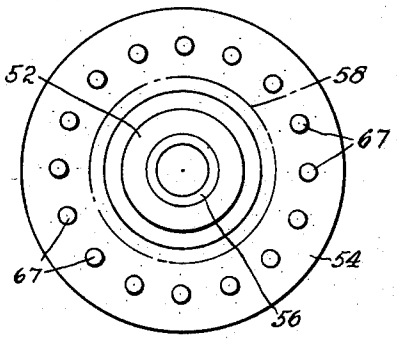



Fig. 9.

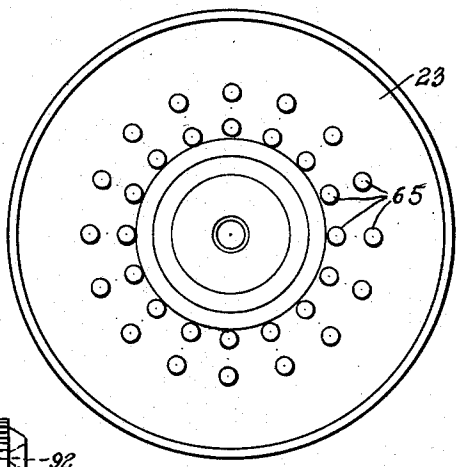
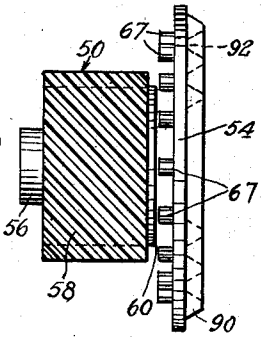



Fig. 10.




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Patented July 14, 1953

2,645,464

# UNITED STATES PATENT OFFICE

2,645,464

## DISPERSING APPARATUS

Duncan Davidson Forbes, Knoxville, Tenn., assignor to Micromax, Inc., New York, N. Y., a corporation of New York

Application November 1, 1950, Serial No. 193,392

5 Claims. (Cl. 259—9)

1

This invention relates to an improved method for the production of dispersions and to an apparatus by means of which the method may be advantageously carried out. Although not confined thereto, the invention is principally concerned with an improved method and apparatus for the production of dispersions of bituminous materials, such as asphalt, coal tar and the like, in aqueous media. While, for convenience, the invention will be described in connection with the production of aqueous dispersions of asphalt, it is to be understood that the method and apparatus of the invention are not restricted thereto and, in fact, have a wide range of utility, as will be pointed out more fully hereinafter.

In Patent No. 2,055,612 of September 29, 1936, there is disclosed a method and apparatus for making emulsions, such as aqueous asphalt emulsions, wherein the material to be emulsified, water, and the emulsifying agent are subdivided and introduced into a flowing stream of a previously-formed emulsion which is continuously recirculated within the dispersing apparatus. The emulsion issuing from the emulsifying zone enters a circulating chamber from which a portion is removed as finished product and the remainder recirculated to the emulsifying zone to receive fresh stock to be emulsified. While reasonably satisfactory throughput rates may be realized according to the process and apparatus of my said patent, the necessity for recirculation of a large volume of material is a limiting factor. Further, by reason of the recirculation, the conditions in the emulsifying zone are to a large extent affected by the properties of the recirculated stream of finished emulsion and are hence not subject to complete control.

It is an object of the present invention to provide an improved method of forming dispersions, particularly aqueous dispersions of asphalt.

It is a further object of the invention to provide an improved apparatus wherein complete and efficient dispersion may be effected in a single pass through the apparatus.

It is a still further object of the invention to provide a method and apparatus wherein dispersion of the material may be effected under optimum dispersing conditions, and products of desired properties produced.

The method and apparatus of the present invention differ in substantial respects from those described in my previous patent and the differences make possible the production of improved dispersions at substantially greater output rates.

