

[72] Inventor **Harry C. Fischer**
 Goose Neck Rd., Royal Oak, Md. 21662
 [21] Appl. No. **692,417**
 [22] Filed **Dec. 21, 1967**
 [45] Patented **Dec. 29, 1970**

2,774,626	12/1956	Gerbracht	239/157
2,983,506	5/1961	Bertsch et al.	285/356
3,233,920	2/1966	Ammann	285/356
3,044,712	7/1962	Tanke	239/155
3,233,832	2/1966	Hallberg	239/155
3,085,364	4/1963	Chapin	239/65X

Primary Examiner—Lloyd L. King
 Attorney—Birch and Birch

[54] **ULTRA-LOW VOLUME SPRAYING APPARATUS
 AND SYSTEMS FOR INSECTICIDES AND THE
 LIKE**
 15 Claims, 11 Drawing Figs.

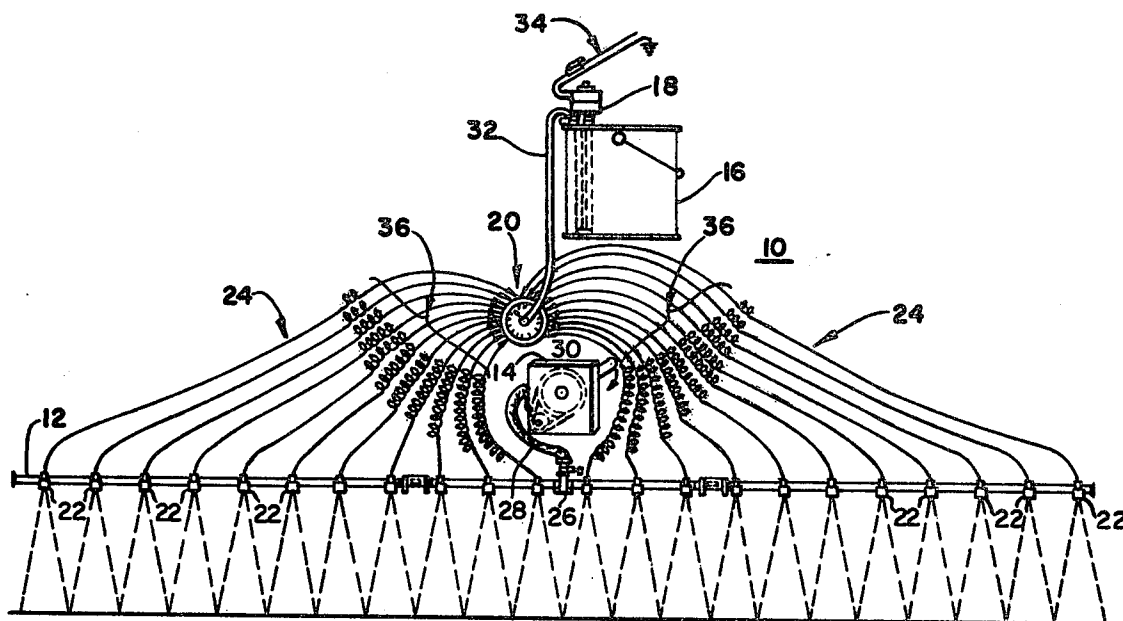
[52] U.S. Cl. 239/155,
 239/124, 239/143, 239/158, 239/550, 239/569
 [51] Int. Cl. B05b 9/06
 [50] Field of Search 239/155,
 158, 124, 143, 550, 569; 285/356, 353, 338

[56] **References Cited**

UNITED STATES PATENTS

2,357,141	8/1944	Singleton	239/158
2,770,494	11/1956	Nelson	239/158

ABSTRACT: Systems and apparatus effecting direct delivery of highly concentrated liquid chemicals and the like to pneumatic spray nozzles are provided wherein individual capillary tube feed from a central chemical reservoir and valve manifold is utilized to control the volume flow of chemical to the spray nozzles. The spray nozzles are normally mounted on an ambulatory boom for overlapping spray pattern delivery and have a common compressed air supply. The capillary tubes have inside diameters which are small relative to the outside diameters and the volume flow of chemical therethrough at a given pressure is directly proportional to tube length.



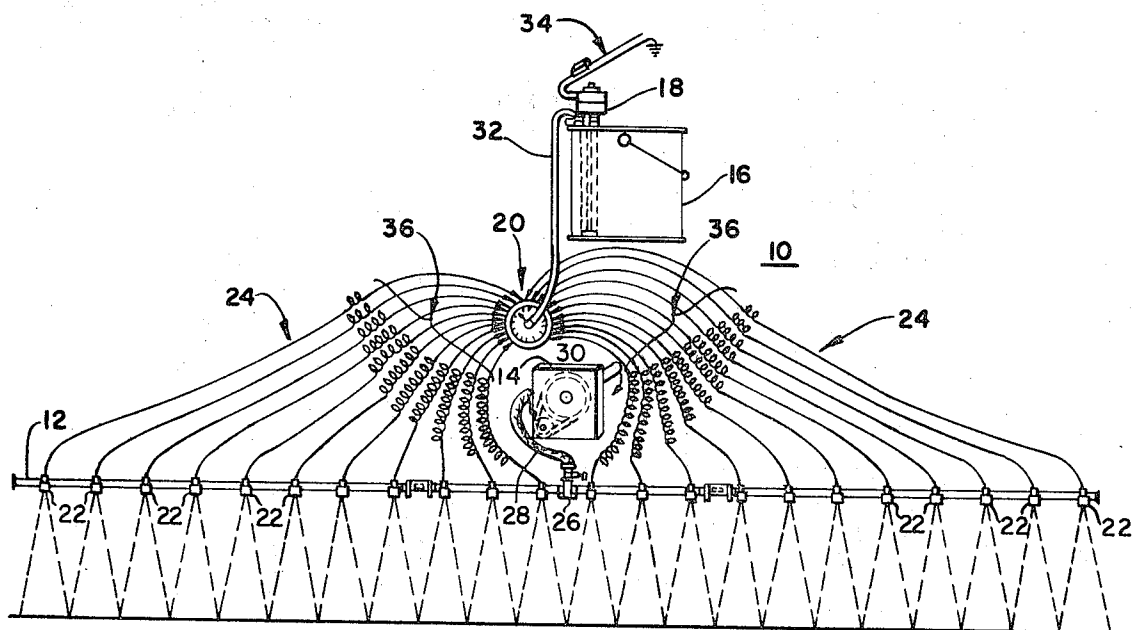


FIG. 1.

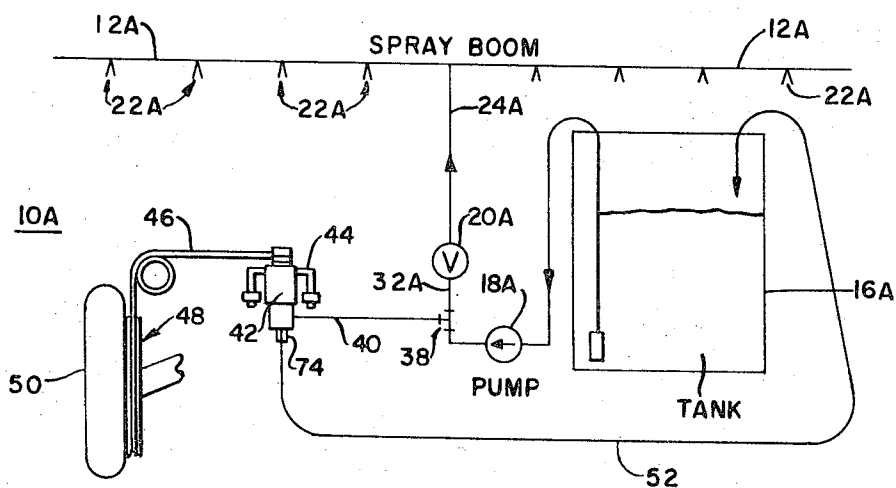


FIG. 2.

