United States Patent

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[54] **ANGIOGRAPHIC INJECTION EQUIPMENT**
24 Claims, 4 Drawing Figs.

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[51] Int. Cl. **A61b 06/00,** A61m 05/20
[50] Field of Search .... 128/2, 2.05, 218, 218 A, 215; 137/30, 36; 318/345, 347, 309–312, 318, 349, 350; 222/55, 63, 76; 103/11, 12, 35, 36

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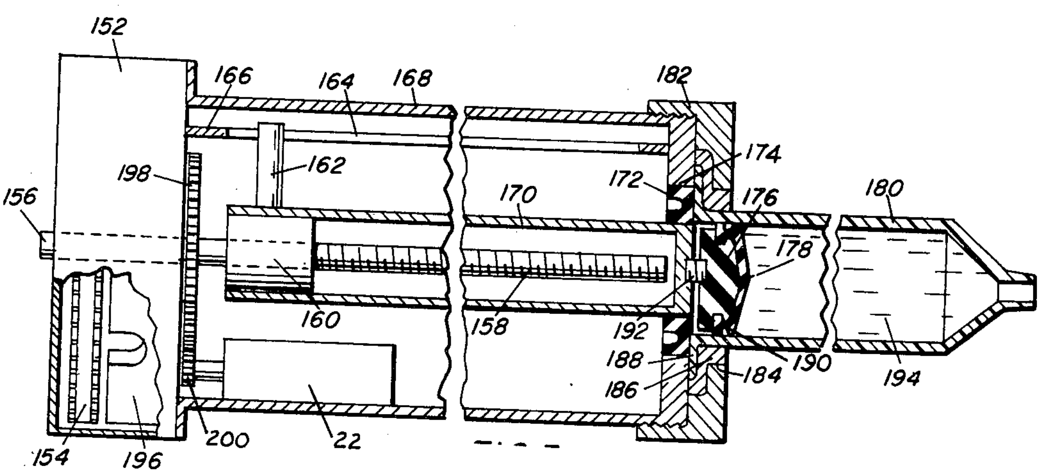
ABSTRACT: An angiographic injector system for producing a controlled rate of flow of injection fluid is described. The injector has a motor-driven piston for ejecting fluid from a syringe cartridge contained within a pressure jacket. The drive motor is operated in accordance with a command voltage which is proportional to the desired rate of flow. Sensing means detects the actual rate of flow and comparison means provides an error signal which controls the motor. Compensating means allow a single control system to operate the drive motor in conjunction with syringes of various sizes, and a tripping circuit halts the motor if the flow rate exceeds the selected rate.