According to my improved method, the materials to be treated, for example, liquefied asphalt and an aqueous suspension of clay or other dispersing agent, are each continuously introduced into a primary dispersing zone and simultaneously brought in contact with a shearing surface which subdivides the entering liquid streams and impels them forward with a rapid circular rolling motion, forming a forwardly-moving relatively-thin rotating annular stream. The annular stream is then suddenly diverted outwardly into a secondary dispersing zone and the circular motion is essentially stopped, with the result that a high degree of turbulence is imparted to the forwardly impelled liquid mass. The turbulent material is forced outwardly and its direction of movement is changed, as by pins or projections extending into the stream, to impart added turbulence. Preferably, the direction of movement of the stream is successively changed in alternately opposite directions. Thus, the stream in its outward progression through the secondary dispersing zone is subjected to repeated change of direction. This creates a high degree of turbulence and effects a completion of the dispersing operation initiated in the primary dispersing zone.

The formation of the dispersion is thus brought about in a single pass. The dispersion may be removed as product from the secondary dispersing zone. Preferably, however, I pass the dispersion through a refining zone. Thus, in the third stage of my process the outward movement of the stream in the secondary dispersing zone is reversed and the stream is moved inwardly through the refining zone in a thin, undulating stream. In the refining zone, lateral movement at right angles to its forward movement is imparted to one face of the thin stream with the result that a stream-line shear of the mass moving through the refining zone is effected. The refined product is removed from this zone. The dispersion may be advantageously treated before it is discharged, either from the secondary dispersing zone or from the refining zone. It is advantageous, for example, to adjust the pH of the dispersion to an optimum value, to add a stabilizer, e. g. casein or otherwise to modify the properties of the dispersion.

In one form of my improved apparatus, the shearing surface acting upon the incoming materials is provided by helical blades arranged to be rapidly rotated in a cylindrical chamber which forms the primary dispersing zone. The streams of materials to be dispersed are directed against these blades, which shear away the forward por-

tions of the streams and divide the sheared portions into smaller streams which are given a rapid circular rolling motion and are simultaneously thrown against the inner wall of the cylindrical dispersing chamber by the action of centrifugal force. The secondary dispersing zone extends radially from the cylindrical chamber containing the helical blades and is defined by a flange formed on the end of the blade-carrying rotor and a radially-extending wall of the apparatus. Projections extending inwardly from this wall and from the opposed face of the rotor flange effect the change in direction of movement of the stream being treated which results in the high degree of turbulence and mechanical action which completes the dispersing operation. The refining zone is defined by the ridged outer face of the rotor flange and a cover member which has ridges complementing those on the flange. The flange and the cover member are closely juxtaposed so as to force the dispersion to form a thin, undulating stream.

Other objects and features of the invention will be apparent from the following detailed description thereof and from the drawings, wherein:

Fig. 1 is a side elevation, partly in section and partly broken away, of an illustrative embodiment of my improved apparatus;

Fig. 2 is a similar view of the apparatus illustrated in Fig. 1 and showing the relative relationship of the dispersing mechanism and the driving means;

Fig. 3 is a plan view of the arrangement shown in Fig. 2;

Fig. 4 is a side elevation partly in section of a modified form of the apparatus;

Fig. 5 is a similar view of another embodiment of the apparatus of the invention;

Fig. 6 is a plan view of the face plate of the apparatus shown in Fig. 1;

Fig. 7 is an end elevation of the rotor member of the apparatus;

Fig. 8 is an elevational view of the inner surface of the rotor flange;

Fig. 9 is an elevational view of the wall of the flange portion of the apparatus casing; and

Fig. 10 is an elevational view of the rotor of the machine showing the pitch of the helical blades.