INVENTOR
Harry C. Fischer

BY *Birch and Birch*

ATTORNEYS

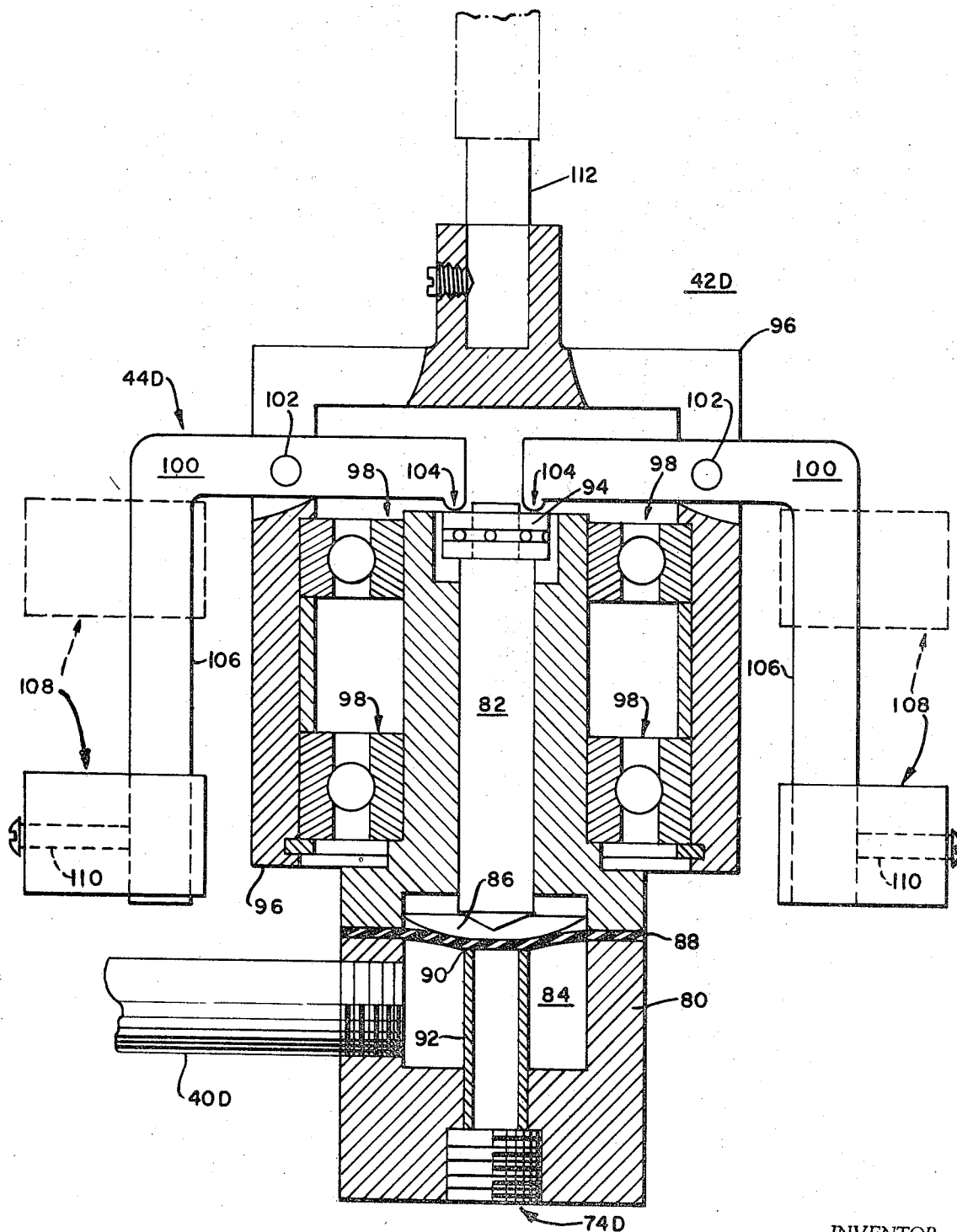


FIG. 5.

INVENTOR
Harry C. Fischer

BY *Birch and Birch*

ATTORNEYS

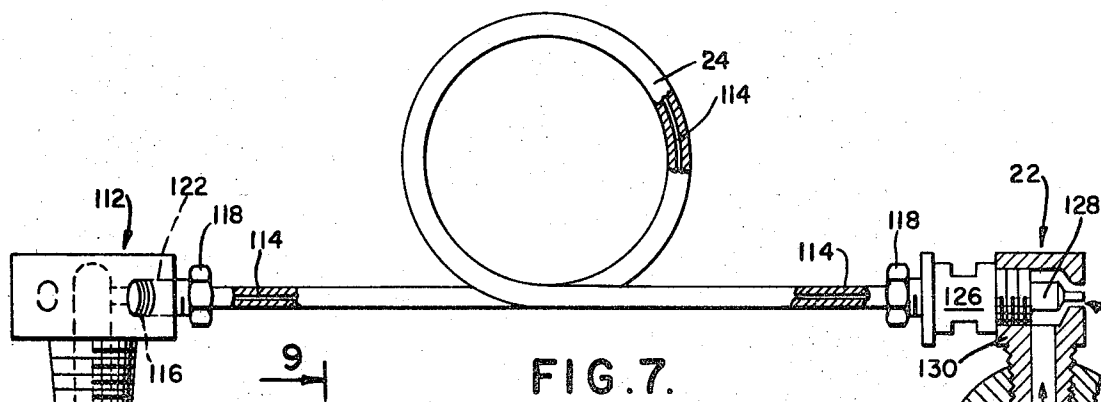


FIG. 7.

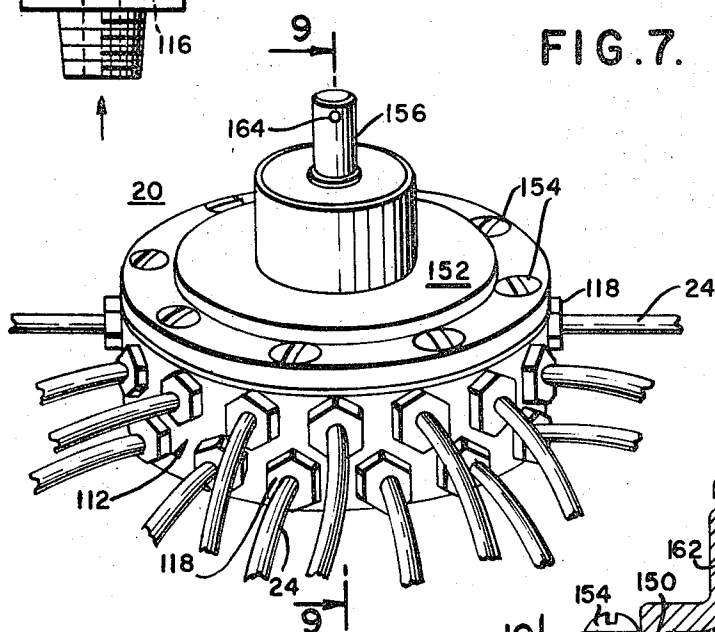


FIG. 8.