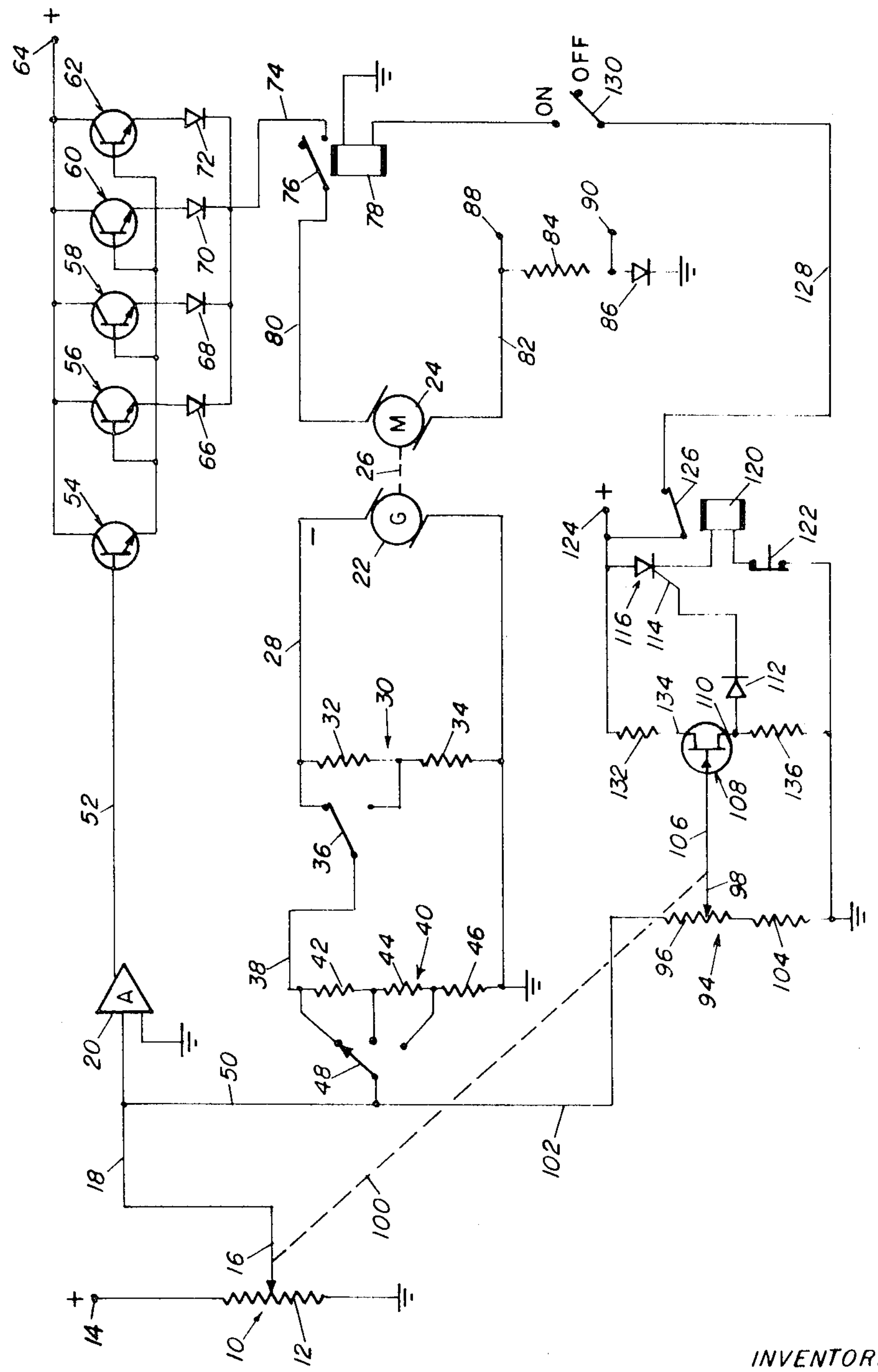


FIG. 1

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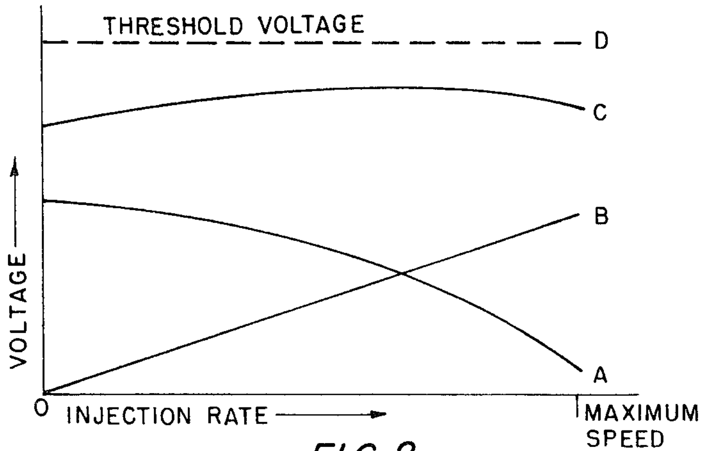

