Dec. 20, 1966 M. C. YOUNG 3,292,431

FLOW MEASURING DEVICES

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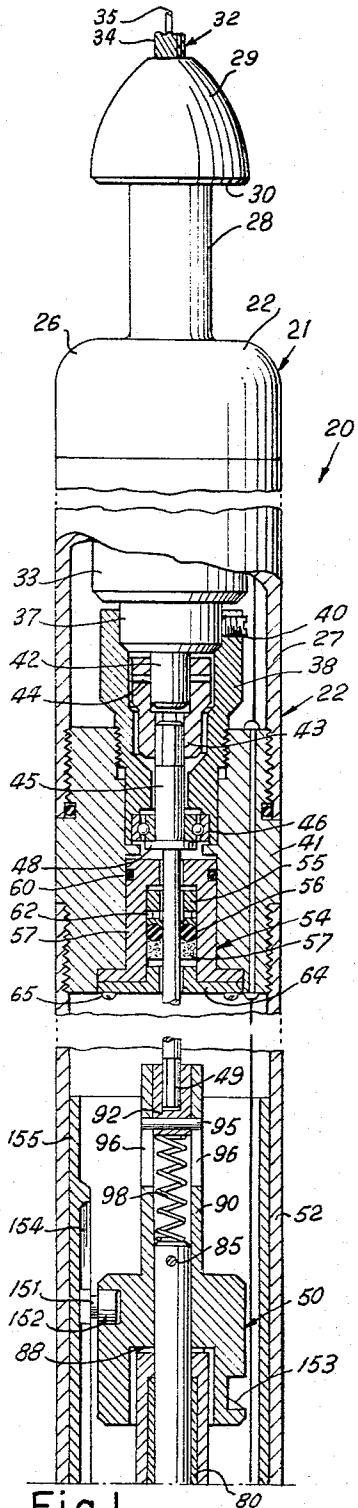


