

“AGRICULTURAL LIQUID APPLICATION SYSTEM”

BACKGROUND TO THE INVENTION

THIS invention relates to an application system for applying agricultural liquids, for example liquid fertiliser, to agricultural lands.

In the context of liquid fertiliser it is of benefit to a farmer have the ability to control accurately the quantity of fertiliser which is applied to the land. On the one hand, if too little fertiliser is applied this can detrimentally affect the growth of the planted crop. On the other hand, if too much fertiliser is applied this can significantly increase the cost of fertilisation and may also affect crop growth detrimentally. The same applies to other agricultural liquids such as pesticides and herbicides.

It is an object of this invention to provide a system which enables accurate control to be maintained over the application of agricultural liquid to the land.

SUMMARY OF THE INVENTION

According to this invention there is provided an agricultural liquid application system for a liquid distributor that moves over a land to which agricultural liquid is to be applied at multiple application locations, the system comprising:

- delivery lines for delivering liquid to the multiple application locations as the liquid distributor moves over the land;
- pumping means for pumping liquid through the delivery lines at a rate dependent on the speed at which the liquid distributor moves over the land;
- programmable system control means which can be programmed with a target liquid flow which is to be delivered through the respective delivery lines to the application locations;
- flow monitoring means associated with the respective delivery lines to monitor the actual flow of liquid delivered through each delivery line and to output to the control means signals related to the actual, monitored flow; and
- flow control means in each delivery line for controlling the actual flow of liquid through the delivery line;

wherein the system control means is arranged to receive the signals output by the flow rate monitoring means and to control the operation of the flow control means in order to align the actual liquid flow delivered in each delivery line with the target liquid flow in the delivery line.

The liquid distributor is typically a multi-row planter and the delivery lines are configured for each delivery line to deliver liquid to one of the rows.

The flow monitoring means may comprise a flow meter in each delivery line for monitoring the actual liquid flow in that delivery line. The flow meter may be a mechanical flow meter, but is preferably an ultrasonic flow meter, most preferably of transit time type.

Conveniently the pumps include modular pumps arranged in side by side relationship and driven by a common drive shaft. The common drive shaft can be driven off a land-engaging wheel of the liquid distributor whereby the pumps pump liquid at a rate dependent on the speed at which the liquid distributor moves over the land. The system may include a shaft rotation sensor for monitoring the rotation of the common drive shaft and for outputting signals related to such rotation to the system control means.

The flow control means in each delivery line may comprise a flow control valve. This may have an inlet, an outlet, a flow orifice between the inlet and outlet, a valve seat about the orifice, a valve closure which is movable relative to the valve seat thereby to control flow through the flow orifice, and means for moving the valve closure member, under the control of the system control means, in response to variations in the actual flow of liquid monitored by the flow monitoring means.

The system may further include at least one liquid tank for containing liquid which is to be delivered to the liquid application locations, and possibly a compressor for pressurising the liquid in the tank(s).

According to a preferred feature the system comprises a check valve in each delivery line downstream of the flow monitoring means and flow control means, the check valve allowing liquid flow to take place in a direction of delivery to an application location but preventing backflow in the opposite direction.

Preferably also, the system control means is configured to generate a warning signal in the event that the actual, monitored liquid flow deviates from the target flow by more than a predetermined amount.

The invention extends to the use of the system summarised above to distribute fertilizer to planting rows in an agricultural land.

Other features of the invention will be apparent from the description which follows.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will now be described in more detail, by way of example only, with reference to the accompanying drawings in which:

- Figure 1** diagrammatically illustrates an agricultural liquid application system according to an embodiment of the invention;
- Figure 2** diagrammatically illustrates a modular pump used in the system of Figure 1;
- Figure 3** shows an exploded perspective view of a flow rate meter mounted in a delivery line in the system of Figure 1;
- Figure 4** shows a perspective view of the assembled flow rate meter of Figure 3;
- Figure 5** shows a cross-sectional perspective view of the assembled flow rate monitor seen in Figures 3 and 4;
- Figure 6** shows a cross-sectional elevation view of the assembled flow rate monitor seen in Figures 3 to 5;
- Figure 7** shows a cross-sectional perspective view of an alternative flow rate monitor;
- Figure 8** shows a cross-sectional elevation view of the flow rate monitor seen in Figure 7;
- Figure 9** shows a perspective view of a shaft rotation sensor;

- Figure 10** shows a cross-sectional perspective view of a flow control valve forming part of the system of the invention;
- Figure 11** shows a cross-sectional elevation view of the flow control valve seen in Figure 10;
- Figure 12** shows a perspective view of an electronic valve control unit of the system illustrated in Figure 1;
- Figure 13** shows a perspective view of the system control unit of the system illustrated in Figure 1;
- Figure 14** diagrammatically illustrates components of an agricultural liquid application system according to another embodiment of the invention;
- Figure 15** illustrates certain components of the second embodiment at a larger scale;
- Figure 16** shows the system control unit of the second embodiment;
- Figure 17** shows a plan view of the ultrasonic flow meter used in the second embodiment;
- Figure 18** shows a sectioned perspective view of the ultrasonic flow meter seen in Figure 17;
- Figure 19** shows a perspective view of the flow control valve used in the second embodiment;
- Figure 20** shows a sectioned side view of the flow control valve seen in Figure 19; and

Figure 21 shows a sectioned perspective view of the flow control valve seen in Figure 19.

DESCRIPTION OF THE ILLUSTRATED EMBODIMENTS

A first embodiment of the invention, which is used to distribute liquid fertiliser to an agricultural land, is illustrated in Figures 1 to 13.

The system 2 illustrated diagrammatically in Figure 1 includes a liquid fertiliser distributor, in this case an eight row planter 3 drawn in use by a tractor 4. The planter 3 carries tanks 5 containing liquid fertiliser. The numeral 6 indicates a compressor which is used to pressurise the tanks 5 internally so that they supply liquid fertiliser to a modular pump assembly 7 including eight modular liquid fertiliser distribution pumps 10, one of which is illustrated at a larger scale in Figure 2.

The liquid fertiliser arrives at inlets 12 of each pump 10 which pumps the fertiliser through outlets 13 to an output or delivery line 14 which in turn conveys the pumped fertiliser to an application location, i.e. a planter row, at which the liquid fertiliser is to be applied to the land.

Each pump 10 is a modular unit which, as shown in Figure 1, is mounted side by side with seven other similar pumps, each pump serving to deliver liquid fertiliser to a different application location, i.e. planter row.

Connected in each delivery line 14 is a flow meter indicated generally by the numeral 16 in Figures 1 and 3 to 6. The meter 16 includes a housing 18 having an inlet 20 and an outlet 22. Located within the housing is a cartridge 24 which is sealed with respect to a lower part of the housing by means of a seal 26 and an O-ring 28. A vaned impeller 30 is supported between impeller guides 32 and is positioned rotatably within the housing.

The assembly of impeller and impeller guides is held together by screws 34, with the arrangement being such that as liquid fertiliser flows through the housing from the inlet to the outlet, the impeller is caused to rotate at a rotational speed corresponding to the delivery or flow rate of the fertiliser.

The impeller carries a series of angularly spaced magnets 36. The rotational movement of the magnets is sensed by a sensing means, in this case in form of a Hall sensor provided on a printed circuit board 38 carried by a top closure member 40 of the meter which is held in position by an annular cap 42 that screws onto the housing 18. The meter 16 generates signals related to the sensed rotational speed of the impeller 30 and outputs these signals via a distribution unit 44 to a programmable control means in the form of an electronic system control means in the form of a unit 46 having programme input and display functions.