FIG. 2

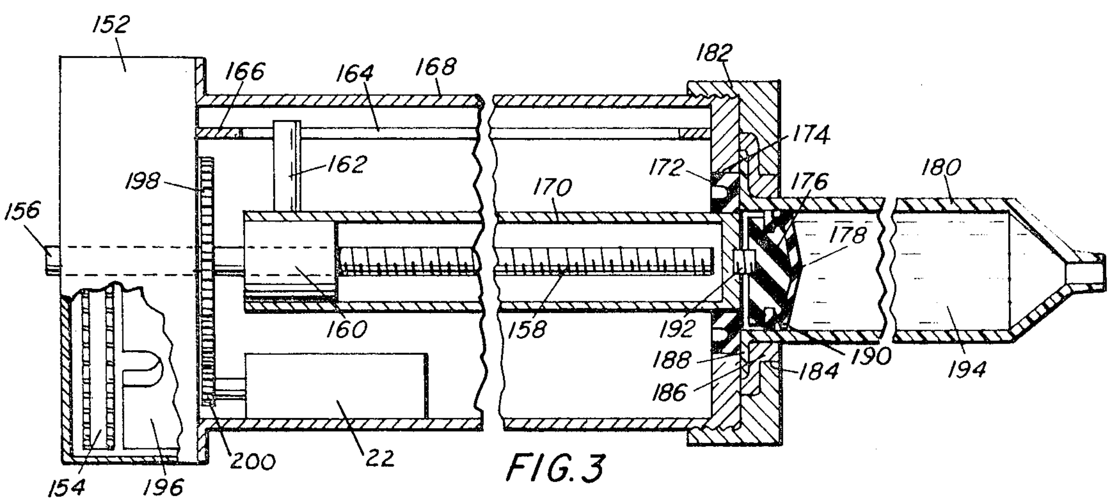

FIG. 3

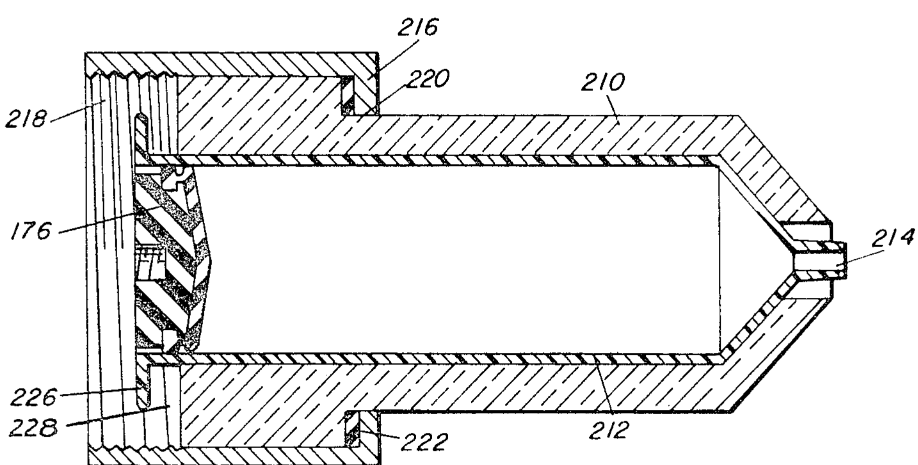

FIG. 4

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ANGIOGRAPHIC INJECTION EQUIPMENT

This application relates, in general, to the medical science of angiography, and, more particularly, to injection equipment for use therein.

Angiography is a radiological technique wherein the arteries of veins of a human or animal body are outlined by injecting suitable contrast material therein, permitting X-ray photographs to be made of the veins and arteries into which the material is injected. Because of its diagnostic value, angiography is enjoying increased use and many new instrumentation needs have arisen.

The contrast material used in angiography must be injected into the desired vein or artery close to the area to be photographed and immediately prior to making the photograph, for the flow of blood therethrough generally dissipates the contrast material very quickly. The material must, therefore, be injected through a long thin tube, generally called a catheter, to the vascular site of interest. Pressures as high as 1,000 p.s.i. have been used to accomplish this injection and, traditionally, the controlling injection variable has been the pressure setting on the injector used to supply the contrast material. However, the injector pressure setting is only one of the factors which determines contrast material flow rate, other factors being the internal diameter of the catheter, the catheter length, the contrast medium viscosity, and the configuration of the flow path, and it is the rate of flow of the contrast medium through the catheter in which the angiographer is interested. It is highly important that these factors be recognized, for failure to do so, and resultant reliance on pressure setting alone, can produce unpredictable flow rates under varying conditions. At best, such variations in flow rate reduce the quality of the X-ray photographs, while at worst may actually damage the vein or artery into which the material is being injected. It is therefore an object of this invention to provide a flow control injector system in which the operator can directly select the rate of contrast medium injection without regard to the many variables which affect flow rate.

Accurate knowledge of the contrast material discharge rate from the catheter tip is required in order to insure that the angiographic procedure is safe, for excessively high flow rates may cause considerable damage. Another object of this invention, therefore, is to provide means for monitoring and recording the actual pressure that is being used to accomplish the injection. A related object of the invention is to provide means for protecting the patient from such damaging flow rates by providing a rate trip network in the control circuitry of the present injector equipment, whereby the injection will be stopped in the event of a system failure that might lead to an injection rate higher than the operator command rate.

In the design of an injection system, a number of practical considerations should be taken into account. Space around an X-ray table is limited. Further, the catheter entrance point in the body of the patient, and, consequently, the ideal position of the injector tip with respect to the patient is variable, and is a function of patient size, position and the exact puncture site. For these reasons, a small injector that may be freely positioned in space around the X-ray table surface is a desirable end. With increased experience, angiographers have learned to place catheter tips in selective small flow areas where injection rates of 1 to 10 cc's per second are adequate for radiological opacification of the vessels under study.

An injector to satisfy the foregoing selective angiographic needs should be very small, should be injection rate-controlled and should be capable of being hand held or freely positioned around the injection site. It is therefore an additional object of the invention to provide an angiographic injector system which is compact and easily movable, yet is capable of providing a rate-controlled flow of sufficient volume to meet the needs of the art.

Inasmuch as the techniques of angiography may be applied in many parts of the body, all of which require different flow rates and which may require different quantities of contrast material, it follows that there is a need for a series of injectors all of which are injection rate-controlled, but differing in size and work capacity. However, such a series of injectors would multiply the cost of angiography, and make it less useful as a diagnostic tool. In order to avoid the duplication of such a series of injectors, and thus substantially to reduce the cost of such a series, the present invention provides a common power source and control system for use with a plurality of injectors and cartridges of differing size and capacity.

Prior art injectors, as well as that of the present invention, are electrically operated, and as a result an electrical potential is established in the injector. The prior injector art does not attempt to electrically insulate the contrast medium from this electrical potential. Rather, attempts are made to maintain the patient at the same potential as the injector. However, recent evidence has shown that voltages and currents as low as 100 millivolts and 100 microamperes transmitted from an injector through a catheter to the heart may cause a fatal heart condition known as ventricular fibrillation. It is an object of this invention to avoid this danger by packaging the contrast material in nonconductive plastic and rubber syringes to insulate the patient from the injector. It is a further object of this invention to protect these plastic syringes from explosion during a high pressure injection by protecting them with a pressure jacket.