Referring more in detail to the drawings and in particular to Fig. 1, the body portion of the dispersing apparatus illustrated is designated generally by the numeral 15, and is formed at one end with a flange portion 16 secured, as by bolts 18, to the driving end of an electric motor 20 which is suitably mounted on any convenient platform or base 22. The hollow body portion 15 has an outwardly extending flange 23 on its free end and is formed with an inwardly-directed radial partitioning rib 25 which divides the interior of the body 15 and defines a seal chamber 26 and a primary cylindrical dispersing chamber 27. Inlet ports 28 and 29 are provided in opposite sides of body portion 15 to permit introduction of materials into the dispersing chamber 27 and suitable conduit pipes 30 and 31, connected to the sources of supply (not shown) of the material to be treated, e. g. the dispersing medium and the material to be dispersed, are threadedly engaged in inlet ports 28 and 29, respectively. The shaft 32 of the motor 20 extends through the seal chamber 26 into the primary dispersing chamber 27. In the seal chamber is a double liquid seal for preventing escape of fluids from the interior of body 15 around motor shaft 32 comprising a sleeve 33 mounted upon the shaft 32 and having a centrally positioned radial rib 34. The radial rib 34 is received between the faces 35 of the two ringed-shaped members of substantially L-shaped cross-section. The faces 35 are urged against the rib 34 by springs 36 seated in rings 37 which are separated by a spacer ring 38. The rings 37 and 38 are secured to the motor 20 and to the partitioning rib 25, as by bolts 40. Lubricant inlets 42 are positioned in apertures 44 formed in spacing ring 38 and provide means for supplying any convenient lubricant to the working parts of the seal.

Mounted upon the free end of the motor shaft 32 is the rotor 50 which is secured to the shaft, as by bolt 51. The rotor 50 has a main body portion 52, and a flanged end portion 54 which will be described more in detail hereinafter. An end portion 56 of reduced diameter extends through the aperture defined by partitioning rib 25 and bears against sleeve 33, acting as a stop to prevent axial movement of the rotor. The outer surface of the main body portion 52 of the rotor is provided with a plurality of radially-extending helical blades 58. It will be observed that the blades 58 are inclined at an angle, e. g. an angle of about 45°, and are arranged to impart a rotational movement to the materials entering the primary dispersing chamber 27 through inlet ports 28 and 29 and simultaneously to propel them in the direction of the flange portion 54 of the rotor 50 upon counter-clockwise rotation of the motor shaft 32, when viewed from the right hand end of Fig. 1. The outer edges of blades 58 terminate close to the inner surface of chamber 27, this spacing being such as to provide a clearance of approximately $\frac{1}{32}$''. It is a feature of the invention, however, that substantial wear of the blades may be tolerated without appreciably affecting the efficacy of the apparatus. While, if desired, the blades 58 may be formed integrally with the main body portion 52 of the rotor 50, in the embodiment shown they are separately formed and press-fitted upon body portion 52. Upon rotation of the shaft 32, the streams of materials entering through inlet ports 28 and 29 are subdivided by the helical blades 58 into a plurality of smaller streams which are then, under the influence of centrifugal force, thrown out against the surface wall of chamber 27 and are moved forwardly in the form of an annular stream, the materials being subjected at the same time to the shearing action of the edges of the blades 58. The blades 58, in combination with the wall of cylindrical dispersing chamber 27, thus create what may be described as a "rolling turbulence" in the forwardly-moving annular stream of materials, insuring effective mechanical mixing of the substances treated and bringing about dispersion of the insoluble substance in the dispersing medium.

It will be observed by reference to Fig. 1, that materials being moved to the right through chamber 27 will strike and be deflected radially outwardly by the rotor flange 54 and the circular motion of the stream will be stopped. The connecting surface 60 between flange 54 and the main body portion 52 of the rotor is outwardly sloping in order to decrease resistance to the moving stream. Extending inwardly from the inner face of body flange 23 are a plurality of projections 65 arranged in two spaced concentric circular rows, as may be clearly seen in Fig. 9. Similarly, extending outwardly from the rotor flange 54 are a plurality of rotor elements 67 arranged to be received in the circular space 68 between the two