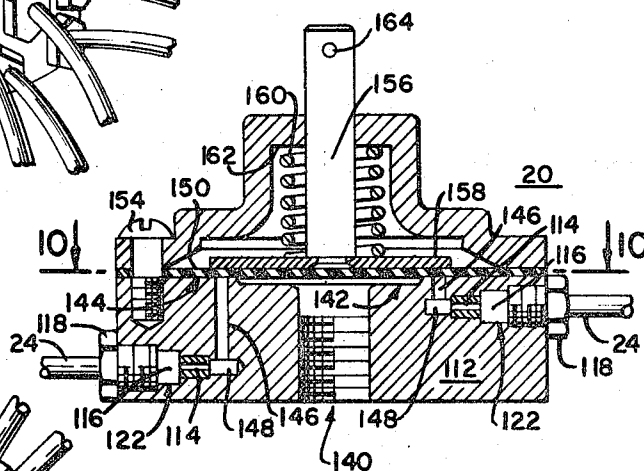


FIG. 9.

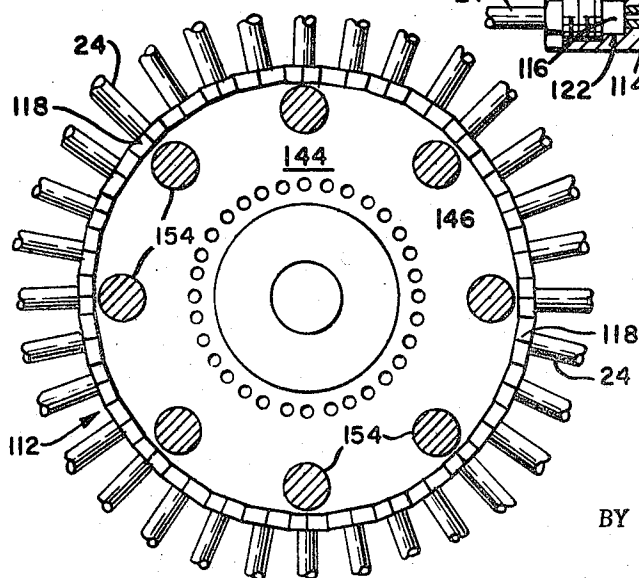


FIG. 10.

INVENTOR
Harry C. Fischer

BY *Birch and Birch*

ATTORNEYS

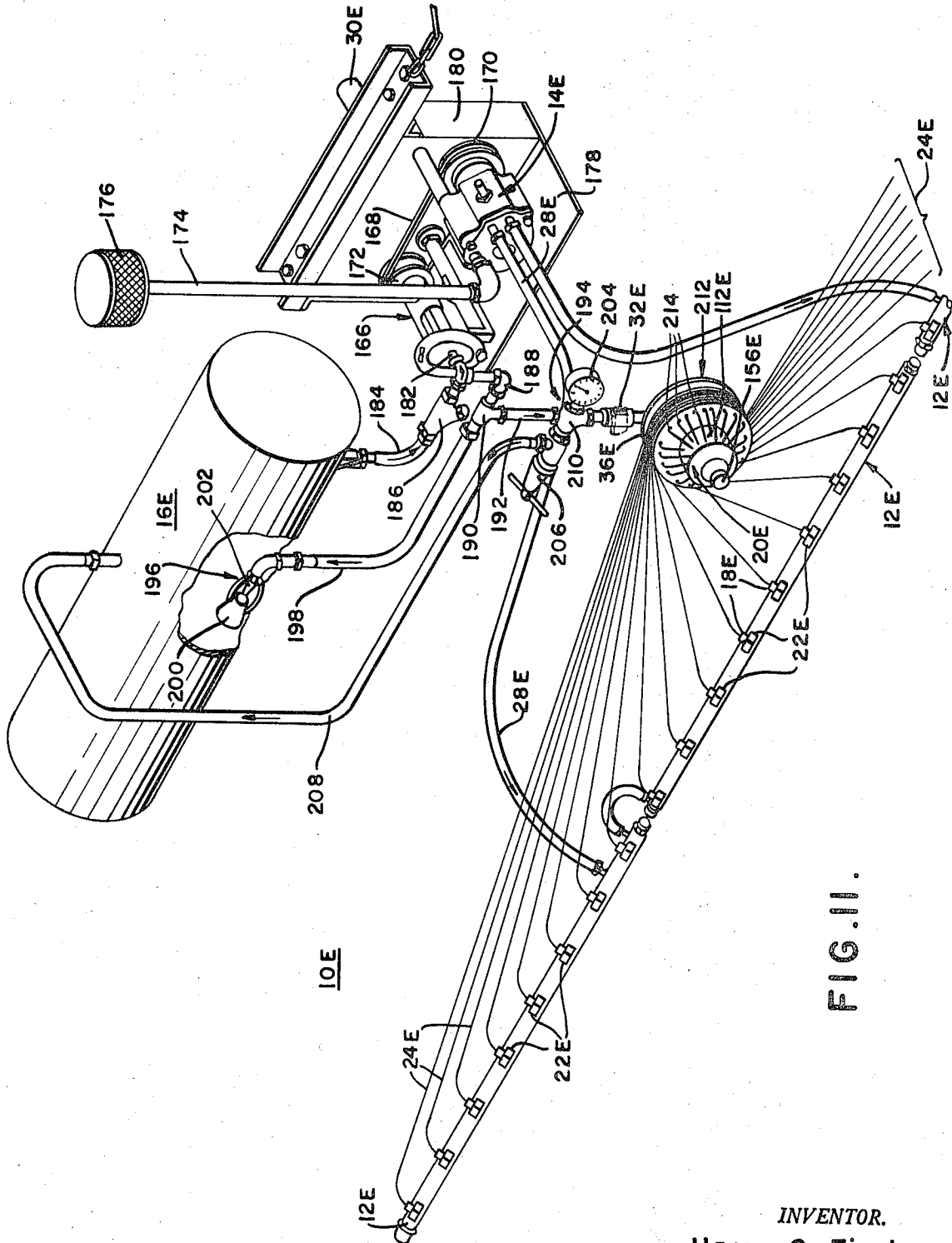


FIG. 11.

INVENTOR.
 Harry C. Fischer
 BY
Birch and Birch
 ATTORNEYS

ULTRA-LOW VOLUME SPRAYING APPARATUS AND SYSTEMS FOR INSECTICIDES AND THE LIKE

This invention relates to apparatus and systems for spraying fluent chemicals and more particularly to apparatus and systems for spraying concentrated chemical solutions, suspensions, and the like in ultra-low volume quantities, precluding both the need for dilution and the loss of chemical for the purpose of precharging known spraying systems.

In the agricultural industry, the spraying of crops and the like with pesticides or other chemical agents is besought with problems of inefficiency, waste and attendant unnecessarily high cost.

Two basic systems are generally employed for the purpose of chemical spraying.

One example is a hydraulic system using conventional dilute chemical spray suspensions or solutions, with either oil or water as the carrying agent for the effective chemical agent. This type of system has the disadvantages of high cost of equipment, large bulk and weight of the equipment which make same difficult to handle in soft field areas, or insufficient carrying capacity when bulk and weight are reduced.

The other type system in general use is a pneumatic system which uses air as the carrying and atomizing agent for the active chemical.

The bulk and weight factor is a lesser problem with this type system but relatively large quantities of chemicals must, of necessity, remain in such systems after spraying operations since the spray nozzles have heretofore been fed by relatively large volume conduits and the like.

When concentrated chemicals are used in solutions or suspensions selling for a large cost per gallon, and several gallons must be used merely to charge the system to permit spraying, the cost and waster problems become acute.