These and other objects and features of the invention will become apparent to those skilled in the art from the following description of a preferred embodiment thereof, taken in conjection with the accompanying drawings, in which:

FIG. 1 is a schematic diagram of a control circuit for a flow rate controlled injector system;

FIG. 2 illustrates in graphical from the operation of the rate trip circuit of FIG. 1;

FIG. 3 is a side plan view, partly in cross section and partly broken away, of an injector suitable for use with the control circuit of FIG. 1; and

FIG. 4 is a cross-sectional side plan view of a modified syringe and supporting pressure jacket suitable for use in the injector of FIG. 3.

Turning now to a consideration of the circuit of FIG. 1, there is illustrated a control system by means of which the operator of the injector system may select an injection flow rate that will be delivered and maintained regardless of the various flow attenuating factors mentioned above. A command voltage directly proportional to the desired injection rate is established by adjustment of a potentiometer **10** having a linear resistor portion **12** connected between a source of reference voltage **14** and a ground point and a slidable arm **16**. Movement of the slidable arm by the operator determines the magnitude of the voltage applied through a line **18** to an amplifier **20**, and thus determines the flow rate, motion of the arm causing a varying flow rate, while a selected position produces a selected constant rate. A tachometer generator **22**, which is mechanically linked to the shaft of the injector drive motor **24** by way of linkage **26**, generates a feedback voltage at its terminals that is directly proportional to the actual injection rate, for as will be described hereinafter, the rate of flow must be directly proportional to the speed of motor **24** because of the nature of its direct drive mechanism. This feedback voltage, which has a polarity opposite to that of the command voltage, is applied by way of line **28** to a generator compensating voltage divider **30** comprised of resistors **32** and **34** connected in series across generator **22**. This voltage divider permits compensation of the control circuitry for different injectors which may have different mechanical linkages and generator output voltages. Selector switch **36** permits selection of the desired voltage level for application through line **38** to a scale factor voltage divider **40** which compensates the feedback voltage for various syringe cross sections, thus permitting the user of different sized syringes with a selected injector device. Voltage divider **40** is comprised of the series arrangement of resistors **42**, **44** and **46** connected between line **36** and ground, and a selector switch **48** for applying the desired voltage level through line **50** to the input of amplifier **20**. Since the feedback and command voltages are of opposite polarity, the algebraic sum of the magnitudes of these voltages at the input of amplifier **20** constitutes an error signal which corresponds to the difference between the desired and the actual injection rates.

The voltage dividers **30** and **40** are provided because it has been found that considerable savings in the cost of injector systems as well as in the space used by such systems, in addition to increased versatility of the system, can be effected if the injector system consists of a single power and control unit which services different size injectors which, in turn are capable of using different size syringes. Voltage divider **30** will then compensate for feedback voltage differences between, for example, a large, high-pressure injector and a small, hand-held injector. Voltage divider **40** will compensate for cross-sectional differences in the syringes used. To provide this versatility, the feedback voltage from the generator **22** is scaled by various constants that correspond first, to the generator voltage output per linear velocity unit of the piston used to drive fluid out of the syringe, and second, to the injection rate of the fluid per linear velocity unit of the piston travel. An example of the first compensating factor involves the use of an injector unit which produces a higher generator feedback voltage per unit piston travel velocity than the setting of the control unit which is to be used with the control unit. Voltage divider **30** permits compensation for such an event, thus allowing interchangeability between control units and injectors, or interchangeability of injectors with a given control unit. If resistors **32** and **34** are chosen so that R34/R32+R34 equals the ratio of the lower to higher generator voltage outputs per velocity unit of piston travel for two injector units, then they will be interchangeable in the control unit.

The injection rate from a syringe is directly related to the piston velocity multiplied by a scale factor which corresponds to the area of the syringe piston i.e., to the diameter of the syringe. The voltage signal which represents the actual injection rate can be held within the desired limits of accuracy, even though syringes of different cross-sectional areas are used. This is done by means of scale factor voltage divider **40**. In the illustrated embodiment, with switch **36** in the position shown, the voltage divider is set for the largest of three syringes having different cross-sectional areas, and provides the maximum voltage output. By positioning switch **48** between resistors **42** and **44**, the feedback voltage is proportional in injector flow rate for a syringe of smaller cross section. To maintain this proportion, the relationship R44+R46/R42+R44+R46 must equal the ratio of the cross-sectional area of the smaller syringe to the larger syringe. A still smaller syringe may be used if the voltage between **44** and **46** is picked up; thus, with a feedback voltage signal exactly proportional to the injection rate, different injectors utilizing different syringes may be controlled by a common control and power module.

The error signal which appears at the input of high gain amplifier **20** is amplified and fed through line **52** to the base of transistor **54**. This transistor acts as a buffer amplifier between amplifier **20** and the bases of parallel-connected power transistors **56, 58, 60** and **62**. The collectors of the power transistors are connected to a common low impedance power source at **64**, and the emitters are each connected through current limiting, low resistance, forward-biased diodes **66, 68, 70** and **72**, respectively, to a common line **74**. The current limiting diodes are provided to prevent excessive emitter degeneration. Line **74** is connected through contact **76** of the on-off relay coil **78** and thence through line **80** to the armature of motor **24**. As illustrated in FIG. 3, the motor may be a permanent magnet, direct current, torque type, having a printed circuit armature. The return motor lead is connected by line **82** through a resistor **84** and a diode **86** to ground.