concentric rows of projections 65. In the embodiment illustrated, the projections 65 and the rotor elements 67 are in the form of rods of circular cross-section suitably threaded in openings in the rotor flange 54 and the body flange 23, respectively. When my dispersing device is in operation, i. e. when the rotor flange 54 is rotated, the projections 67 will, of course, be caused to move continuously past the stator projections 65 and will impart lateral motion to the materials moving radially outwardly from the dispersing chamber 27 in the annular channel 70 defined between the wall of body flange 23 and the inner surface of rotor flange 54. It will be apparent that when the annular stream issuing from chamber 27 engages the rotor flange 54 and is directed outwardly in a direction at right angles to its former direction of movement, a great degree of turbulence will be created. The turbulent mass will then be moved outwardly under the combined influence of centrifugal force and the pressure from the materials in chamber 27 and will be engaged alternately by stator projections 65 and the rotor projections 67 which will impart motion to the mass at right angles to its radial direction of movement. The inner row of projections 65 will tend to stop the rotational movement of material, the rotor elements 67 will drive the material in rotational direction and the outer row of projections 65 will again tend to stop the rotational movement of the materials. The material will thus be subjected to alternate successive changes in direction of movement. This portion of the apparatus thus defines a secondary dispersing zone wherein the dispersing operation initiated in the primary dispersing zone, i. e. in chamber 27, is completed. While, as indicated, the rotor projections 67 and the stator projections 65 in the embodiment illustrated are in rod form, they may be in any convenient form which will have the effect of interrupting the outward flow of materials through channel 70.

The outlet end of my dispersing apparatus is closed by a face plate or end member 75 which is bolted, as by bolts 76, to a ring member 78 which in turn is secured, as by bolts 80 to the outer end of the body flange 23. A gasket 81 is provided between the ring member 78 and the outwardly-directed face of flange 23, and a gasket or shim 85, apertured to permit passage of bolts 76 separates plate 75 from ring 78. An axial outlet port 86 is formed in plate 75 in which may be threadedly engaged a conduit pipe 88 for conducting away the finished product discharged through the outlet port 86. Referring to Figs. 1, 8 and 9 the opposed surfaces of the rotor flange 54 and the plate 75 are formed with complementary projections. Thus, the outer face of rotor flange 54 is formed with a series of concentric ridges 90 having a substantially trapezoidal cross-section and spaced to define valleys 92 of similar trapezoidal cross-section. Similarly, the end plate 75 is formed with a plurality of ridges 94 of like trapezoidal cross-section and arranged to be received in the valleys 92. These opposed ridged surfaces define a refining zone adapted for treating the dispersion leaving channel 70. To reach the outlet port 86, the materials forced outwardly through channel 70 will pass in the form of a thin undulating stream inwardly toward port 86 between the complementary surfaces of the ridges 90 and 94. Since this movement will be against centrifugal force, a substantial pressure will be developed and the undulating film of material will be subjected to stream-line shear which will effect a refining action upon the material and serve to reduce further the particle size of the dispersed phase of the dispersion. It will be obvious that one surface of the undulating stream will flow over a stationary surface while the other face will be in contact with a rotating surface. This combination of surfaces acting upon the moving thin film of dispersed material effects the stream-line shearing action which is responsible for the high effectiveness of my device.

The clearance between the opposed ridged faces of the rotor flange 54 and the end plate 75 is readily adjusted by varying the thickness of the gasket or shim 85. Thus, the degree of refining may be easily controlled. Furthermore, in order to insure continuous flow toward outlet port 86 and in order to avoid any unnecessary restriction of the material, the surface of the inner ridges 90 of the rotor flange 54 are partly reduced in height, as clearly shown in Fig. 1.

In order to permit temperature control of the material passing over the inner surface of end plate 75, this member is formed with an inner compartment 95 through which a heating or cooling medium may be circulated, an inlet and an outlet for the heat transfer medium being provided at 96 and 97, respectively.