Referring to Figure 3 a slot 39 can be provided at the bottom of the cartridge 24. A suitable cleaning tool can be inserted through this slot to clean out any dirt or other foreign matter which may have accumulated and which could detrimentally affect the free rotation of the impeller 30.

There is a flow meter 16 in each delivery line 14, and the distribution unit 44 collects signals from all of the meters and directs these to the control unit 46. In the specific example illustrated in Figure 1, where there are eight modular pumps 10 each with a delivery line 14, so the control unit 46 receives signals, via the unit 44, from all eight of the associated meters 16.

In the illustrated example, the pumps 10 are mounted, by fasteners 50, on mounting plates 52 connected to the planter by means of fasteners (not shown) passing through holes 54. Figure 2 shows how a single modular pump 10 is mounted on the planter by such plates and fasteners, while Figure 1 shows how the assembly of side by side modular pumps are connected in this manner.

In Figures 1 and 2, the numeral 56 indicates a common drive shaft which drives internal components of the pumps 10 in order to pump the liquid fertiliser. The shaft 56 is common to all the modular pumps which are mounted side by side with one another on the planter. The shaft is driven off a land-engaging wheel of the planter at a rotational speed dependent on the rotary speed of the land-engaging wheel and hence on the speed at which the planter is drawn over the land by the tractor 4.

Two magnets 58 are mounted on or embedded in the shaft 56, outside the housing of an endmost modular pump 10, as illustrated in Figure 2. The magnets rotate beneath the housing 60, seen in Figures 2 and 9, of a shaft rotation sensor. The housing 60 is supported by a support plate 62 which is in turn connected to the endmost pump housing. The housing 60 accommodates a printed circuit board 64 including a sensor, typically a Hall sensor, which is sensitive to the movement of the magnets carried by the shaft 56. The shaft rotation sensor is provided to sense whether the shaft 56 is rotating or stationary. It also senses shaft rotations, which are in turn related to rotations of the land-engaging wheel and hence, depending on the diameter of the land-engaging wheel, to the distance traversed by the planter. Signals corresponding to the measured parameters are output to the control unit 46.

In practice, before fertiliser application begins, the farmer or other operator determines the required quantity of liquid fertiliser to be delivered to each planter row. This target quantity, which may for example be specified in $\ell/100\text{m}$ (litres per 100 metres) or kg/hectare , is programmed into the unit 46, which is supported by a mounting plate 48 at a position where it will be visible to the operator of the planter 2, typically on board the tractor 4.

The processor of the unit 46 receives signals from the flow meters 16 and computes from these signals the actual flow of liquid fertiliser applied to the land for each of the eight planter rows to which fertiliser is applied. The instantaneous, actual flow is displayed for each of the planter rows on one of the screens 70 of the unit 46.

A flow control valve 80, the operation of each of which is controlled by the unit 46, is provided in each delivery line 14. A typical flow control valve 80 is seen in Figures 10 and 11. The illustrated valve has an inlet 82 and an outlet 84 and a flow orifice 85 between the inlet and outlet. A valve closure member 86 can reciprocate in the valve housing 88, relative to a valve seat about the orifice 85, in order to control the flow of liquid fertiliser from the inlet 82 to the outlet 84. The closure member can be driven in one direction by a stepper motor 89 and in the opposite direction by a spring 87. The action of the stepper motor, which is located in an upper part of the valve housing, is controlled by the unit 46. With this feature, the flow rate in each delivery line can be controlled automatically in response to the signals output by the flow rate meter 16. In practice, the control unit 46 controls the flow control valves 16 in order to align the actual flow in each delivery line with the pre-programmed, target flow.

The arrangement may be such that if the actual flow as monitored by the flow meters 16 should deviate from the target value by more than a predetermined, amount, the unit 46 generates an alarm signal, for example with a flashing, visible light or an audible continuous or intermittent buzzer. On seeing or hearing the alarm, the operator can immediately take remedial steps to rectify the problem.

When the distributor is travelling over the ground, but actual fertilisation has not yet commenced, for example during times when the distributor is being transported to a land which is to be fertilised, the shaft 56 does not rotate, i.e. the pumps 10 are inoperative. The absence of shaft rotation is sensed by the shaft rotation sensor, with the result that the unit 46 will at this time will give no indication of fertiliser application.

The unit 46 includes various control buttons 81 which may be operated as necessary in order to perform initial calibration of the unit. Typically it will be necessary to calibrate the system so that it is accurately able to determine, for the diameter of the land-engaging wheel, the distance traversed.

It will also be necessary to calibrate the flow meters 16 so as to output values accurately related to the actual, instantaneous flow rate in each delivery line 14.

Many variations are possible within the scope of the invention. In the example described above, the invention is applied to fertiliser delivery by an eight row planter. It will however be understood that the principles of the invention are applicable to planters or fertiliser distributors for more or less rows.

In practice, the system of the invention may be used to control the distribution of agricultural liquids other than fertiliser, for example pesticides and/or herbicides. It is also possible for the control unit 46 to be pre-programmed to deliver more than one such liquid, possibly as a mixture, to each application location and/or for different liquids or mixtures of liquids to be delivered to different application locations.

Figures 7 and 8 illustrate an alternative flow meter 16' in which the rotational speed of meshing, oval gears 92 is monitored, for example using a Hall sensor as described above. Both the impeller-type and oval gear-type alternatives are illustrated in Figure 1.

The values computed by the unit 46 for each land in which the system is operated may be downloaded onto an external computer for record-keeping, monitoring and planning purposes.

As indicated by the numeral 100 in Figure 1, a GPS (global positioning system) device may be interfaced with the unit 46 so that the computed values may be correlated to geographical position on each land.

During operation, the operator can consult the relevant screen(s) 70 to see whether the correct quantity of fertiliser is in fact being applied to the land during fertilisation.

Either through the intervention of the operator or by the GPS system and associated computer files, which could be comma separated values, spread sheets or shape files, the operation of the fertiliser delivery system may be adjusted to increase or decrease the applied rate. The flow rate for each row is then electronically adjusted to meet the required set or target rate. If it is found that too little or too much fertiliser is being applied, the flow meter of each row can be calibrated by adjusting the associated rate of delivery.

The numeral 102 in Figure 1 indicates a delivery check valve which is included in each delivery line 14 to allow flow in the delivery direction but to prevent reverse flow.

The liquid flow rate data, typically in litres per 100m or kg/hectare for each application location or row may, along with other factors such as date, time, speed, distance position, area and time in operation, can be saved in real time in RAM in the unit 46 and can, as indicated above, be downloaded to a computer for appropriate manipulation. Maps of land with GPS and liquid target information are also saved to RAM for the purposes of setting target application values for the land in question.

Figures 14 to 21 illustrate features of a second embodiment of the invention. This embodiment has many similarities to the first embodiment described above, and components corresponding to those of the first embodiment are designated by the same reference numerals prefixed by the numeral "2".