Utilizing the linear relationship which exists in this type of motor between the motor output torque and the input current, the voltage drop, due to the armature current, which appears across resistor **84**, will be directly proportional to motor output torque and thus to the pressure generated by the injector. Diode **86** is chosen such that its voltage drop corresponds to the amount of motor output torque taken up by the mechanical friction of the injector. The voltage across resistor **84** may then be measured at terminals **88** and **90**, and used for pressure sensing and recording purposes.

In operation, the rate of rotation of motor **24**, which rate is proportional to the actual injection flow rate from the syringe, is measured by means of a generator **22**, producing a rate voltage. This injection rate voltage is compared to a command voltage representing the desired injector rate, and any error signal is amplified and used to control the conductivity of the parallel power transistors **56, 58, 60** and **62** connected in series with the motor to control its torque. The control system responds to an error signal to insure that the torque exerted by the motor on the piston of the syringe is sufficiently great to produce the desired flow characteristics regardless of variations in flow attenuation in the injector or the catheter.

Should the control system fail, an over-rate condition might result that could deliver an excessive flow of the contrast medium to the patient. To protect against this possibility, a rate trip circuit is provided as follows. A potentiometer **94**, having resistor portion **96** and sliding arm **98**, is ganged by means of mechanical linkage **100** with the injector rate command potentiometer **10**, but differs from element **10** in that it has an exponential, rather than a linear, response curve and, further, has a decreasing voltage output with clockwise rotation of slidable arm **98** instead of the increasing voltage with clockwise rotation of arm **16** used in potentiometer **10**.

The conceptual basis for the rate trip circuit is illustrated in FIG. 2, wherein curve A represents the exponential output of potentiometer **94** with clockwise rotation of its slidable arm, while curve B represents the linear output of potentiometer **10** with clockwise rotation of its slidable arm. Curve C represents the product of curves A and B.

Resistor portion **96** of potentiometer **94** is connected through lines **102** and **50** to the input of amplifier **20**, and thus the voltage appearing at this input is applied to resistor portion **96**. The output voltage on slider arm **98**, therefore, is the product of the settings of arms **16** and **98**, which product is represented by curve C of FIG. 2. Resistor **104** is connected in series with potentiometer **94** in order to maintain an output voltage on arm **98** that is above ground, so that the voltage represented by curve C does not fall to zero when the injection command voltage is at its maximum value.

The output appearing on arm **98** is applied through line **106** to the emitter of a unijunction transistor **108**. This transistor type is utilized because of its extremely low emitter current when in the "off" condition and because, at a predictable threshold voltage (indicated by curve D in FIG. 2), which equals a known fraction of the interbase voltage, the transistor **108** will fire and produce a voltage pulse on electrode **110** which is fed through a diode **112** to the control electrode **114** of a silicon controlled rectifier (SCR) **116**. The SCR is thus triggered into a self-latching "on" condition, allowing current to flow through relay coil **120** and normally closed switch **122** to ground from voltage source **124**. Energization of relay coil **120** shifts its normally closed contact **126** to open the current path from source **124**, through contact **126**, through line **128**, through master "on-off" switch **130** and through relay coil **78** to ground. This deenergizes coil **78**, allowing contact **76** to open and halt the injection. Opening of switch **122** allows the SCR **116** to return to its nonconductive state, thus permitting relay coil **120** to be deenergized and relay coil **78** to be reenergized. This resets the rate trip circuit and conditions the injector control system for further generation. Diode **112** allows only a positive pulse from transistor **108** to trigger the SCR **116**. The unijunction transistor **108** is biased by a resistor **132** connected between electrode **134** and voltage source **124** and by a resistor **136** connected between electrode **110** and ground.

By selecting appropriate values for reference voltage sources **14**, and **124**, the characteristics of potentiometers **10** and **94** and the value of resistor **104**, one can specify the shape of curve C (FIG. 2) which, under normal operational conditions will be a known percentage below threshold curve D.

Curve D is, in turn, a function of the reference voltage 124, the operating characteristics of unijunction transistor 108, and the value of resistors 132 and 136. However, should an overrate condition occur through a control system failure, the voltage seen by the arm 98 of potentiometer 94 would rise to the threshold voltage of the unijunction transistor 108, firing the transistor and activating the trip mechanism to stop the injection. An alternative method of activating the unijunction is to compare the command rate voltage with the feedback voltage in a differential amplifier, the output of this amplifier triggering the unijunction transistor when the feedback signal exceeds the command signal by a present amount.