The present invention obviates such cost and waste problems by drastically reducing the volume of chemicals in the spraying system between the main chemical reservoir and the spray nozzles.

All prior art systems of practical size have the attendant problem of downtime to refill chemical reservoirs. The present invention minimizes such downtime and provides steady spraying intervals of, for example, 4 to 8 hours without the need for refilling.

Further, the present invention provides new and novel flow control techniques which preclude chemical leakage and system corrosion and provides linear flow control.

Still further, mixing of and/or container transfer of dangerous chemicals can be precluded and problems of chemical contamination are minimized.

The problem of handling highly concentrated or high strength pesticides becomes readily apparent when it is considered that such chemicals as Di Brom and Malathion have effective applications rates in the range of one (1) ounce to sixteen (16) ounces per acre of crops.

The present invention makes direct application of such quantities possible without dilution of the chemicals.

It is, therefore, an object of this invention to provide a new and novel spraying apparatus and system for ultra-low volume (ULV) spraying of chemicals and the like, ULV being flow rates resulting in deposition of chemicals in the amount of one (1) gallon or less per acre of crop area.

It is another object of this invention to provide new and novel pneumatic spraying apparatus and systems utilizing ganged spray nozzles and effecting ULV chemical flow rates in such apparatus and systems.

Another object of this invention is to provide new and novel chemical metering means for ULV pneumatic spraying apparatus.

Still another object of this invention is to provide new and novel simultaneous flow control means for a plurality of chemical delivery lines to a like plurality of spray nozzles to preclude leakage loss of dangerous and/or expensive chemicals.

Yet another object of this invention is to provide new and novel ULV pneumatic spraying apparatus and systems wherein the amount of chemical in the systems between the main reservoir and the spray nozzles is optimally minimized.

These and other objects of this invention will become more fully apparent with reference to the following specification and drawings which relate to several preferred embodiments of this invention.

In the drawings:

FIG. 1 is a schematic of a first embodiment of a pneumatic ULV spraying system and apparatus incorporating a pump drive for the chemical to be sprayed;

FIG. 2 is a schematic of a modification of the embodiment of FIG. 1 in which the flow rate of chemical is controlled by the ground speed of the ambulatory system;

FIG. 3 is a schematic of a second embodiment of the invention incorporating a pneumatic pressure drive of the chemical to be sprayed;

FIG. 4 is a schematic of a ground-speed controlled flow rate modification of the embodiment of FIG. 3;

FIG. 5 is a cross section of a ground speed responsive governor valve for the embodiments of FIGS. 2 and 4;

FIG. 6 is an exploded detail of a capillary metering tube, nozzle and interconnecting means of the present invention;

FIG. 7 is a detail view of a capillary metering tube, manifold connection and nozzle assembly of the present invention;

FIG. 8 is a perspective of a manifold valve assembly and interconnected capillary metering tubes of the present invention as utilized in FIGS. 1, 2, 3 and 4;

FIG. 9 is a cross section taken along line 9-9 of FIG. 8;

FIG. 10 is a cross section taken along line 10-10 of FIG. 9, and

FIG. 11 is a perspective of a fifth embodiment of a chemical pumping and spraying system of the present invention which is particularly well-adapted to spraying wettable powders in slurry or suspension form.

THE SYSTEMS

Referring in detail to the drawings, and more particularly to FIG. 1, one basic system 10 of the present invention is shown as comprising a spray boom 12 mounted on a tractor or the like (not shown), an air compressor 14, a chemical reservoir 16, a chemical pump 18, a manifold valve 20, spray nozzles 22 spaced along the boom 12, and a plurality of capillary metering tubes 24 each extending from the manifold valve 20 to one of the individual spray nozzles 22.

The spray boom 12 comprises a hollow conduit (as illustrated in FIG. 7) and is connected through a pneumatic coupling 26 and supply line 28 to the output of the air compressor 14, the latter being driven by a power takeoff shaft 30.

The manifold valve 20 is supplied with chemical under pressure through a chemical supply line 32 which is connected to the controlled pressure output of the chemical pump 18, the latter being shown as an electrically energized pump with power leads 34.

All of the capillary metering tubes 24 are of substantially identical length, the respective lengths being equally varied to achieve selectively desired flow rates. Since the metering tubes 24 are flexible tubes of polyethylene, nylon, or the like, they are adapted to be contained in coils or other faked configurations 36, the length of tubing 24 in the inboard coils 36 being greater than that in the outboard coils 36 leading to the spray nozzles 22 on the spray boom 12.

Referring next to FIG. 2, wherein like parts to the embodiment of FIG. 1 carry like numerals with the suffix A, a modification of the chemical supply circuit of the embodiment of FIG. 1 will now be described.

A T-joint 38 is placed in the chemical supply line 32A between the pump 18A and the manifold valve 20A, providing connection for a branch line 40 leading to the input side of a bypass regulator valve 42.

The regulator valve 42 includes a fly-ball governor mechanism 44 which is driven by a belt 46 and pulley 48 combination or the like from a ground wheel 50 on a tractor or other vehicle (not shown) carrying the spray system 10A.

The outlet of the regulator valve 42 is connected through a bypass return line 52 which returns bypassed chemicals to the chemical reservoir or container 16A.

As will be hereinafter more fully described, the pressure or delivery force and flow rate of the chemical from the container 16A to and through the manifold valve 20A and the capillary metering tubes 24A (schematically shown as a single flow line) is controlled by the ground speed of the ground wheel 50 through the speed responsive action of the regulator valve 42 and fly-ball governor 44.

Referring next to FIG. 3, another embodiment of the invention will now be described in which the chemical feed is effected by pneumatic pressure instead of by pumping and wherein like parts to the embodiment of FIG. 1 carry like numerals with the suffix B.

In this embodiment, the spray system 10B is powered by the air compressor 14B through first and second pressure outputs 54 and 56, respectively.

The first pressure output 54 delivers air pressure to the boom 12B through the air supply line 28B and pressure coupling 26B. In this embodiment, and in all other embodiments of this invention, a pressure regulator valve 55 can be placed in the air supply line 28B (28, 28A, etc.) to selectively regulate the air pressure in the spray boom 12B (12, 12A, etc.).

The second pressure output 56 delivers air pressure into the chemical reservoir 16B through a second air supply line 58 and a reservoir manifold 60.

The manifold 60 includes a concentric feed-tube assembly 62-64 which includes an external air feed tube 62 supplied by the second air supply line 58 and an internal chemical egress tube 64 which lead directly to the metering tube manifold valve 20B. As indicated by the columns of bubbles 66 rising in the chemical in the reservoir tank 16B, the incoming air in the feed tube 62 is utilized to agitate the chemical in the reservoir tank 16B as will be hereinafter more fully described. A filter assembly 68 is provided over the outlet of the feed tube 62 and the inlet of the egress tube 64 to prevent contamination of the chemical solution and preclude egress of particles of excess size from the reservoir tank 16B through the egress tube 64. The filter assembly includes an elastomeric band or other one-way valve means 68' over the outlet of the feed tube 62 to prevent chemical from exhausting therethrough when the compressor stops.

The pressure manifold assembly 60 is completed by a calibrated pressure indicator 70 connected through a pressure port 72 with the pressure feed tube 62. By selective adjustment of a calibrated pressure relief valve 71 on the compressor 14B, the back pressure in the reservoir tank 16B can be precluded from exceeding a predetermined maximum.

Referring next to FIG. 4, wherein like parts to FIGS. 1, 2, and 3 carry like numerals with the suffix C, a ground speed controlled system will now be described for regulating the pressure in the reservoir tank 16C and hence, the rate of feed of the chemical therein.