In the second embodiment, the flow rate of the liquid pumped along each delivery line 214 is measured by an ultrasonic flow meter 216 seen in Figures 17 and 18. The ultrasonic flow meter 216 is of a transit time type in which the difference in transmit times for sound waves propagated in the flow line in upstream and downstream directions, between respective upstream and downstream ultrasonic transducers 216.1, 216.2, is used to determine the instantaneous velocity of the liquid fertiliser, from which the

instantaneous flow rate can be determined. When compared to the mechanically based flow meters 16, 16' described above, the ultrasonic flow meter 216 has the advantage that there are no moving parts in contact with the metered liquid. This enables the flow meter to operate accurately despite possible contamination of the liquid by, for example, dirt or other impurities.

The second embodiment also has a somewhat modified flow control valve 280 in each delivery line 214. As shown in Figures 19 to 21, the valve closure 286 in this case includes a plunger 286.1 connected at its lower end to an elastic diaphragm 286.2 and acted upon at its upper end by a cam 286.3 driven by a stepper motor 289. Downward movement of the plunger under the action of the cam is opposed by an upward biasing force applied by the diaphragm. Accordingly, as the cam is rotated to different angular positions by the stepper motor 289, the lower end of the plunger 286.1 is moved to different positions relative to a valve seat 300 located about a flow orifice 302 situated between an upstream flow inlet 304 and a downstream flow outlet 306, thereby controlling the flow of liquid fertiliser through the valve.

The stepper motor 289 is operated under the control of the control unit 246 so as to maintain the desired, target flow rate through the delivery line 214.

The second embodiment differs from the first embodiment in that there is a dedicated electronic valve control unit 308 for each control valve 280. The valve control unit 308 receives feedback signals from the associated flow meter 216 and outputs these to the control unit 246. In response to control signals received from the control unit 246, the valve control unit 308 controls the operation of the associated stepper motor 289, thereby controlling the position of the valve closure plunger 286.1 and hence controlling the actual flow passing through the valve.

It will be noted that, as in the first embodiment, each delivery line 214 in the second embodiment is fitted with a delivery check valve 202 to prevent any backflow of fertiliser or other liquid.

CLAIMS

1. An agricultural liquid application system for a liquid distributor that moves over a land to which agricultural liquid is to be applied at multiple application locations, the system comprising:

- delivery lines for delivering liquid to the multiple application locations as the liquid distributor moves over the land;
- pumping means for pumping liquid through the delivery lines at a rate dependent on the speed at which the liquid distributor moves over the land;
- programmable system control means which can be programmed with a target liquid flow which is to be delivered through the respective delivery lines to the application locations;
- flow monitoring means associated with the respective delivery lines to monitor the actual flow of liquid delivered through each delivery line and to output to the control means signals related to the actual, monitored flow; and
- flow control means in each delivery line for controlling the actual flow of liquid through the delivery line;

wherein the system control means is arranged to receive the signals output by the flow rate monitoring means and to control the operation of the flow control means in order to align the actual liquid flow delivered in each delivery line with the target liquid flow in the delivery line.

2. A system according to claim 1 wherein the liquid distributor is a multi-row planter and the delivery lines are configured for each delivery line to deliver liquid to one of the rows.

3. A system according to claim 1 or claim 2 wherein the flow monitoring means comprises a flow meter in each delivery line for monitoring the actual liquid flow in that delivery line.

4. A system according to claim 3 wherein each flow meter is a mechanical flow meter.

5. A system according to claim 3 wherein each flow meter is an ultrasonic flow meter.
6. A system according to claim 5 wherein each flow meter is an ultrasonic flow meter of transit time type.
7. A system according to any one of the preceding claims wherein the pumps include modular pumps arranged in side by side relationship and driven by a common drive shaft.
8. A system according to claim 7 wherein the common drive shaft is driven off a land-engaging wheel of the liquid distributor whereby the pumps pump liquid at a rate dependent on the speed at which the liquid distributor moves over the land.
9. A system according to claim 8 comprising a shaft rotation sensor for monitoring the rotation of the common drive shaft and for outputting signals related to such rotation to the system control means.
10. A system according to any one of the preceding claims wherein the flow control means in each delivery line comprises a flow control valve.
11. A system according to claim 9 wherein each flow control valve has an inlet, an outlet, a flow orifice between the inlet and outlet, a valve seat about the orifice, a valve closure which is movable relative to the valve seat thereby to control flow through the flow orifice, and means for moving the valve closure member, under the control of the system control means, in response to variations in the actual flow of liquid monitored by the flow monitoring means.
12. A system according to any one of the preceding claims comprising at least one liquid tank for containing liquid which is to be delivered to the liquid application locations.

13. A system according to claim 11 comprising a compressor for pressurising the liquid in the tank(s).
14. A system according to any one of the preceding claims comprising a check valve in each delivery line downstream of the flow monitoring means and flow control means, the check valve allowing liquid flow to take place in a direction of delivery to an application location but preventing backflow in the opposite direction.
15. A system according to any one of the preceding claims wherein the system control means is configured to generate a warning signal in the event that the actual, monitored liquid flow deviates from the target flow by more than a predetermined amount.
16. A system according to any one of the preceding claims comprising display means to display the flow rate of liquid in each delivery line.
17. Use of a system according to any one of the preceding claims to distribute fertilizer to planting rows in an agricultural land.

ABSTRACT

The invention concerns an agricultural liquid application system for a liquid distributor, for example a multi-row planter (3, 23) drawn by a tractor (4, 24), that moves over a land to which agricultural liquid is to be applied at multiple application locations. The agricultural liquid may for example be a liquid fertilizer, pesticide and/or herbicide. The system of the invention has delivery lines (14, 214) for delivering liquid to the multiple application locations as the liquid distributor moves over the land as well as pumping means (7, 27) for pumping liquid through the delivery lines at a rate dependent on the speed at which the liquid distributor moves over the land. Also included are a programmable system control means (46, 246) which can be programmed with a target liquid flow which is to be delivered through the respective delivery lines to the application locations and flow monitoring means (16, 16', 216) associated with the respective delivery lines to monitor the actual flow of liquid delivered through each delivery line. The flow monitoring means outputs to the control means signals which are related to the actual, monitored flow. A flow control means (80, 280) is also provided in each delivery line for controlling the actual flow of liquid through that delivery line. The system control means is arranged to receive the signals output by the flow rate monitoring means and to control the operation of the flow control means in order to align the actual liquid flow delivered in each delivery line with the target liquid flow in the delivery line.