Turning now to a consideration of the structure of an injector device suitable for use with the control system above described, there is illustrated in FIG. 3 an injector syringe mechanism 152 which is particularly designed for hand-held use. The injector mechanism is constructed for lightness and compactness, without sacrificing the required power, and thus is driven by direct current permanent magnet motor 24 having a printed circuit armature 154. The shaft 156 of the motor is drivingly coupled to a threaded screw shaft 158 for rotation with the motor armature 154. Threadedly engaging shaft 158 for rotation with the motor armature 154. Threadedly engaging shaft 158 is a ball nut 160 which is prevented by pin 162 from rotating, but which is free to move axially along shaft 158, the pin sliding in a guide slot 164 formed in a guide bar 166 supported in the housing 168 of the injector 150. The axial movement of ball nut 160 in response to rotation of threaded shaft 158 converts the rotary motion of motor 24 to linear motion. Ball nut 160 is connected to a piston tube 170 which moves with the ball nut along shaft 158. The outer end of the tube is supported, during its linear motion, by an oil seal 172 secured in an opening 174 at one end of housing 168. Piston tube 170 abuts directly against a piston head support member 176, which, in turn, provides mechanical support for a rubber piston cap 178. A syringe, or cartridge, 180 is mounted on the injector housing 168 by means of an internally threaded nut 182 adapted to engage external threads on the end of the housing 168. Nut 182 has a centrally located aperture 184 which receives the syringe and a seal member 186 to permit an airtight fitting on the end of the housing. A flanged portion 188 is provided on the end of the syringe which faces the housing to facilitate a tight seal between sealing members 174 and 186 when nut 182 is tightened.

The internal diameter of the syringe and the external diameter of piston 176 are selected to provide the clearance required to permit the flanged edge 190 of rubber piston cap 178 to seal the interior of the syringe. It will be apparent that different sizes of syringes will require pistons having varying diameters, but the construction of this mechanism is such that the various sizes are easily connected to the injector drive mechanism. The aperture in nut 182 is sufficiently large to permit larger syringes than that illustrated, while by providing smaller diameter syringes with sufficiently large flanges, they can be used with this equipment as well. Piston member 176 and cap 178 may be driven in a forward direction (toward the right as viewed in FIG. 3) by piston tube 170 without any mechanical connection being made between the piston and the tube. This arrangement is often used where it is essential to prevent reversal of the motion of the piston. Alternatively, piston 176 may be connected to piston tube 170 by means of screws 192, to permit both forward and reverse driving of the piston. It will be apparent that forward motion of the piston will expel fluid or any other matter within the syringe 180, such as contrast medium 194. If the piston is attached to the piston tube 170, reverse driving can be used to fill the syringe with the desired amount of contrast material while the syringe is attached to the injector drive mechanism.

The broken-away portion of motor 24 illustrates, in addition to armature 154, the arrangement of the permanent magnet 196. In operation, direct current is commutated to the armature conductors, an the resultant alternating magnetic field interacts with the stationary magnetic field of the permanent magnet to produce torque on shaft 156. Gears 198 and 200 provide a mechanical linkage of known gearing ratio between the motor shaft and tachometer generator 22. The use of a printed circuit armature, permanent magnet torque motor allows maximum power for minimum size and makes practical a hand-held injector much smaller than conventional electromechanical injectors.

Where greater injection power is required than can be delivered by the hand-held unit, a larger injector unit may be provided and mounted, for example, upon a suitable base member. Such a unit would require a more powerful motor and thus would not, as a practical matter, be a hand-held unit. However, both injectors would use the same power and control unit, being connected to that unit through suitable multiconductor connectors. It is contemplated that the power and control unit would be mounted, for example, in an instrument console adjacent an X-ray table, with a connector jack located at or on the table. A series of injectors would then be available for various uses, each one being plugged into the connector jack as needed. If desired, each injector may be connected to the power unit through some common and some individual conductors so that the proper compensating resistors would automatically be connected in circuit upon connection of a particular injector.

When the small, hand-held injector mechanism is used, the pressures involved are relatively low, in the neighborhood of 150 p.s.i. and a disposable plastic syringe or contrast medium cartridge may be used. However, when greater injector power is required, such containers are entirely inadequate, and they tend to explode long before the pressures of 800 p.s.i. used in angiography are encountered. This tendency has prevented the use of plastic containers in angiography, the accepted materials being glass for the smaller units and stainless steel for the more powerful units. This type of construction made the use of disposable containers out of the question, and required reuse, with its attendant danger of infection. The present invention overcomes the problem of container explosion and permits the use of disposable syringes or cartridges by providing the modified syringe mounting illustrated in FIG. 4, wherein a pressure jacket 210 is utilized to prevent the enclosed syringe 212 from bursting when injection pressures in excess of the strength limitations of the syringe are used. The pressure jacket is made to fit exactly the syringe, cartridge or ampule being used in the injector. This exact fit is obtained by making a positive mold of the syringe, the mold preferably being of metal. A high-strength, transparent plastic, such as styrene, acrylic polycarbonate or epoxy, is formed around the metal mold to a thickness sufficient to withstand the anticipated pressure. A circumferential flange is formed around the molded plastic to provide a bearing surface for the longitudinal forces exerted during injection. Preferably the syringe is slightly tapered toward the discharge end so that it can easily be inserted into and removed from the jacket. It will be apparent that the pressure jacket can be machined to the proper fit, if desired, but the molding process is preferred. With the internal dimensions of the jacket exactly corresponding to the outside dimensions of the syringe, the syringe is protected against the pressure induced by the driving of piston 176 against the resistance offered by a restricted flow path connected to the syringe tip 214.