While, as previously mentioned, in the preferred embodiment of my invention, I pass the dispersion through the refining zone, I may for some purposes desire to remove the material from the apparatus at the end of the dispersing operation, i. e. at the outlet of the secondary dispersing zone. For this purpose I provide an outlet port 100 in ring 78 which is advantageously closed by a plug 102 when not in use but which may readily be connected to a conduit pipe 104.

In addition, while it is a feature of my invention that by my process and apparatus I effectively produce a high-quality dispersion in a single pass, without recirculating any of the product to the dispersing zone, I advantageously make suitable provision for recirculating the discharge from the secondary dispersing zone to the primary dispersing zone. Thus, referring to Fig. 4, I provide a pipe 106 arranged to communicate through an aperture 108 with the interior of primary dispersing chamber 27 and I provide a connection between pipe 106 and pipe 104. A valve 109 controls the quantity of material recirculated. I also provide a valve 110 for controlling the discharge of material from the secondary dispersing zone.

I may also provide means for recirculating a portion of the defined product issuing from outlet port 86 to the primary dispersing zone, i. e. the chamber 27. As shown in Fig. 5, for this purpose I provide a pipe line 112 connecting pipe 88 with an aperture 114 in the wall of chamber 27, a valve 116 being inserted in the line 112 to control the quantity of material to be circulated.

As I have indicated, it is a feature of the invention that the dispersed product may be suitably treated to adjust its characteristics before it is discharged from the unit without, however, thereby changing the operating conditions prevailing in the dispersing zone. It is known, for example, that an aqueous dispersion of asphalt is more effectively formed at a higher pH than is desired in the final product. For example, the optimum pH for forming the dispersion may be 10, while the optimum pH desired in the finished product may be 7. Similarly, a stabilizing agent, such as casein, may be necessary in the final dispersion but may interfere with the effective

formation of the dispersion if present during the initial stages of the dispersing operation. In accordance with my invention, I may suitably treat the dispersion produced to give it the desired characteristics, as by adjusting its pH or by adding any desired stabilizing agent, just prior to its discharge from the apparatus, without affecting the conditions of dispersion in the dispersion zone. For this purpose, the adjusting materials may be suitably introduced under pressure through pipe 104.

In the operation of my improved apparatus, for example in the formation of an aqueous asphalt dispersion employing an argillaceous emulsifying agent, the asphalt, previously liquefied as by heating in any convenient means, is conducted through conduit 30 into inlet port 28, and an aqueous suspension or "slip" of clay, e. g. bentonite, is carried by conduit 31 into inlet port 29. The streams of asphalt and clay slip, introduced under pressure, are fed directly against helical blades 58 which are driven, as by motor 20, at a high rate of speed, e. g. 3600 R. P. M. The streams of asphalt and clay slip are sheared by the blades and subdivided into a plurality of smaller streams, and these subdivided streams are simultaneously propelled out from between the blades by the action of centrifugal force and thrown against the wall of chamber 27 in the form of a thin annular stream to which is imparted a circular motion. This annular stream is acted upon by the ends of the blades 58, resulting in a smearing action which shears the asphalt into small particles and the creation of a rolling turbulence. The blades 58 at the same time propel the annular stream forwardly toward the flange portion 54 of the rotor, i. e. toward the right as viewed in Fig. 1. As the stream strikes the rotor flange and is diverted outwardly at right angles to its previous direction of flow, the circular motion of the stream is interrupted and a high degree of turbulence is created. This turbulent mass is then directed outwardly through channel 70 under the combined influence of centrifugal force and the pressure of the materials issuing from chamber 27. As the turbulent stream moves outwardly through channel 70, portions of it are successively moved laterally at right angles to the outward direction of flow, first by the inner row of projections 65 on the body flange, then by the rotor 67 which reverse the lateral movement of the material, and then by the outer row of projections 65 which again stop the lateral direction of flow. This action completes the dispersion of the asphalt in the aqueous medium. As the material issuing from channel 70 strikes the ring member 78 it is directed inwardly between the opposed faces of the rotor flange 54 and the end plate 75, toward the outlet port 86. As the material moves inwardly toward outlet port 86, it is constrained to flow as a relatively thin undulating film, one surface of which is in contact with the stationary ridged face of the end plate 75 while the other surface is in contact with the rotating ridged face of the rotor flange 54, which tends to impart a rotary movement to the film. This action effects a stream-line shearing of the dispersed particles, i. e. the particles of asphalt, and causes a subdivision of these particles to a fine particle size to produce a high-grade dispersion.