Fig.1

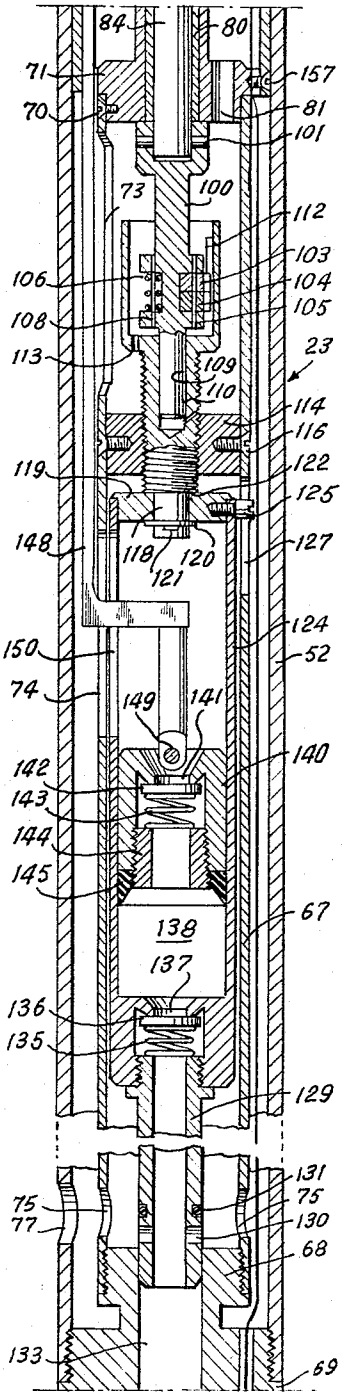


Fig.2

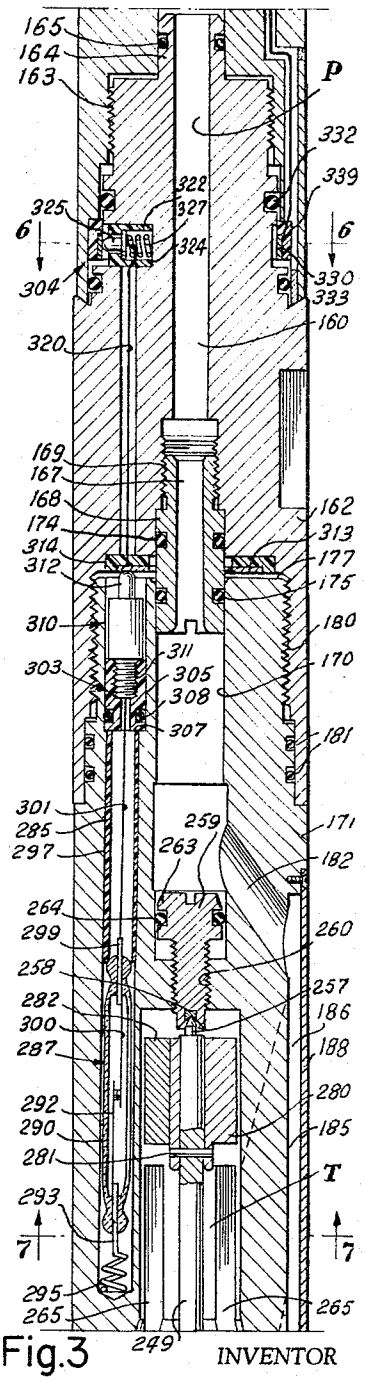


Fig.3

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Dec. 20, 1966 M. C. YOUNG 3,292,431

FLOW MEASURING DEVICES

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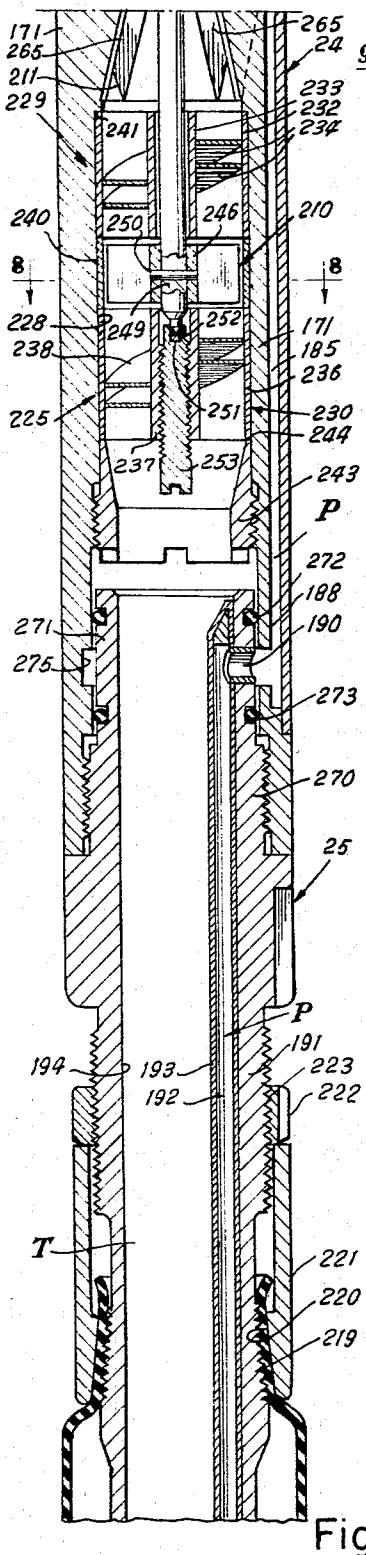