Although prior automatic injectors have illustrated fluid containers resting in jackets of various types, these prior jackets have been no more than positioning devices designed to align the containers with the injector devices. Since the prior art contemplated low flow rates at low pressures, and did not anticipate the art of angiography, the container devices were not intended to withstand high pressures, and were not capable of doing so.

By making the pressure jacket of a high strength, transparent molded plastic material, the operator of the device not only may visually monitor the progress of the piston and the amount of fluid remaining in the syringe, but may also inspect the contrast medium for air bubbles and the like. The jacket is mounted on the external threads of housing **168** by means of a connecting nut **216** having internal threads **218**. A central aperture **220** in nut **216** receives the pressure jacket **210**, the connecting nut abutting against shoulder **222** of the jacket to force the syringe against housing **168**. An elastic bearing member **224** is interposed between nut **216** and the bearing surface of shoulder **222** for the purpose of evenly distributing the transmission of longitudinal force. Syringe **212** is provided with a flange **226** which abuts against housing **168** when properly seated, as described with respect to syringe **180** in FIG. 3. However, this flange serves an additional purpose in the present embodiment in that it is designed to extend a short distance out of the pressure jacket, leaving a small space **228** to allow the syringe to be grasped by flange **226** for removal from the pressure jacket.

The construction of the pressure jacket permits the use of a disposable, preloaded syringe of light weight glass or plastic, providing a quick, convenient method of loading an injector while at the same time providing insurance against the transmission of infection from one patient to another. Although the syringe shown in the accompanying drawings does not include a plunger means, but relies on the injector plunger **170** to drive the contrast medium out, it will be apparent that the injector can be modified to accept syringes which are manufactured with a plunger. Such a construction would permit the manufacture of a disposable plastic syringe, prepackaged to contain the contrast medium, which could be used for manual injections, could be used in the small, hand-held injector, or could be used in the larger injector after insertion in a pressure jacket.

Although the syringes in FIGS. 3 and 4 are shown without closure means on the outlet tips, it will be apparent that appropriate means would be provided for a prepackaged syringe. It is preferred that the outlet tips also be provided with Luer-Lok fasteners for easy attachment of catheters and the like.

Thus, there has been provided a compact, inexpensive injection apparatus designed for use in angiography. This invention recognizes that the major factor in the injection of contrast fluid is the maintenance of a constant flow rate, rather than of a constant pressure, and the system is accordingly directed to an injector apparatus and control circuit capable of producing this type of operation. The result is an angiographic injector having improved operating characteristics over prior art devices, but which eliminates the complexity and bulk of the prior art. The invention also recognizes that on occasion a variation in flow rate may be desired, and thus there is provided a command voltage which is proportional to the desired flow. This command voltage may be derived from the slide arm of a potentiometer, or from some other suitable source, and may be varied in either direction. The system will respond to any changes in the command voltage to produce a corresponding variation in the flow rate, and it will be apparent that the flow rate will thus be a function of the command voltage. These, and such other modifications of the described embodiment as will become apparent to those skilled in the art, are within the spirit and scope of the present invention as defined by the following claims.

I claim:

1. In an injector system for producing a controlled rate of flow of injection fluid for use in angiography and having an injector including syringe means for said fluid, movable piston means for ejecting said fluid from said syringe means, a drive motor for moving said piston, electrical control means including command means for producing a command signal which is a function of a desired rate of fluid flow, sensing means for producing a second signal which is a function of the actual injection flow of said fluid, and means for comparing said command and second signals to produce a resultant signal for operating said drive motor at a selectable, controlled rate to produce a desired flow of fluid whereby the rate of flow of said injection fluid will be substantially independent of flow-attenuating factors in the path of said fluid, the improvement comprising electrical circuit means responsive to said control means for stopping said drive motor and thereby automatically terminating the flow of said fluid upon the occurrence of a condition within said system that could result in an excessive rate of flow of said fluid.

2. The system of claim **1**, wherein said circuit means is responsive to an overrate condition, said circuit comprising means for producing a threshold signal in response to said overrate condition and gating means responsive to said threshold signal for thereupon disabling said drive motor.

3. The system of claim **2**, wherein said means for producing a threshold signal comprises potentiometer means connected to said command means and to said sensing means.

4. The system of claim **3**, wherein said potentiometer means comprises a nonlinear resistor having a first movable arm, said first arm being electrically connected to said gating means, said command means including a linear potentiometer having a second movable arm, said first and second movable arms being mechanically interconnected.

5. The injector system of claim **4**, wherein said circuit means further includes normally closed relay means for controlling said drive motor, and silicon controlled rectifier means in series with said relay means, said rectifier means being connected to and responsive to the operation of said gating means to open said normally closed relay means to deenergize said drive motor.

6. The injector system of claim **1**, wherein said control means is mounted in a control cabinet separate from said injector, said control means being connected to said injector through flexible electrical conductor means, said injector being sufficiently small and compact to facilitate use as a hand-held unit.