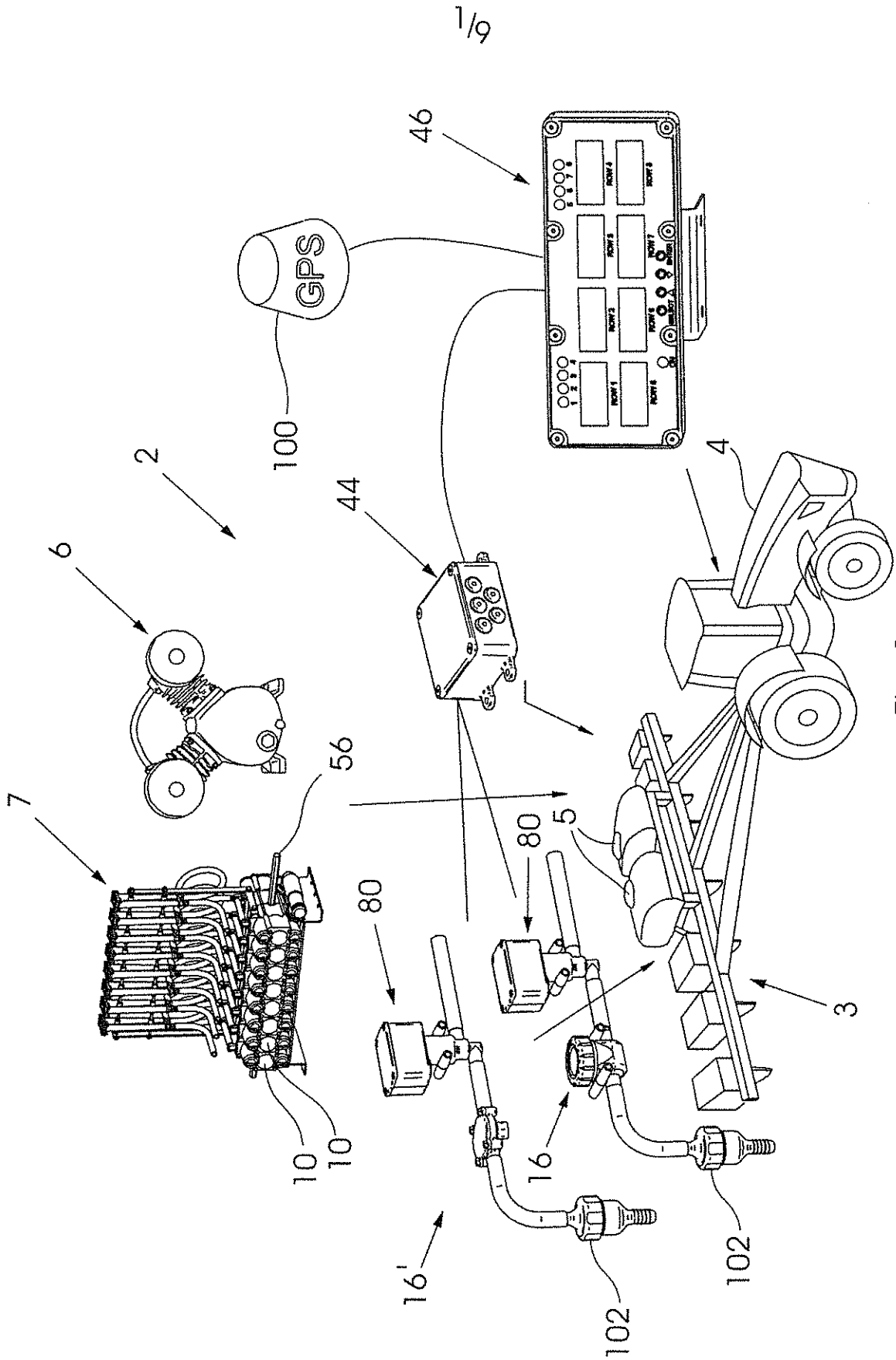
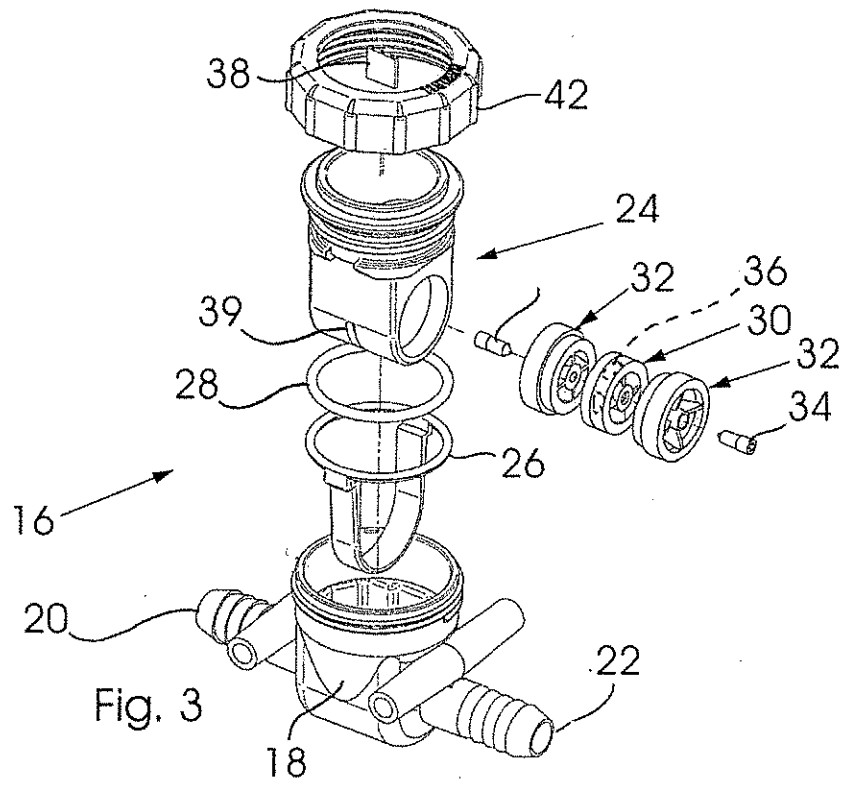
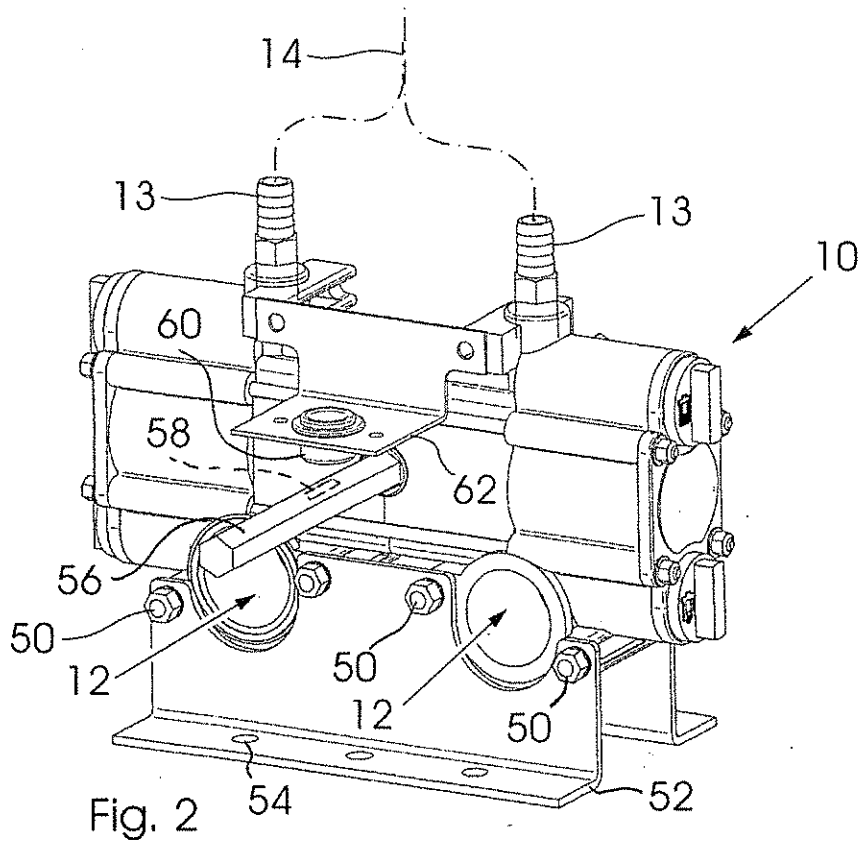