As in the embodiment of FIG. 2, the capillary metering tubes 24C and the metering tube manifold valve 20C are only schematically shown.

The bypass regulator valve 42C has its outlet open to atmosphere as indicated at 74. The inlet of the regulator valve 42C is connected through the bypass lead 40C to a third compressor outlet 76 which communicates through an internal pressure port 78 with the air pressure supply line 58C.

With the calibrated relief valve 71C on the compressor 14C set for a predetermined maximum supply pressure within the reservoir tank 16C, the pressure in the feed line 58C is exhausted to atmosphere through the regulator valve 42C as a function of the ground speed of the ground wheel 50 to modulate the pressure in the reservoir tank 16C below the upper limit set by the calibrated relief valve 70C.

THE GROUND SPEED RESPONSIVE REGULATOR VALVE

The details of the ground speed responsive pressure regulator valves 42 and 42C will now be described with reference to FIG. 5, the said valve now bearing the numeral 42D and the fly-ball governor bearing the numeral 44D. Further, the inlet line to the valve 42D now bears the numeral 40D and is equivalent to the bypass lines 40 and 40C in the embodiments of FIGS. 2 and 4. Still further, the outlet of the regulator valve 42D now bears the numeral 74D and is equivalent to the return line connection 52 of FIG. 2 or the exhaust vent 74 of FIG. 4, as the case may be.

The valve 42D has a stepped, sectional cylindrical body or housing 80 which is bored to receive a valve stem 82, provide an enlarged valve chamber 84 which receives an actuator button 86 mounted on the lower end of the valve stem 82, and secure a valve diaphragm 88 in position across a combined annular valve seat 90 and exhaust conduit 92, the latter two elements being coaxial with the valve stem 82.

The valve inlet connection 40D communicates with the valve chamber 84 on the same side of the diaphragm 88 as the annular valve seat 90 and exhaust conduit 92, the latter communicating directly with the valve exhaust or outlet vent 74D.

The actuator button 86 is on the opposite side of the diaphragm 88 from the annular valve seat 90 and is adapted to constrain said diaphragm toward said seat 90 in response to axial displacement of the valve stem 82.

The axially displaced position of the valve stem 82 is controlled by the fly-ball governor 44D through an end mounted thrust bearing assembly 94.

The governor 44D includes an externally concentric sleeve 96 journaled for rotation about the housing 80 by suitable concentric bearings 98. The upper end of the sleeve 96 is slotted or spidered to receive bellcrank levers or ball arms 100 pivoted intermediate the ends thereof at pivots 102 on the sleeve 96.

The inner ends of the ball arms 100 are provided with actuating thrust buttons 104 which engage the thrust bearing 94 on the valve stem 82 so as to apply axial thrust thereto.

The dependent outer legs 106 of the ball arms 100 carry axially adjustable fly-balls 108, held in adjusted positions by set screws 110.

The upper end of the governor sleeve 96 carries an axially extending power input shaft 112 which is adapted to be driven by the drive belts 46 and 46C of the embodiments of FIGS. 2 and 4, or other suitable power take off means which is ground speed responsive.

THE CAPILLARY METERING TUBES, COUPLINGS AND NOZZLES

Referring jointly to FIGS. 6 and 7, the capillary metering tubes 24 of the present invention are shown as comprising relatively thick-walled flexible tubes of polyethylene or the like extending from a manifold valve body or fitting 112 on one end thereof to one of the spray nozzles 22 at the other. The metering tubes 24 are those identified by the numerals 24, 24A, 24B and 24C in FIGS. 1, 2, 3 and 4, respectively. The spray nozzles 22 are likewise identified by the numerals 22, 22A, 22B and 22C, respectively, in those FIGS.

The metering tubes 24 have been successfully utilized with an outside diameter of 0.114 inches to 0.125 inches and internal capillary bore diameters ranging from 0.022 inches to 0.082 inches.

As shown in FIGS. 6 and 7, the capillary bores bear the numeral 114.

The metering tubes 114 are adapted for fingertight rapid connection to the nozzles 22 and manifold valve fittings 112 by means of a concentric elastomeric sealing sleeve 116 frictionally telescoped over the ends of the metering tubes 24, and sliding, concentric, externally-threaded coupling or gland nuts 118 on the said metering tubes 24, inboard of the sealing sleeves 116.

The metering tube ends 120 are received in a counterbored socket 122 in the spray nozzles 22, as shown in FIG. 6; the larger counterbored portion of the socket 122 also receiving the sealing sleeve 116 and including internal threads 124 in the lead-in portion thereof to threadably receive the gland nut 118. Substantially identical sockets are provided in the manifold valve fittings 112 for receiving the opposite ends 120 of the metering tubes 24.

To effect proper coupling of the metering tubes 24 in the coupling socket 122, the tube end 120 and sealing sleeve 116 are pushed into the socket 122 and the gland nut 118 engaged with the internal threads 124. By turning the gland nut 118 fingertight, the elastomeric sleeve 116 is upset into sealing engagement with the inner walls of the coupling socket 122 and simultaneously caused to increase its frictional force on the metering tube 24, thereby retaining the said tube 24 securely in the socket 122.

The spray nozzles 22 are shown as two-piece brass assemblies including a chemical inlet body 126 containing the coupling socket 122 and an integral stepped nozzle cone 128 and a main body portion 130, the latter including an externally threaded air inlet coupling 132 and a spray orifice 134 into which the said nozzle cone 128 extends.

The nozzle cone 128 includes a capillary discharge bore 136 aligned with the capillary bore 114 in the metering tube 24 and discharging in the immediate vicinity of the spray orifice 134.

The threaded air inlet fitting 132 is threadably engaged with the hollow boom 12 (or 12A, 12B or 12C as the case may be) and communicates with the internal bore 138 thereof (FIG. 7) to admit the pressurized supply air therein into the main nozzle body 130.

Then, with chemical being present in the bore 114 of the metering tube 24 and the discharge bore 134 of the nozzle 22, the air pressure swirling around the nozzle cone 128 and discharging through the spray orifice 134 atomizes the chemical emitted by the discharge bore 134 and effects a fine spray.

The droplet size of the chemical in the spray can be selectively controlled for a purpose and in a manner to be hereinafter more fully described.

THE MANIFOLD VALVE

Referring to FIGS. 8, 9 and 10, the manifold valve 20 (or 20A, 20B or 20C as the case may be) will now be described.

The manifold valve body 112, which was schematically shown in FIG. 7, is shown as a cylindrical body having a central chemical inlet bore 140 therethrough with a shallow counterbored or dished portion 142 at its internal end. This provides an annular, peripheral shoulder or surface 144 on the remainder of the internal face of the valve body 112.

A plurality of axial flow ports 146 are drilled or otherwise formed in the valve body 112 about the inner periphery of the annular shoulder 144 (peripherally disposed about the chemical inlet 140), with alternate adjacent ones of said flow ports 146 being of respectively different predetermined blind depths. The axial flow ports 146 are joined by radial flow ports 148 extending to the outer periphery of the valve body 112 and each including a metering tube coupling chamber 122.

The gland nuts 118 and sealing sleeves 116 are shown in the sockets 122 in FIG. 9, and as also shown in FIG. 8, the outer periphery of the valve body 112 displays an array of two axial tiers of metering tubes 24 and gland nuts 118, those of one tier being disposed intermediate those of the other and axially displaced therefrom on the said valve body 112.

The internal face of the valve body 112 is covered by a coterminate flexible diaphragm 150, which fully engages the annular shoulder surface 144 and seals off the axial flow ports 146 therein.