7. The injector system of claim **6**, wherein the drive motor for said injector is a direct current, permanent magnet, torque-type motor having a printed circuit armature to provide a small, lightweight, compact injector.

8. The injector system of claim **1**, the improvement further comprising signal generator means responsive to the operation of said motor for producing said second signal, and scale factor means for maintaining said second signal proportional to the injection flow of said fluid for various cross sections of said syringe means, whereby said system can be used with a variety of syringes.

9. The injector system of claim **8**, wherein said scale factor means comprises selectively variable voltage divider means.

10. The injector system of claim **1**, the improvement further comprising signal generator means on said injector responsive to the operation of said motor for producing said second signal, and said control means further including generator compensating means connected to said generator for maintaining said second signal proportional to the injection flow of fluid for various injectors and their corresponding signal generators, whereby said system may be used with a variety of injectors.

11. The injector system of claim **10**, further including scale factor means for maintaining said second signal proportional to the injection flow of said fluid for various cross sections of said syringe means, whereby said system can be used with a variety of syringes.

12. The injector system of claim **1**, the improvement further comprising housing means for said injector and threaded shaft means within said housing mechanically connected to said drive motor for rotation therewith, ball nut means engaging the threads of said threaded shaft, means mounted in said housing for preventing said ball nut from rotating, where by rotation of said drive motor moves said ball nut along the axis of said threaded shaft, piston tube means extending along the length of said threaded shaft and having an end portion extending beyond the end of said threaded shaft, said end portion abutting said piston to drive said piston along the axis of said syringe in response to the movement of said ball nut.

13. The injector system of claim **12**, said injector further including removable connector means between said end portion of said piston tube and said piston, whereby said piston tube can be connected to said piston for driving said piston in two directions, said piston tube being normally disconnected to permit said piston to be driven only in a direction to eject said fluid from said syringe.

14. The injector system of claim **13** wherein said sensing means further includes compensating means for maintaining said second signal proportional to said rate of flow for various mechanical linkages between said drive motor and said piston.

15. The injector system of claim **1**, the improvement further comprising disposable syringe means for said injector, said disposable syringe means including a disposable cartridge containing said fluid to be ejected and a transparent pressure jacket adapted to receive said cartridge and said piston means, said pressure jacket preventing deformation of said cartridge when said system is operative to apply pressure to said fluid to produce said fluid flow, a housing for supporting said piston means, and means for removably connecting said disposable syringe means to said housing, said last-named means including retainer means threadedly engaging said housing and having a central aperture adapted to receive said pressure jacket, said pressure jacket having a peripheral shoulder against which said retainer means abuts to hold said pressure jacket and housing in assembled relationship, whereby said pressure jacket can be removed from said housing for replacement of said disposable cartridge.

16. The injector system of claim **15**, further including electrically insulating means interposed between said housing and said syringe and said syringe means being electrically nonconductive, whereby electric potentials on said housing are isolated from said fluid.

17. The injector system of claim **15**, wherein said piston means comprises a piston head support and a flexible piston cap mounted on said support, said cap being replaceable to permit said piston means to be adapted to the internal diameter of said syringe means.

18. The injector system of claim **17**, the improvement further comprising signal generator means responsive to the operation of said motor for producing said second signal, and scale factor means for maintaining said second signal proportional to the injection flow of said fluid for various cross sections of said syringe means, whereby said system can be used with a variety of syringes.

19. The injector system of claim **1**, the improvement further comprising means for producing a voltage proportional to the output torque of said drive motor, whereby the pressure developed in said injection fluid can be monitored.

20. The injector system of claim **19**, wherein said means for producing a voltage proportional to the output torque of said drive motor comprises a resistor in series with the armature of said motor, said voltage being measured across said resistor and being proportional to said fluid pressure.

21. The injector system of claim **20**, wherein said drive motor is a direct current, permanent magnet, torque-type motor having a printed circuit armature for moving said piston means.

22. In an injector system for producing a controlled rate of flow of injection fluid for use in angiography and having an injector including syringe means for said fluid, movable piston means for ejecting said fluid from said syringe means, a drive motor for moving said piston, electrical control means including command means for producing a command signal which is a function of a desired rate of fluid flow, sensing means for producing a second signal which is a function of the actual injection flow of said fluid, and means for comparing said command and second signals to produce a resultant signal for operating said drive motor at a selectable, controlled rate to produce a desired flow of fluid whereby the rate of flow of said injection fluid will be substantially independent of flow-attenuating factors in the path of said fluid, the improvement comprising electric circuit means including a resistor connected to said drive motor for producing a voltage proportional to the output torque of said drive motor, said voltage being measured across said resistor and being proportional to said fluid pressure.

23. The injector system of claim **22**, wherein said drive motor is a direct current permanent magnet, to torque-type motor having a printed circuit armature, said resistor being connected in series with said armature.

24. The injector system of claim **22**, wherein said syringe means is electrically nonconductive and includes a disposable cartridge and a transparent pressure jacket adapted to receive said cartridge, said cartridge containing a prepackaged quantity of said fluid to be ejected, and said pressure jacket holding said cartridge in operative position while said injecting pressure is generated in said cartridge.

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