Fig. 4

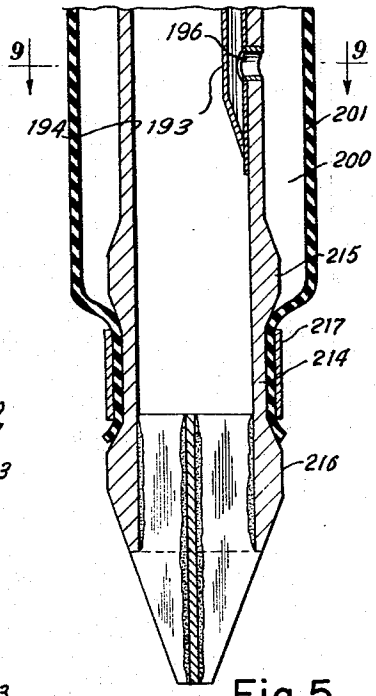


Fig. 5

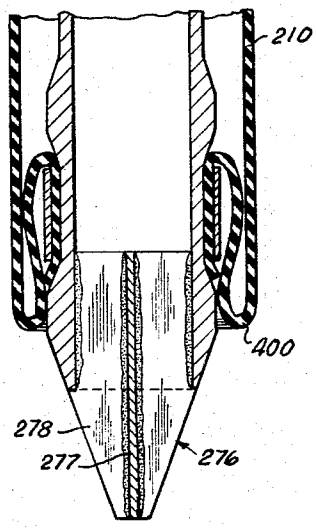


Fig. 10

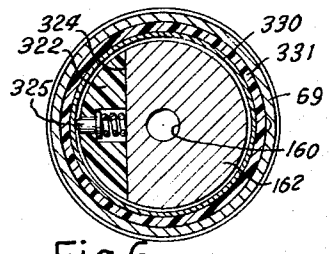


Fig. 6

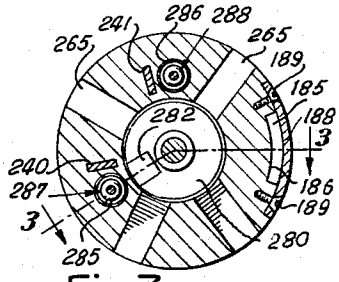


Fig. 7

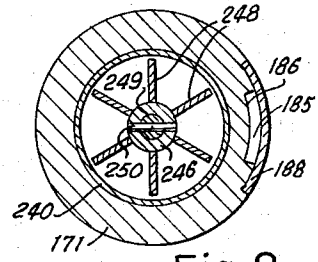


Fig. 8

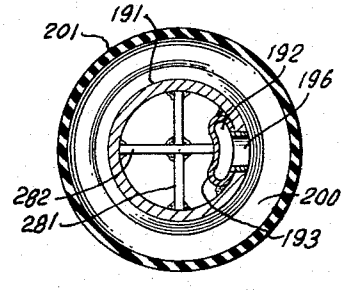


Fig. 9

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Dec. 20, 1966 M. C. YOUNG 3,292,431

FLOW MEASURING DEVICES

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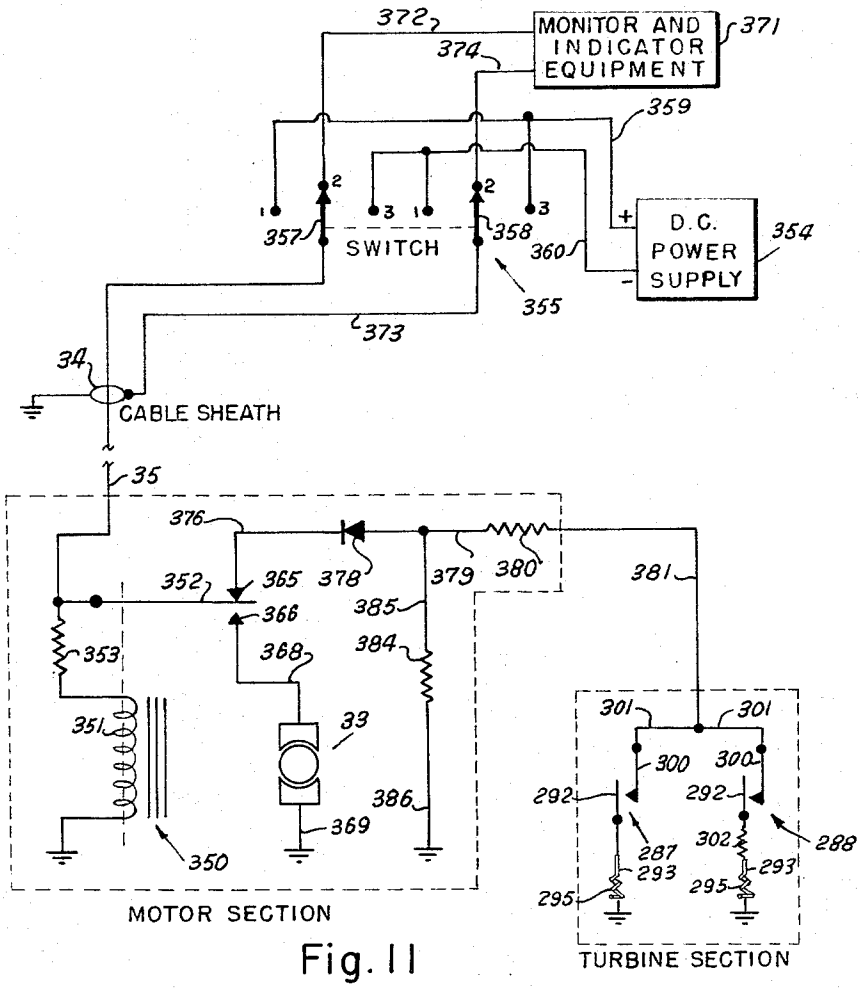