The diaphragm 150 is maintained in place by a hollow valve cover 152, bolted to the valve body about its periphery by means of a plurality of axially extending bolts 154.

The valve cover 152 houses and vertically journals a valve stem 156 having a flat, annular diaphragm actuator 158 on its inner end in juxtaposition with the diaphragm 150. The diaphragm actuator 158 is of sufficient diameter to fully overlap the axial flow ports 146 in the annular shoulder 144 of the valve body 112, the said annular shoulder 144 acting as a boss to determine the limit of travel of the valve stem 156 and diaphragm actuator 158 toward the diaphragm 150.

A helical compression spring 160 is concentrically mounted and axially extended over that portion of the valve stem 156 which is internally disposed in the valve cover 152. The said spring 160 extends between an inner wall 162 of the valve cover 152 and one side of the diaphragm actuator 158.

A coupling 164 is provided on the outer end of the valve stem 156 for connecting a manual actuator (not shown) thereto. Alternatively, a calibrated compression force adjustment (not shown) may be provided for the compression spring 160 to permit automatic opening of the axial flow ports 146 by displacement of the valve diaphragm 150 in response to a predetermined pressure at the chemical inlet 140. A manual override (not shown) may also be provided to close the axial flow ports 146 regardless of the pressure at the chemical inlet 140.

Because of the ULV capabilities of the systems 10-10C of the present invention, the chemicals to be sprayed need not be removed from their conventional shipping containers 16-16C and placed in tanks of larger volume.

Accordingly, the electrically energized chemical pump 18 (indicated schematically in FIG. 2 as 18A), as well as the previously described pneumatic pumping assembly 60-72 (60C-72C) of the embodiments of FIGS. 3 and 4, are adapted to be inserted directly into the chemical containers 16-16C to obviate any need for transfer of often dangerous chemicals from one container to another. Further, contamination of concentrated and relatively expensive chemicals is minimized.

WETTABLE POWDER SLURRY SPRAYING SYSTEM WITH RESERVOIR AGITATION MEANS

Referring to FIG. 11, a wettable powder spraying system embodiment similar to that of FIGS. 1, 2, 3 and 4 will now be described, with like parts to those embodiments bearing the same numerals with the suffix E.

In this embodiment, a centrifugal pump 166 is provided for the slurry or chemical media externally of the tank or reservoir 16E. The pump 166 is driven by a drive belt 168 on drive pulleys 170 and 172 on the compressor 14E and pump 166, respectively. The compressor 14E is provided with an up-standing inlet pipe 174 and airfilter 176; and the said compressor 14E and pump 166 are mounted on an assembly plate 178 which includes a gear box 180, the latter being coupled with the power takeoff shaft 30E to effect the drive of the pump 166 and compressor 14E.

The pump 166 is provided with an axial slurry intake 182 which communicates with the bottom of the reservoir 16E through an intake hose 184, the latter containing an inline strainer 186 to prevent oversized particles or impurities in the slurry from reaching the centrifugal pump 166. An outlet 188 is provided on the pump 166 and communicates through a T-coupling 190 and output line 192 with the input side of a pressure regulator assembly 194.

The T-coupling 190 carries a portion of the output from the pump 166 to a slurry agitator 196 in the bottom of the reservoir 16E through an agitator feed line 198.

The slurry agitator 196 comprises a self-aspirating cone 200 and feed nozzle 202, the latter being fed by the agitator feed line 198, which creates a continuous circulation in the reservoir 16E to prevent settling of slurry therein.

The pressure regulator assembly 194 includes a pressure gauge 204, the main outlet line 32E connecting the outlet of the regulator assembly 194 to the inlet of the manifold valve 20E, a pressure regulator valve 206, and a pump output bypass line 208, all connected to a common four-pipe coupling 210.

The pressure regulator valve 206 is connected with the pump-output bypass line 208 to control the ultimate pressure or delivery force behind the slurry or chemical media through the main output line 32E. The bypass line 208 communicates with the reservoir 16E to return bypassed slurry media thereto from the regulator assembly 194.

The faked portions 36E of the capillary metering tubes 24E are individually wound on a faking reel 212 which is provided with a plurality of ports 214 through the flanges thereof to permit connection of the metering tubes 24E to the body 112E of the manifold valve 20E.

OPERATION OF THE SYSTEMS

Referring first to FIG. 1, and assuming energization of the pump 18 and compressor 14, chemical under pressure is delivered through the delivery line 32 to the intake 140 (FIG. 9) of the manifold valve 20 and pressurized air is delivered through the air supply line 28 to the interior 138 (FIG. 7) of the spray boom 12.

A flow of pressurized air is thus established, through the boom 12 and out through the spray outlets 134 (FIG. 9) of the spray nozzles 22.

The desired chemical flow rate for a given pumping pressure is determined and a capillary metering tube 24 of the length and internal diameter for such a flow rate are coupled between the manifold valve 20 and each of the spray nozzles 22, by the fingertight couplings described in detail in the embodiments of FIGS. 6 and 7. All of the capillary metering tubes 24 must be of the same length from the manifold valve 20 to each nozzle 22 to effect substantially identical chemical feed rates to each nozzle 22. Accordingly, apparently excess length of metering tubes, particularly on the more inboard nozzles 22 on the spray boom 12 are coiled or faked as shown at 36 in FIG. 1, to provide a neat and workable apparatus.

As specifically described in the embodiment of FIGS. 8, 9 and 10, the manifold valve 20 either opens the axial flow ports 146 therein in response to the pump delivery pressure at its input 140 or is manually actuated by axially displacing the valve stem 156.

Chemical is thus admitted simultaneously to the radial flow ports 148 and into the capillary bores 114 of capillary metering tubes 24.

All of the capillary metering tubes 24 are of the same outside diameter, regardless of the diameter of the capillary bores 114, and, therefore, the fingertight couplings to the manifold valve 20 and spray nozzles 22 are universally adapted to all contemplated flow rates for the system 10.

As previously described in the embodiments of FIGS. 6 and 7, chemical from the metering tubes 24 is emitted from the discharge bore 138 of the nozzles cones 128 and atomized into a predetermined spray pattern emitted from the nozzle outlet orifices 134.

Referring now to FIG. 2, all of the conditions in the description of operation of the embodiment of FIG. 1 apply. However, the flow rate of chemical through the metering tubes 24A from the manifold valve 20A is modified with respect to the ground speed of the spray boom 12 by means of the governor valve 42.

Referring additionally to FIG. 5, at zero ground speed of vehicle wheel 50, the pump pressure in the delivery line 32A at the inlet 40 (40D) of the governor valve 42 (42D) is sufficient to axially move the diaphragm 88 and valve stem 82 to a fully open position with reference to the valve seat 90 and permit substantially the entire volume of fluid in the delivery line 32A to exhaust through the governor outlet port 74 (74D) and return through the bypass return line 52 to the chemical tank 16A. This minimizes the flow of chemical through the manifold valve 20A and metering tubes 24A to the nozzles 22A, and, in practice, the back pressure inherent in the metering tubes 24A effects substantially no chemical feed to the spray nozzles 22A.

As the vehicle wheel 50 begins to turn, the fly-ball assembly 44 (44D) including the fly-balls 108 and governor input shaft

112 are rotated by the drive belt 46, causing the fly-balls 108 to move radially outward of the valve body 80 and exert an axial force, through the thrust buttons 104 on the bell crank levers 100 and the thrust bearing 94 on the valve stem 82. The force is directed against the diaphragm 88, through the diaphragm actuator 86 to modulate the proximity of the diaphragm 88 with respect to the valve seat 90, between maximum separation at a minimum or zero ground speed and a closed or contacting position once groundspeed has exceeded a predetermined maximum.