Fig. 1



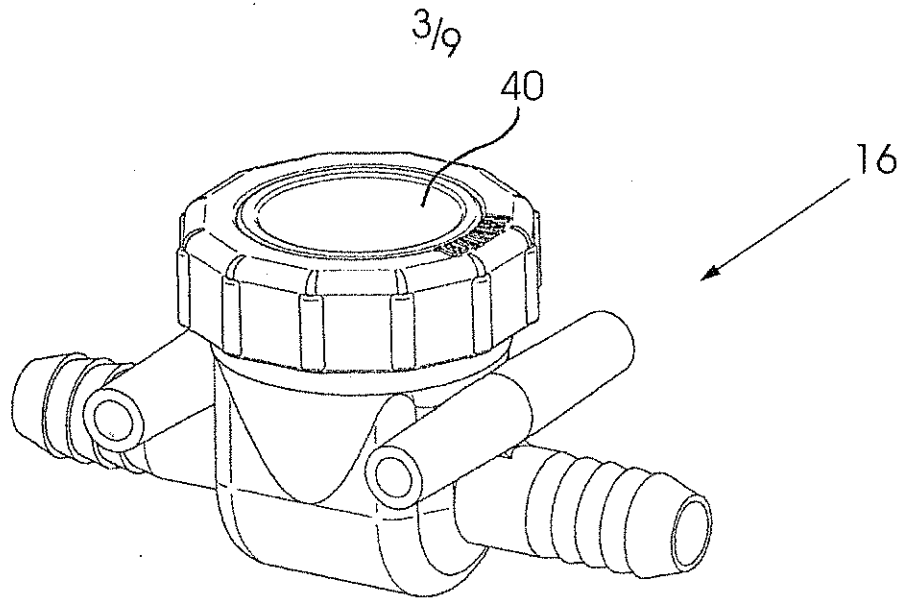


Fig. 4

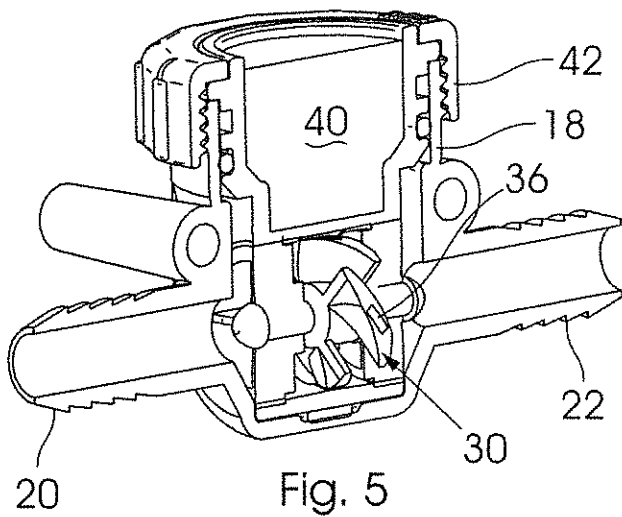


Fig. 5

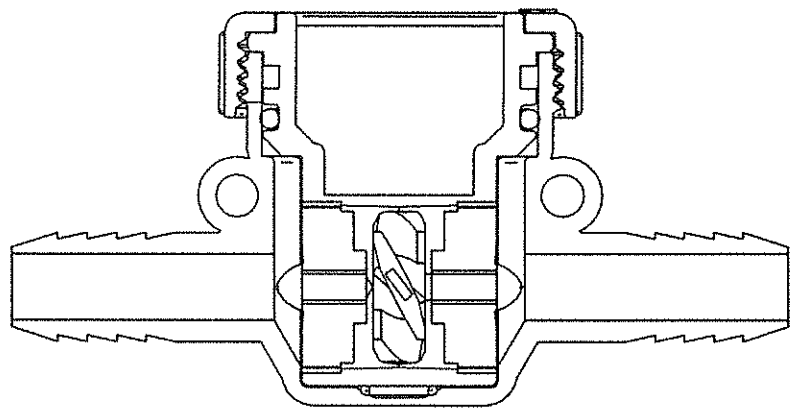


Fig. 6

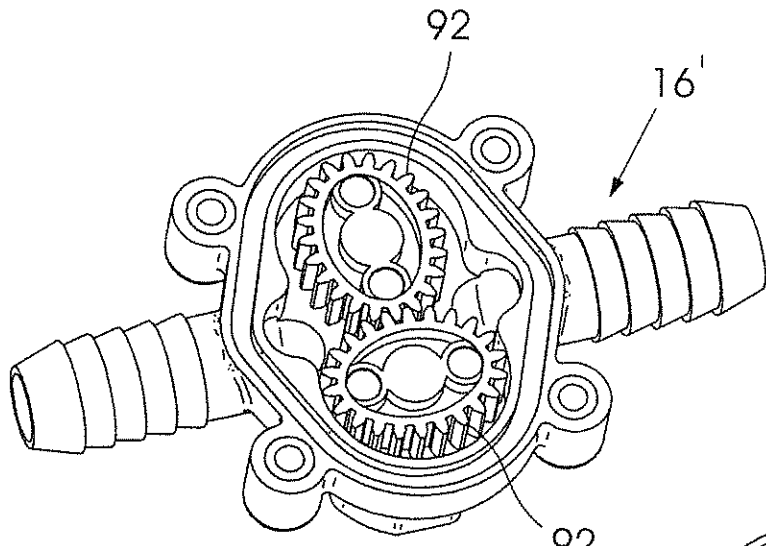


Fig. 7