Fig. 11

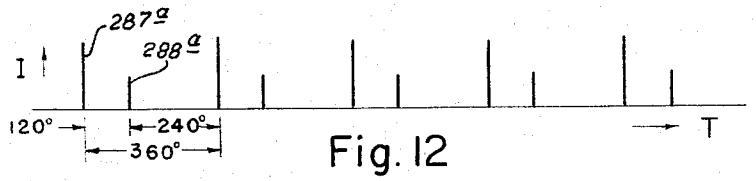


Fig. 12

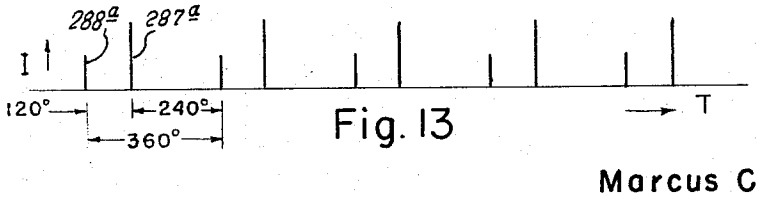


Fig. 13

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United States Patent Office 3,292,431
Patented Dec. 20, 1966

3,292,431

FLOW MEASURING DEVICES

Marcus C. Young, Odessa, Tex., assignor to Cardinal Surveys Company, Odessa, Tex., a corporation of Texas

Filed May 15, 1964, Ser. No. 367,678
5 Claims. (Cl. 73—155)

This invention relates to flow measuring devices and more particularly to a flow measuring device for measuring the rate and indicating the direction of flow of fluids in a well bore, flow conductor and the like.

An object of this invention is to provide a measuring device or flow meter which measures the rate of flow of fluids in a well bore, flow conductor and the like, very accurately over a very wide range of the rate of flow.

Another object is to provide a new and improved flow meter illustrated and described in the patent to H. M. Buck et al., 2,856,006, which is movable through a well bore and has a flow passage, a turbine in the flow passage and an expansible seal or packer for closing the annular space between the internal surfaces of the well defining the well bore and the flow meter in order that all fluid flow in the well bore be directed through the flow passage and past the turbine.

Still another object is to provide a flow meter having means operable by the turbine as it is rotated by fluids flowing through its flow passage which produce signals indicating the direction and rate of flow of fluids through the passage.

A further object is to provide a flow meter wherein the means for producing a signal does not have any component driven by the turbine which is in frictional engagement with any other component thereof in order that the flow meter indicate or measure very accurately the rate of flow of fluids over a wide range of rates of flow.

A further object is to provide a flow meter having a turbine having a pair of switches spaced in predetermined relation relative to each other and a magnet rotated successively past the switches for closing the switches as it moves therepast, one of the switches being connected in a circuit providing a signal of different amplitude than the circuit in which the other switch is connected whereby the direction of rotation of the turbine may be easily determined.

A still further object is to provide a flow meter having means for ensuring that only one switch is closed by the magnet at any position of the magnet relative to the two switches in order that the switches function properly regardless of the speed of movement of the magnet therepast.

A still further object is to provide a flow meter wherein the lower end of the expansible packer element when in collapsed position does not extend any substantial distance radially outwardly of the flow meter and the flow meter does not have any portions located therebelow which prevent inward movement of any lower end portions of the expansible element to preclude damage thereto during the movement of the flow meter past external obstructions in a well bore or a flow conductor especially when the lower end portion of the packer due to use or age tends to sag over lower portions of the flow meter.