When it is desired to adjust the properties of the dispersion prior to its removal from the unit, e. g. to adjust pH, or to add stabilizers, e. g. casein, or diluting agents, e. g. water, the necessary adjusting materials are introduced, under pressure, through conduit 104. The adjusting materials enter outlet port 100 and are rapidly and efficiently mixed into the dispersion by the rotor flange 54. Instead of using outlet port 100 for the introduction of dispersion adjusting materials, I may advantageously provide a second port 115 (Fig. 4) in ring member 78, disposed for example, radially opposite port 100, and use this second port for the introduction of pH adjusters, diluents, stabilizers and like materials. This permits the use of port 100 for the recirculation or discharge of materials from the secondary dispersing zone.

While, as previously indicated, my invention permits the formation of dispersions without the necessity of recirculating any of the dispersed material through the dispersing zone, yet it permits the operation to be carried on with controlled recirculation in circumstances when such operation is desirable. This is done by adjusting either or both of the valves 109 and 116 to allow some of the treated material to pass into chamber 27 in contact with blades 58. My apparatus is thus characterized by operational flexibility and accordingly has wide utility.

The operation of my process and apparatus has been described with particular reference to the formation of aqueous asphalt emulsions, but my invention is also eminently suited for the production of other types of dispersions such as lubricating greases, solvent cutbacks of bitumens and the like. In the manufacture of lubricating greases, the soap and oil may be rapidly and effectively dispersed and blended to form a superior product. The mixing of solvents with asphalt, resins and the like to form solvent cutbacks is, according to my invention, similarly effected in a rapid, efficient manner. My invention may also, for example, be employed in the dispersion of carbon black in paints or in aqueous vehicles.

It will be apparent that various changes may be made without departing from the scope of the invention as defined in the appended claims and it is intended that the foregoing description and the drawings shall be interpreted as illustrative and not in a limiting sense.

What I claim and desire to secure by Letters Patent is:

1. Dispersing apparatus which comprises, in combination, a chamber, inlet means in said chamber for the materials to be treated, an outwardly extending flange at one end of said chamber, a rotor in said chamber having a flange portion parallel to said flange and spaced therefrom to define an annular channel therebetween, a plurality of spaced helical blades extending radially from said rotor in said chamber, said blades being pitched to propel materials introduced into said chamber in an annular stream toward said channel, a plurality of spaced studs projecting axially from the stator flange into proximity to the rotor flange and a plurality of spaced studs projecting axially from the rotor flange into close proximity to said stator flange, said studs being so disposed that the studs on the rotor flange pass close to the studs of the stator flange as the rotor rotates, plate means parallel to and spaced from said flange in fluid-tight relationship whereby to enclose said rotor, concentric ridges on the inner wall of said plate means and concentric ridges on the outer face of said rotor flange arranged to complement said first-named ridges and to form therewith an undulant path for the materials flowing from

said channel, and outlet means in said plate means.

2. Dispersing apparatus which comprises, in combination, a chamber, inlet means in said chamber for the materials to be treated, an outwardly extending flange at one end of said chamber, a rotor in said chamber having a flange portion parallel to said flange and spaced therefrom to define an annular channel therebetween, a plurality of spaced helical blades extending radially from said rotor in said chamber, said blades being pitched to propel materials introduced into said chamber in an annular stream toward said channel, stator elements extending inwardly from said flange into said annular channel, projections extending inwardly from said rotor flange portion into said channel, plate means parallel to and spaced from said flange in fluid-tight relationship whereby to enclose said rotor, concentric ridges of substantially trapezoidal cross-section on the inner wall of said plate means and concentric ridges of substantially trapezoidal cross-section on the outer face of said rotor flange arranged to complement said first-named ridges and to form therewith an undulant path for the materials flowing from said channel, and outlet means in said plate means.