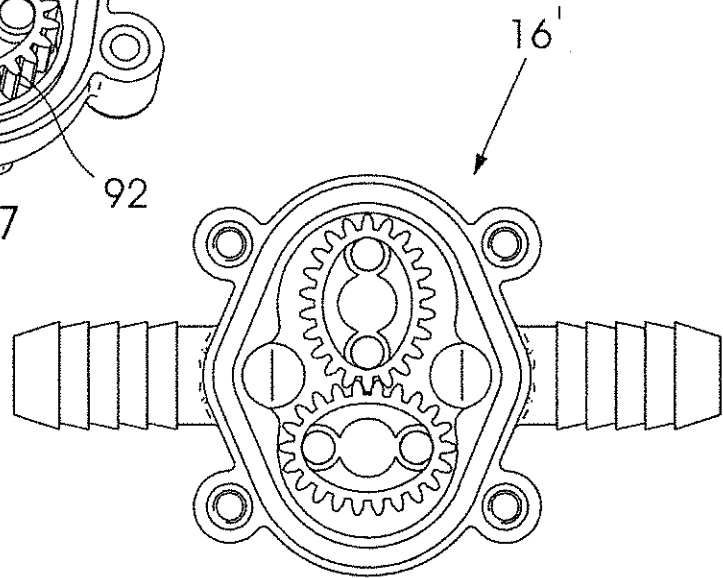


Fig. 8

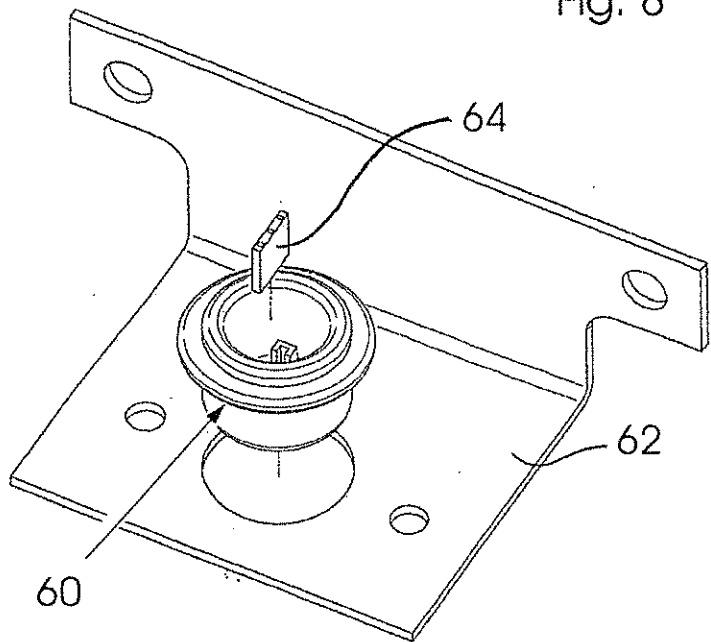


Fig. 9

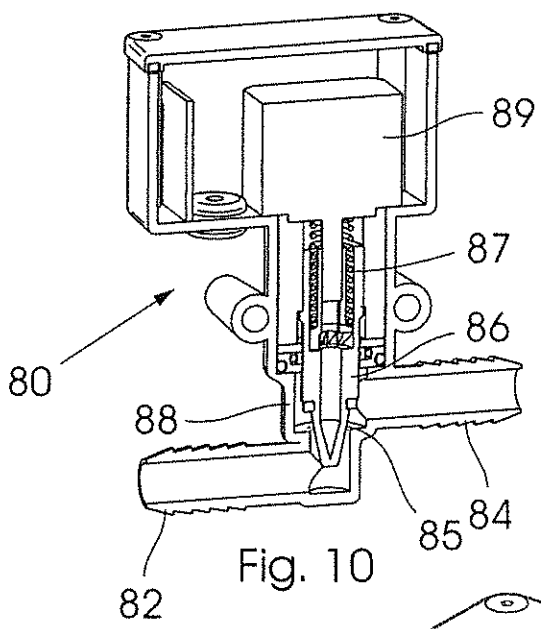


Fig. 10

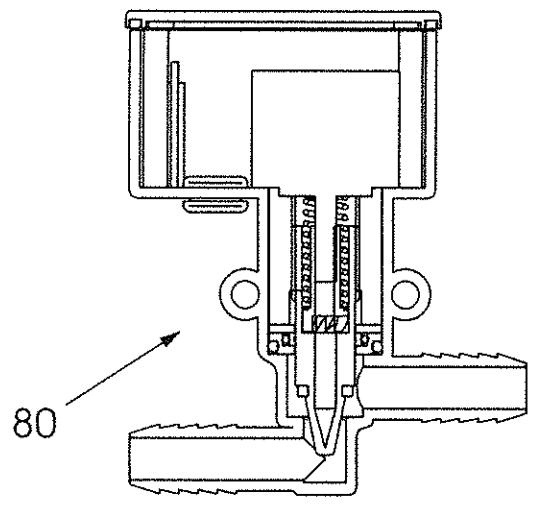


Fig. 11

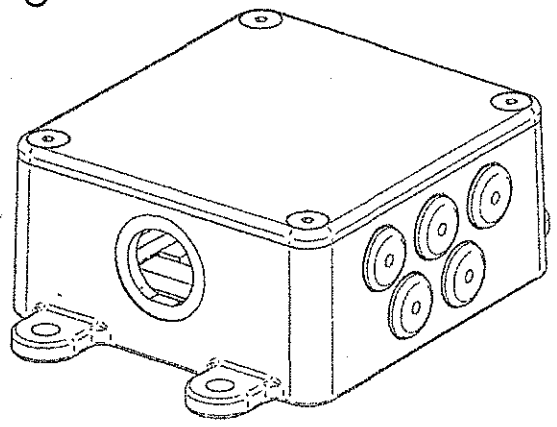