Additional objects and advantages of the invention will be readily apparent from the reading of the following description of a device constructed in accordance with the invention, reference to the accompanying drawings thereof, wherein:

FIGURE 1 is a vertical, partly sectional view of the upper portions of the flow meter embodying the invention;

FIGURE 2 is a continuation of FIGURE 1 and shows an intermediate portion of the flow meter;

FIGURE 3 is a continuation of FIGURE 2 and is a vertical, sectional view taken on line 3—3 of FIGURE 7;

FIGURE 4 is a continuation of FIGURE 3 and is a vertical, sectional view of a lower portion of the flow meter;

FIGURE 5 is a continuation of FIGURE 4 and is a vertical, sectional view of the bottom portion of the flow meter;

FIGURE 6 is a cross-sectional view taken on line 6—6 of FIGURE 3;

FIGURE 7 is a cross-sectional view taken on line 7—7 of FIGURE 3;

FIGURE 8 is a cross-sectional view taken on line 8—8 of FIGURE 4;

FIGURE 9 is a cross-sectional view taken on line 9—9 of FIGURE 5;

FIGURE 10 is a fragmentary sectional view showing the position assumed by the lower end portion of the packer after it has sagged from its initial position;

FIGURE 11 is a schematic diagram of the electrical circuit employed in the operation of the flow meter;

FIGURE 12 is a chart illustrating the signals produced by the flow meter by the rotation of the turbine in one direction about its longitudinal axis;

FIGURE 13 is a view similar to FIGURE 11 showing the signals produced by the flow meter when the turbine is rotated in the opposite direction.

Referring now to the drawing, the flow meter **20** includes a housing **21** having a motor section **22**, a pump section **23**, a turbine section **24** and a packer section **25**. The motor housing section **22** includes a top body **26** threaded in the upper end of a hollow cylinder **27**. The fish neck body **26** has a reduced upper portion **28** provided at its upper end with a head **29** which provides a downwardly facing annular shoulder **30**. The fish neck body has a longitudinal passage through which extends a cable **32** to the reversible motor **33** mounted in the motor housing section **22**. The cable may include a metallic sheath **34** and an insulated inner conductor **35**. The motor **33** is located within the hollow cylinder and has a reduced lower portion **37** of its housing or stator telescoped in the upper portion of a tubular holder **38** and rigidly secured thereto by a set screw **40**. The motor holder **38** has an intermediate portion thereof threaded in a tubular connector section **41** of the housing whose upper reduced portion is threaded in the cylinder **27**. The drive shaft **42** of the motor is connected to a coupling **43** by a pin **44**. An opening in the lower end of the coupling is hexagonal in cross section in order to engage with the upper end portion of a shaft **45** which is also hexagonal in cross section. The shaft **45** extends through the inner race of a thrust bearing **46** and is held against upward movement by the engagement of its external flange **48** with the inner race. The shaft **45** has a lower end portion **49** of eccentric or hexagonal cross section for driving a cam **50** disposed in a hollow cylinder **52** of the pump housing section whose upper end is threaded on the reduced lower end portion of the connector housing section **41**.

A seal assembly **54** is disposed in the connector housing section **41** and includes a bronze bushing **55**, an O-ring **56**, felt packing **57** and a tubular holder **58** in which the bushing, the O-ring and the packing are disposed. An O-ring **60** disposed in an external recess of the holder seals between the holder and the housing connector section **41**. A plurality of grease escape ports **62** are provided in the bronze bushing **55** to transmit fluid pressure to the O-ring **56** to deform the O-ring and cause a positive fluid seal between the rotating shaft **45** and the holder **58** when fluid pressure is exerted below the packing assembly **54**. The holder **58** is rigidly secured to the connector housing section by a shaft aligning washer or

plate 64 rigidly secured to the connector housing section by means of screws 65.

A hollow cylinder or sleeve 67 is disposed in the cylinder 52 of the pump housing section 23 and its lower end is threaded on an upwardly extending portion 68 of a connector housing section 69 whose reduced upper end portion is threaded into the cylinder 52. The upper end of the sleeve 67 is rigidly secured, as by screws 70, to a cam shaft holder 71. The sleeve 67 is provided intermediate its ends with longitudinal slits or slots 73 and 74 and adjacent its lower end with fluid entry and drain slits or apertures 75. The cylinder 52 of the pump housing section has lateral ports 77 adjacent the ports 75 of the sleeve 67. The cam shaft holder 71 has a sleeve bearing 80 and a longitudinally offset passage 81 which communicates with the sleeve 67 at its upper end. A shaft 84 extends through the bearing 80 and the cam 50 and is attached at its upper end to the cam by means of a pin 85. A washer 88 disposed about the shaft 84 serves as a bearing between the cam 50 and the cam shaft holder.