3. In dispersing apparatus, a stator comprising a chamber, inlet means in said chamber for the materials to be treated, an outwardly extending flange at one end of said chamber, a cover plate secured to the periphery of said flange and having a portion spaced from said flange to form an annular channel, a rotor having a portion disposed in said chamber and an outwardly projecting annular flange disposed in said channel, a plurality of spaced helical blades projecting radially from the rotor portion in said chamber into close proximity to the chamber walls, said blades being pitched to propel materials introduced into said chamber in an annular stream toward said channel, a plurality of spaced studs projecting axially from the stator flange into proximity to the rotor flange and a plurality of spaced studs projecting axially from the inner face of the rotor flange into close proximity to the stator flange, said studs being arranged in circular rows with a row on one of said flanges interposed between rows on the other of said flanges so disposed that the studs on the rotor flange pass close to the studs on the stator flange as the rotor rotates, a plurality of spaced annular ridges of trapezoidal cross-section on the outer face of the rotor flange, said ridges being concentric with the axis of rotation of the rotor, a plurality of mating concentric annular ridges on the inner face of said cover substantially filling the spaces between the ridges on said rotor flange with clearance between the mating ridges, means for adjusting the clearance between the rotor flange and the cover plate and outlet means for the treated material in the central portion of said cover plate.

4. In dispersing apparatus, a stator comprising a chamber, inlet means in said chamber for the material to be treated, an outwardly extending flange at one of said chamber, a cover plate secured to the periphery of said flange and having a portion spaced from said flange to form an annular channel, a rotor having a portion disposed in said chamber and an outwardly projecting annular flange disposed in said channel, a plurality of spaced studs projecting axially from the stator flange into proximity to the rotor flange and a plurality of spaced studs projecting axially from the inner face of the rotor flange into close proximity to the stator flange, said studs being arranged in circular rows with a row on one of said flanges interposed between rows on the other of said flanges so disposed that the studs on the rotor flange pass close to the studs on the stator flange as the rotor rotates, a plurality of spaced annular ridges of trapezoidal cross-section on the outer face of the rotor flange, said ridges being concentric with the axis of rotation of the rotor, a plurality of mating concentric annular ridges on the inner face of said cover substantially filling the spaces between the ridges on said rotor flange with clearance between the mating ridges, means for adjusting the clearance between the rotor flange and the cover plate and outlet means for the treated material in the central portion of said cover plate.

5. In dispersing apparatus, a stator having an annular flange portion, a cover plate secured to said flange at its periphery and having an inner circular portion spaced from said flange to form an annular channel, inlet means for admitting the material to be treated into said channel, a rotor having an annular flange disposed in said channel, a plurality of spaced studs projecting axially from the stator flange into proximity to the rotor flange and a plurality of spaced studs projecting axially from the inner face of the rotor flange into close proximity to the stator flange, said studs being arranged in circular rows with a row on one of said flanges interposed between rows on the other of said flanges so disposed that the studs on the rotor flange pass close to the studs on the stator flange as the rotor rotates, a plurality of spaced annular ridges of trapezoidal cross-section on the outer face of the rotor flange, said ridges being concentric with the axis of rotation of the rotor, a plurality of mating concentric annular ridges on the inner face of said cover substantially filling the spaces between the ridges on said rotor flange with clearance between the mating ridges, means for adjusting the clearance between the rotor flange and the cover plate and outlet means for the treated material in the central portion of said cover plate.

DUNCAN DAVIDSON FORBES.

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| 2,055,512 | Robinson | Sept. 29, 1936 |
| 2,094,548 | Meeker | Sept. 28, 1937 |
| 2,526,598 | Barrett et al. | Oct. 17, 1950 |