Fig. 12

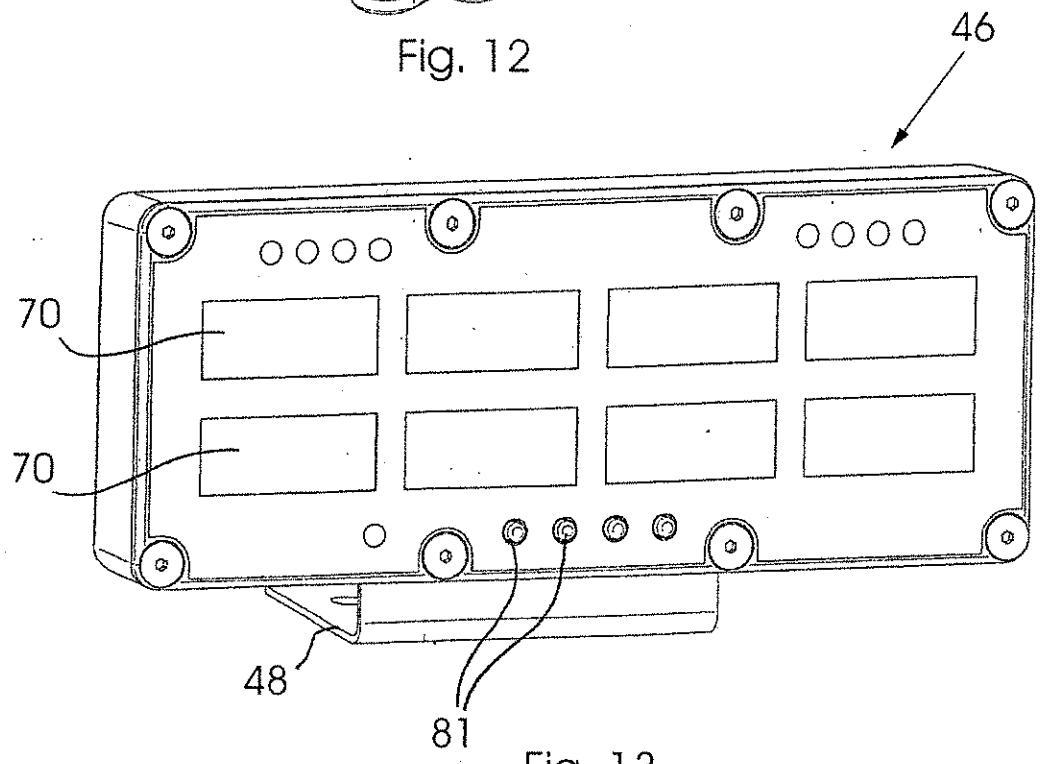


Fig. 13

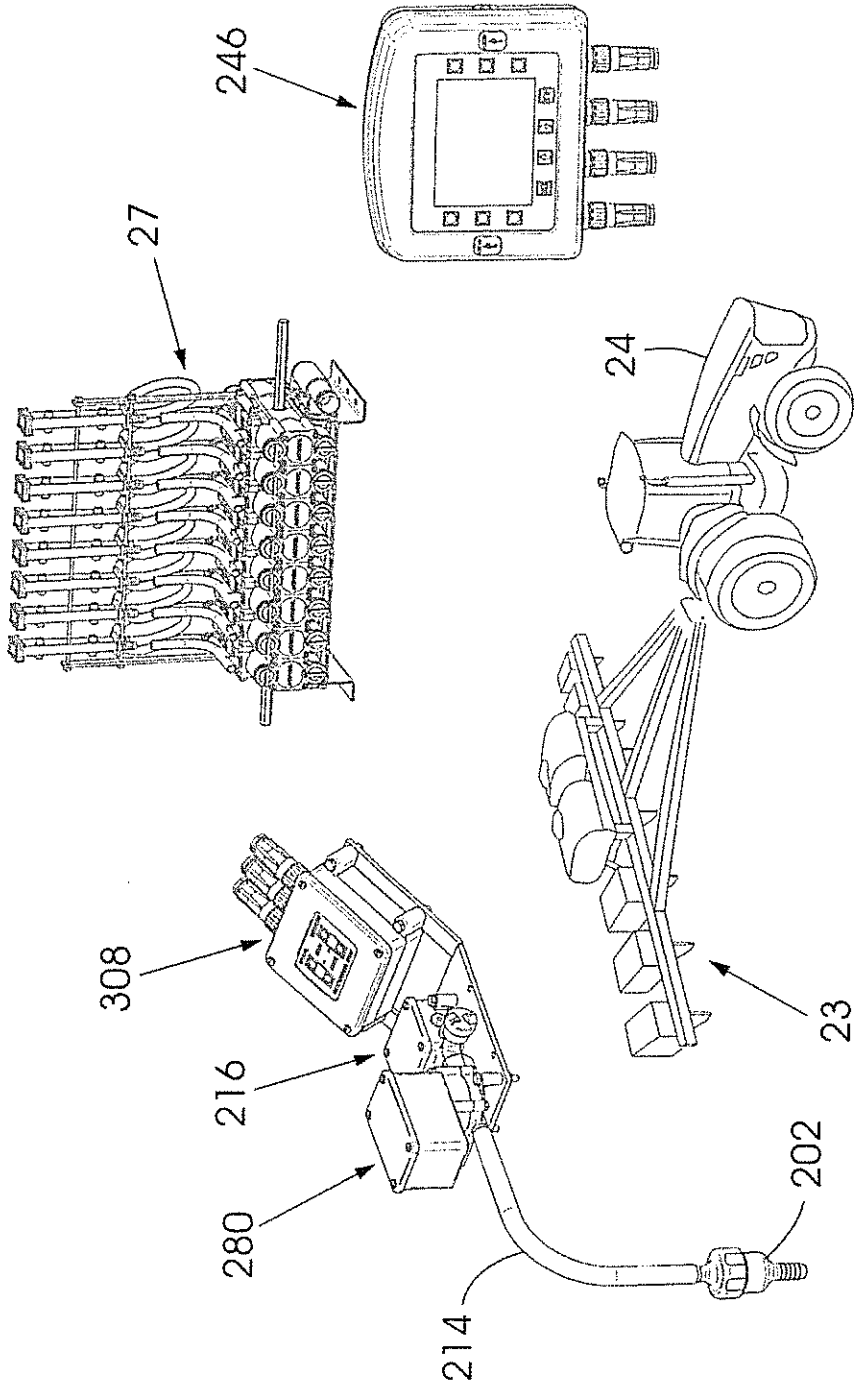


Fig. 14

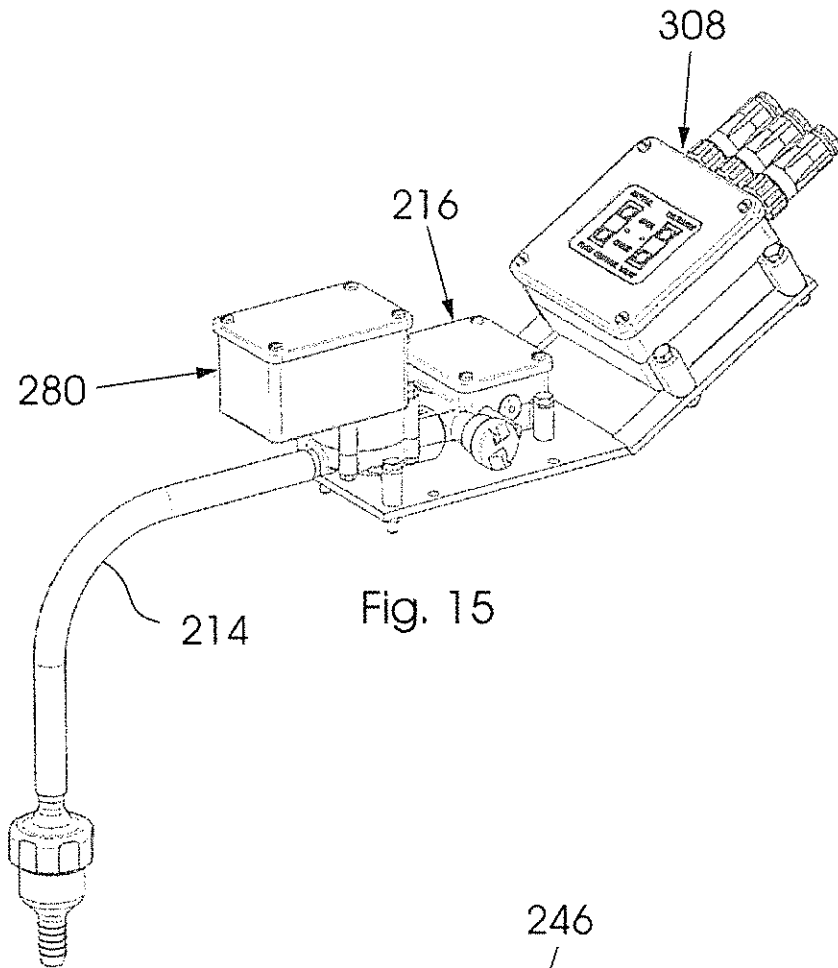


Fig. 15

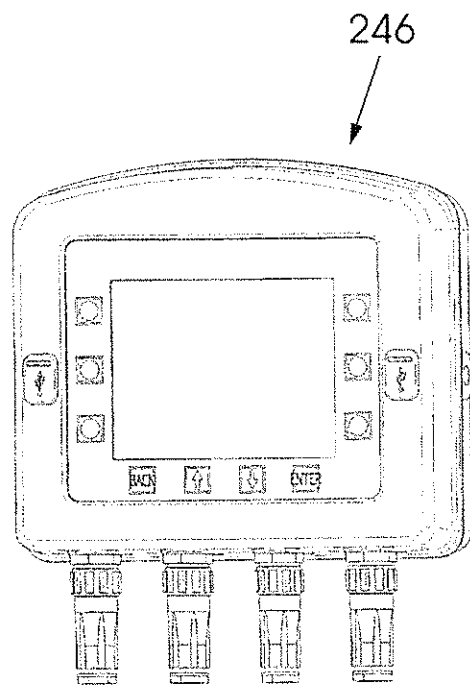