Thus, below a predetermined maximum ground speed the flow rate of chemical to and through the manifold valve 20A, the capillary metering tubes 24A and spray nozzles 22A is controlled in direct proportion to groundspeed. The chemical flow in the bypass governor valve 42 is controlled in inverse proportion to groundspeed to effect this desired flow modulation.

Referring now to FIGS. 3 and 4, the manifold valves 20B and 20C, capillary metering tubes 24B and 24C, spray nozzles 22B and 22C, and spray boom 12B and 12C function as described in the embodiments of FIGS. 1, 2, 6, 7, 8, 9 and 10.

In FIG. 3, the pressure on the supply of chemical through the pressure manifold 60 to the manifold valve 20C is controlled as to maximum by the calibrated relief valve 70 as previously described with reference to this embodiment.

Actuation of the manifold valve 20B will therefore deliver chemical through and into the metering tubes 24B, whereby delivery of the chemical to the spray nozzles 22B is effected.

In FIG. 4, the bypass governor valve 42C will operate in response to groundspeed as previously described with reference to FIGS. 1 and 5 and will bypass the main air supply to the manifold 60C and chemical tank 16C to atmosphere in inverse proportion to groundspeed over a predetermined speed range.

bypass is effected by the governor valve inlet line 40C and air lines 76 and 78 which communicates from the tank supply line 58C, to atmosphere at the governor valve outlet 74.

Therefore, the chemical in the tank 16C is pressurized for delivery to the manifold valve 20C, via the delivery tube 64C and pressure manifold 60C at a pressure which is directly proportional to groundspeed. The flow rate of the chemical to the spray nozzles 22C through the metering tubes 24C is thus similarly modulated as in the embodiment of FIG. 2.

The maximum pumping or driving pressures for the chemical in the capillary metering tubes 24-24C are selected such that the flow in said tubes remains in the laminar flow region (i.e., with a Reynolds Number of less than 3000) for all of the foregoing embodiments. This provides a linear flow rate response to changes in the supply pressure, thereby rendering the chemical flow rates readily and linearly controllable by such devices as pressure regulators and/or ground speed governors.

Referring now to FIG. 11, the manifold valve 20E, metering tubes 24E, spray nozzles 22E, and spray boom 12E function as described in the embodiments of FIGS. 1 through 10.

The compressor 14E and centrifugal pump 166 are driven through the gear train (not shown) in the gear box 80 by the power takeoff shaft 30E and create a pressure head of chemical media or slurry in the pump output line 192 on the inlet side of the pressure regulator assembly 194. The spray boom sections 12E are pressurized through the compressor output lines 28E previously described.

The pressure head in the pump output line 192 forces chemical media or slurry through the agitator feed line 198, feed nozzle 202 and cone 200 to effect constant agitation and circulation of the chemical media or slurry in the reservoir 16E.

The pressure regulator valve 206 is then adjusted to give a predetermined head pressure on the pressure indicator 204, whereby the flow of chemical media or slurry through the bypass line 208 back to the reservoir 16E is regulated to maintain the selected pressure head in the pump output line 192.

This pressure head is also established in the main output line 32E through the four-pipe coupling 210 at the inlet side of the manifold valve 20E.

Thereafter, the operation of the spray system 10E is as previously described in the embodiments of FIGS. 1 through 10, it being understood that a ground speed modulation system can be interconnected with the system 10E at the main output line 32E similar to the connection 38 in the output line 32A of the embodiment of FIG. 2.

SPRAY DROPLET SIZE MODULATION

The spray systems 10, 10A, 10B and 10C of the present invention are suitable for the application of liquid fertilizers as well as the application of herbicides, fungicides and insecticides, the latter three being generically referred to as pesticides.

In the art of pest control, in order to achieve effective results, it is necessary to know for given chemicals, just what is the biologically effective area of a given droplet of chemical deposited on crops or the like from a spray pattern.

The biologically effective area of a droplet is determined by the fundamental properties of the chemical involved, its solubility, its ability to be translocated in a leaf or other portion of a plant, whether or not it is to be incorporated in the soil, and the ability of the droplet of chemical to project its lethal properties in the area immediately surrounding it.

The biologically effective area of each droplet determines the number of droplets per square inch that one must apply in order to get effective end results from the chemical. This property is determined by the chemical manufacturer and is a prerequisite parameter to control for proper use of the chemical in a spray system.

The amount of active chemical needed to be effective with minimum number of biologically active deposits in a given area is again a property of the chemical. The amount of chemical that must be deposited in each droplet for a very active and potent chemical is less than one which has less ability to kill or to inhibit. Knowing both the biologically effective area and the amount of active chemical that must be deposited per given area determines the number of droplets per square inch and the size of droplets necessary to get effective pesticide action.

As will be hereinafter more fully described, the size of the droplets in the spray systems of the present invention can be controlled by varying the flow rate of the air from the spray nozzles 22-22C, i.e., varying the pressure of the air supply within the spray booms 12-12C.

Having determined the number of droplets and the minimum size of the droplets necessary to get the proper pesticide action, it must then be determined how to apply the chemical to minimize drift of the sprayed chemicals through the atmosphere, thereby reducing chemical waste and the attendant hazards to animal life and adjacent fields of crops. Thus, the droplet size should be the largest practical size that will minimize drift and at the same time maximize the action of the pesticide.

Liquid chemical formulations to be deposited by the present invention may comprise either chemicals in natural liquid form or in the form of wettable powders in liquid suspension, i.e., slurries.

The spray systems of the present invention use air as the carrier and the atomizing medium for the chemical to be deposited.

The speed of the air stream and the mass of air flowing determines the droplet size of the pesticide. Since it takes more energy to produce small droplets it follows that high air pressure will produce the smallest droplets. Conversely low air pressures will produce larger droplets. This basically is an energy equation with mass velocity determining the amount of energy available to break up the chemical. It has been determined that a pressure in the spray boom 12-12C of 3 pounds per square inch (3 p.s.i.) is adequate for most agricultural

spraying, except in the case of pesticides wherein a minimum droplet size is more advantageous.

The volume and velocity of the air through the nozzle spray outlets 134 determine the amount of mass flow that is obtained. By opening up the air nozzle to obtain this extra volume, there is provided a mist blowing action which will roll the leaves and allow the cloud of droplets to penetrate the foliage of the crop better than droplets created without a large velocity vector.

Thus, by reduction of air pressure in the spray booms 12-12C, larger droplet sizes are emitted from the nozzles 22-22C. Conversely, by increasing air pressure in the booms 12-12C, smaller droplet sizes are achieved, including droplet sizes effective as aerosols for insect control. Consequently, the present invention possesses optimum utility and versatility.

The versatility of the systems of the present invention is further enhanced by the fact that for the ULV and low volume flow rates of suspensions or slurries of wettable powders, conventional orifice sizes for flow control must often be less than 0.032 inches. For wettable powders having particle sizes on the order of one micron, such orifices will clog and prevent chemical emission. Capillary metering tubes which are operated in the laminar flow region, however, to effect the same ranges of flow rates (i.e., 0.1 oz. to 0.3 oz. per minute per nozzle for ULV and 1 oz. to 3 oz. per minute per nozzle for low volume) have internal diameters which are much larger than corresponding conventional flow control orifice valves. For example, internal diameters of 0.052 inches to 0.062 inches may be used, precluding clogging or stoppage with wettable powder suspensions or slurries.