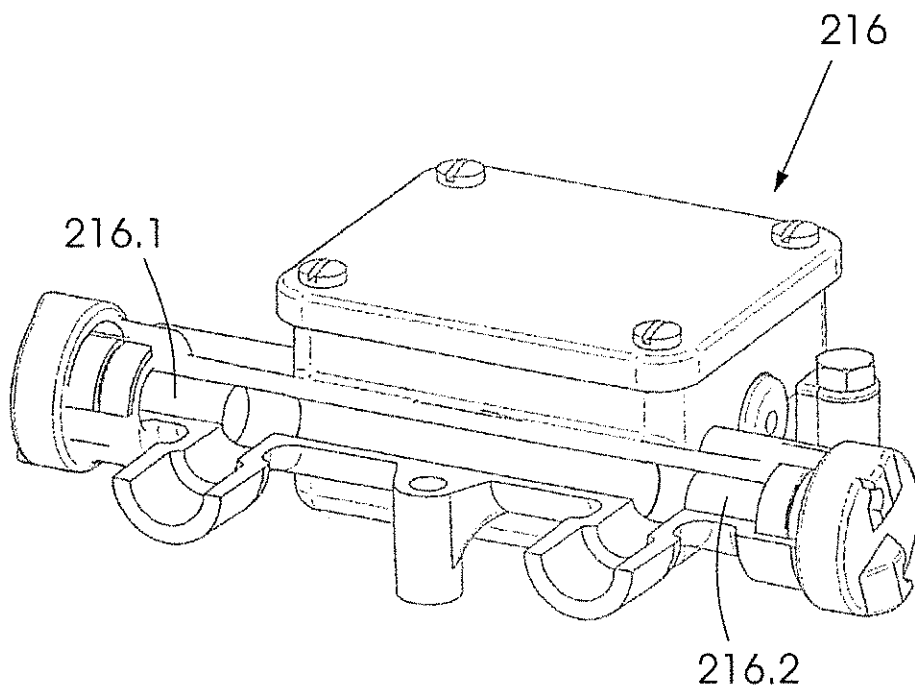
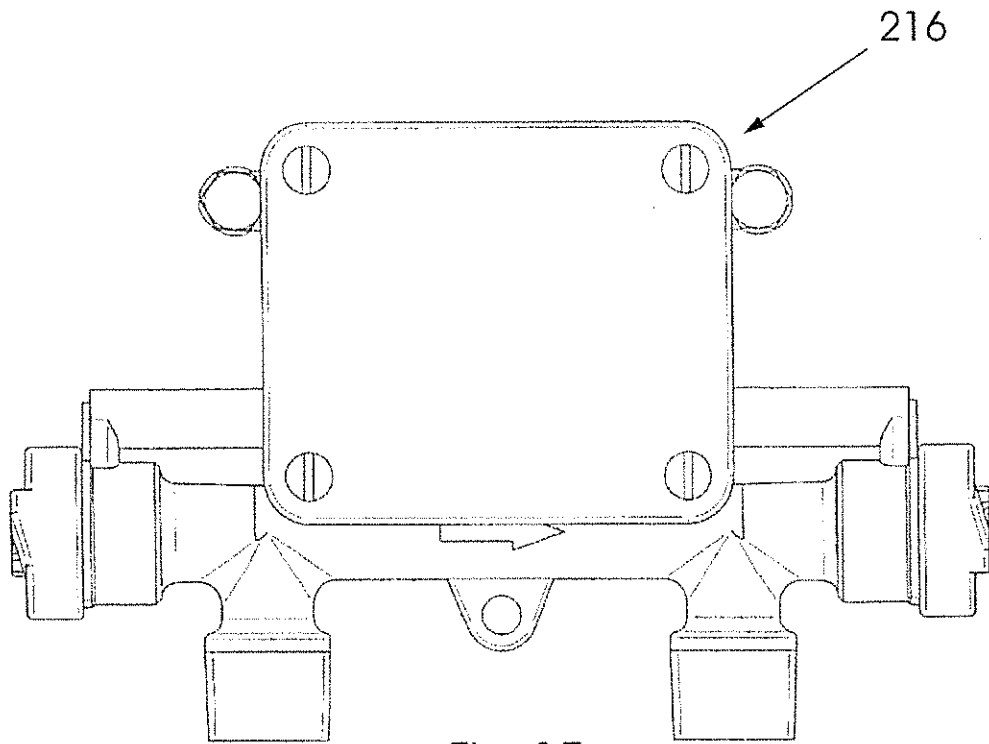


Fig. 16



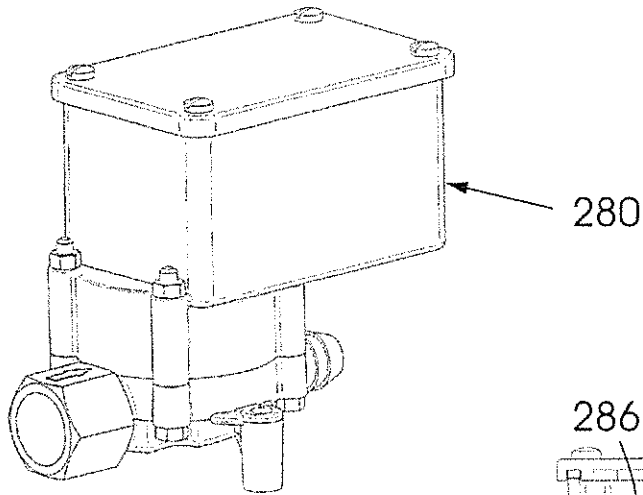


Fig. 19

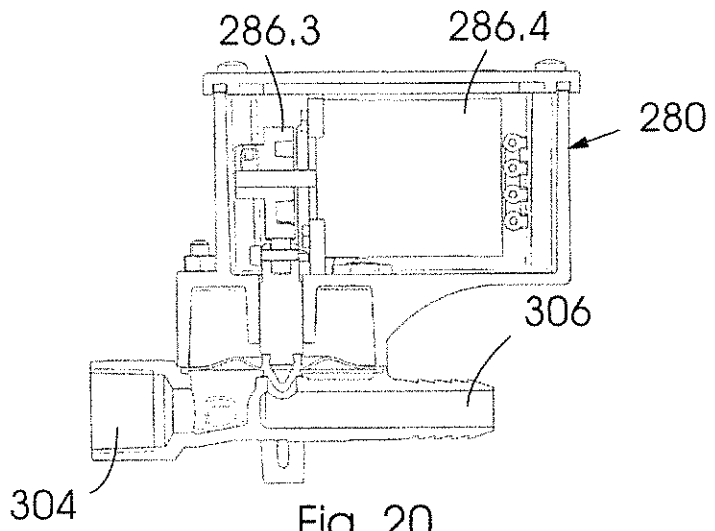


Fig. 20

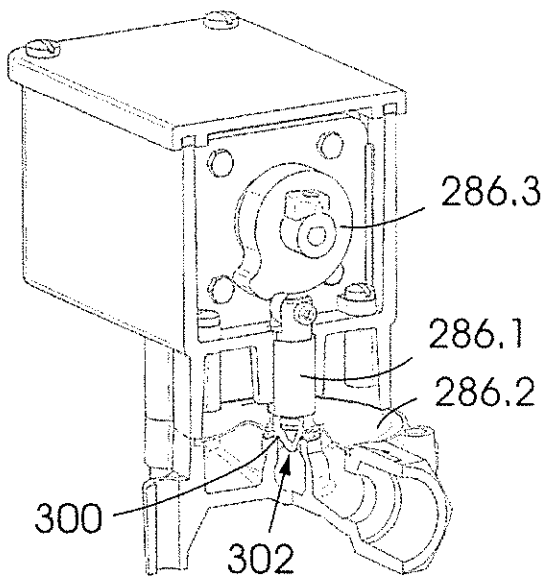


Fig. 21