When this ability to control droplet size is coupled with the ability to deliver volumes of chemical entrained in a spray at linearly and readily controlled delivery rates of several cubic centimeters per minute per spray nozzle, it is readily seen that the present invention provides spray systems heretofore unattainable and satisfying a long felt need in the art.

While only several specific embodiments are hereinbefore illustrated and described, it is to be expressly understood that this invention is not intended to be limited to the exact formations, construction or arrangement of parts as illustrated and described because various modifications may be developed in putting the invention to practice.

I claim:

1. For use in spraying systems for atomizing liquid and slurry media, a liquid and slurry media handling apparatus comprising reservoir means containing said media, spray nozzle means, capillary tube means including at least one capillary tube interconnecting said reservoir means with said spray nozzle means and pressure means forcing said media through said capillary tube means to effect, by said capillary tube, a metered delivery of said media from said reservoir to said spray nozzle means; said media being maintained in a condition of laminar flow in said capillary tube during discharge of said media from said spray nozzle means; wherein said spray nozzle means comprises a plurality of spray nozzles; said capillary tube means comprises a like plurality of capillary tubes and a common manifold valve selectively connecting like ends of said tubes to said reservoir means; wherein the opposite ends of said capillary tubes are connected one to each of said spray nozzles; wherein said capillary tubes are of substantially identical internal diameter and length, effecting substantially identical rates of flow of said media from said reservoir means to each of said spray nozzles; and, further, wherein said pressure means includes control means providing a selectively variable delivery force to said media to effect flow modulation through said capillary tubes in direct linear proportion to said delivery force to control the rate of flow of said media to said spray nozzles.

2. The invention defined in claim 1, wherein said reservoir, said capillary tube means, said spray nozzles means and said pressure means are all mounted on an ambulatory means, said ambulatory means including ground speed monitoring means; and wherein said control means further includes governor

means controlled by said monitoring means, said governor means including flow control means modulating the effect of the delivery force provided by said pressure means to said media in predetermined relationship to said ground speed.

3. The invention defined in claim 1, wherein said reservoir, said capillary tube means, said spray nozzle means and said pressure means are all mounted on an ambulatory means, said ambulatory means including ground speed monitoring means; and wherein said control means further includes governor means controlled by said monitoring means, said governor means including flow control means modulating the effect of the effect of the delivery force provided by said pressure means to said media in predetermined relationship to said ground speed; wherein said pressure means includes pumping means in said reservoir means effecting delivery of said media therefrom to said manifold valve means with a predetermined delivery force; and said governor means comprises variable bypass means selectively diverting media delivered by said pumping means from said manifold valve means.

4. The invention defined in claim 1, wherein said reservoir, said capillary tube means, said spray nozzle means and said pressure means are all mounted on an ambulatory means, said ambulatory means including ground speed monitoring means; and wherein said control means further includes governor means controlled by said monitoring means, said governor means including flow control means modulating the effect of the delivery force provided by said pressure means to said media in predetermined relationship to said ground speed; wherein said pressure means includes a source of pneumatic pressure connected with said reservoir means to pressurize same and effect a discharge of said media therefrom to said manifold valve means with predetermined delivery force, and said governor means comprises variable bleed means selectively venting said source to vary the pressure delivered thereby to said reservoir, thereby modulating said delivery force.

5. The invention defined in claim 1, wherein said manifold valve means comprises a valve body providing a common manifold connection for said plurality of capillary tubes, an inlet connected with said reservoir means to receive said media from said reservoir means, a valve seat including outlet means communicating with each of said capillary tubes, a valve member engageable with said valve seat effecting selective communication of said outlet means with said inlet, and actuator means for said valve member.

6. The invention defined in claim 5, wherein said actuator means comprises force responsive biasing means maintaining said valve member closed on said valve seat in the absence of a predetermined delivery force on said media at said inlet.

7. The invention defined in claim 5 wherein said outlet means comprises a plurality of individual outlet ports connected one with each of said capillary tubes; and wherein displacement of said valve member by said actuator means effects substantially simultaneous selective connection and disconnection of said outlet ports with said inlet.

8. The invention defined in claim 1, wherein said pressure means further includes bypass means continuously returning a portion of said media to reservoir means and agitator means in said reservoir means actuated by said media from said bypass means, maintaining a circulation of said media in said reservoir means.

9. For use in spraying systems for atomizing liquid and slurry media, a liquid and slurry media handling apparatus comprising reservoir means containing said media, spray nozzle means, capillary tube means including at least one capillary tube interconnecting said reservoir means with said spray nozzle means and pressure means forcing said media through said capillary tube means to effect, by said capillary tube, a metered delivery of said media from said reservoir to said spray nozzle means; said media being maintained in a condition of

laminar flow in said capillary tube means during discharge of said media from said spray nozzle means; wherein said spray nozzle means comprises a plurality of spray nozzles; said capillary tube means comprises a like plurality of capillary tubes and a common manifold valve selectively connecting like ends of said tubes to said reservoir means; wherein the opposite ends of said capillary tubes are connected one to each of said spray nozzles; and wherein said manifold valve means comprises a valve body providing a common manifold connection for said plurality of capillary tubes, an inlet connected with said reservoir means to receive said media from said reservoir means, a valve seat including outlet means communicating with each of said capillary tubes, a valve member engageable with said valve seat effecting selective communication of said outlet means with said inlet, and actuator means for said valve member; said actuator means comprising force responsive biasing means maintaining said valve member closed on said valve seat in the absence of a predetermined delivery force on said media at said inlet.

10. An ambulatory spraying system for spray deposition of liquid and slurry chemical media in controlled ultra-low-volume quantities comprising an ambulatory support means; a source of pneumatic pressure; a spray boom on said support means mounting a selected number of spray nozzles and including means supplying said nozzles with pneumatic pressure media from said source; reservoir means on said support means containing chemical media to be sprayed; capillary tube means comprising a like selected number of capillary tubes connected at like ends thereof one to each of said spray nozzles and a common manifold valve selectively connecting the other like ends of said capillary tubes to said reservoir means; and pressure means forcing said chemical media from said reservoir to and through said manifold valve and said capillary tubes to said spray nozzles; said spray nozzles including means intermingling said chemical media and said pneumatic pressure media to effect atomization of said chemical media in said pneumatic pressure media and discharge thereof from said spray nozzles; said chemical media being maintained in a condition of laminar flow in said capillary tube means during discharge of said chemical media from said spray nozzle means.

11. The invention defined in claim 10, wherein each of said capillary tubes are of substantially identical internal diameter and length, effecting substantially identical rates of flow of said chemical media from said reservoir means to each of said spray nozzles.

12. The invention defined in claim 10, wherein each of said capillary tubes are of substantially identical internal diameter and length, effecting substantially identical rates of flow of said chemical media from said reservoir means to each of said spray nozzles; and wherein said pressure means includes control means providing a selectively variable delivery force to said chemical media to effect flow modulation through said capillary tubes in direct linear proportion to said delivery force to control the rate of flow of said media to said spray nozzles.

13. The invention defined in claim 12, wherein said control means further includes governor means responsive to the ground speed of said ambulatory support means, said governor means including modulating means modulating the effect of the delivery force provided by said pressure means to said media in predetermined relationship to said ground speed.

14. The invention defined in claim 10, wherein said manifold valve means includes means selectively effecting substantially simultaneous connection and disconnection of said capillary tubes with said reservoir means.

15. The invention defined in claim 10, wherein said means supplying said nozzles with pneumatic pressure media from said source include pressure regulator means.