The cam has an upward tubular extension 90 in whose upper end is disposed an engaging member 92 whose upper end is provided with an upwardly opening recess of hexagonal cross section in which is received non-rotatably the end portion 49 of the shaft 45. The engaging member 92 is held in the extension by a pin 95 whose opposite ends extend into the longitudinally extending slots 96 of the tubular extension. The pin 95 permits limited longitudinal movement of the engaging member 92 relative to the extension and therefore of the cam relative to the shaft 45. A spring 98 disposed in the tubular extension 90 biases the engaging member 92 upwardly therein, its upper end engaging the lower end of the engaging member and its lower end engaging the upper end of the shaft 84.

The lower end of the shaft 84 is connected to a pawl holder 100 by means of a pin 101. The pawl holder 100 carries two identical but oppositely directed pawls 103 and 104 mounted on a common pin 105. A pawl biasing spring 106 is mounted on a pin 108. The lower end of the pawl holder extends into an upwardly opening recess 109 of a pawl follower 110. The pawl follower is provided with a key 112 which projects internally from the pawl follower wall and is engageable by the pawls. A plurality of drain holes 113 of the pawl follower permit drainage of fluid or sediment which may enter into the pawl follower.

The lower threaded end portion of the pawl follower extends through a threaded bore of a wall member 114 disposed in the sleeve 67 between the longitudinal slots 73 and 74 and rigidly secured to the sleeve by the screws 116. The lower end portion 118 of the pawl holder extends rotatably through a pump cylinder head 119 and is held against upward longitudinal movement relative to the head by a washer 120 secured to the lower end portion of the pawl holder, by any suitable means, as by a pin 121. The pawl holder is held against downward movement relative to the pump cylinder head by its downwardly facing annular shoulder 122. The pump head 119 is rigidly secured to the upper end of the pump cylinder 124 by a screw 125 whose head is free to move longitudinally in a longitudinal slot 127 of the sleeve 67.

The lower end of the pump cylinder is threaded on the upper end of a tubular stinger 129. The stinger 129 has fluid exhaust ports 130 and an O-ring 131 which seals between the stinger and the connector body section 69 when the lower end portion of the stinger moves downwardly into the longitudinal passage 133 of the connector body section 69. The upper end of the stinger 129 supports a spring 135 which in turn bears against a check valve or member 136 positioned in the lower portion of the pump cylinder 124. The check member permits only downward flow through the port 137 of the pump cylinder from its chamber 138. A piston 140 which is slidably

movable in the pump cylinder 124 has a fluid entry port 141, a check member or valve 142, a biasing spring 143, a cup washer or seal 145 and a retainer 144 for the seal and the spring threadedly connected to the piston. The piston is connected to a piston rod 148 by a pin 149. The piston rod has a lateral portion which extends outwardly through the longitudinal slot 150 of the pump cylinder 124 and the slot 74 of the sleeve 67. The piston rod adjacent its upper end has an inwardly extending axle 151 on which is rotatably mounted a cam follower wheel 152 which moves in an external continuous helical slot 153 of the cam 50. The upper end portion of the piston rod is movable longitudinally in an internal recess by key-way 154 of a cylinder 155 telescoped in the pump housing cylinder 152 and rigidly secured to the cam shaft holder 71 by a screw 157.

It will now be apparent that the upper motor and pump sections of the flow meter 20 described hereinabove are identical to the upper sections of the flow meter illlustrated and described in the patent to H. L. Buck et al., No. 2,856,006 and accordingly no further detailed description thereof will be made herein. As is fully described in Patent No. 2,856,006, when pump motor 33 is energized and causes rotation of the shaft 45 in one direction, the shaft 80 and the cam 50 are also rotated. Rotation of the shaft 80 in such one direction also causes the rotation of the pawl follower 110 which moves downwardly in the wall member 114 until the pawl 103 moves over the top of key 112. This downward movement of the pawl follower moves the pump cylinder 124 and the stinger 129 downwardly until the O-ring 131 sealingly engages the internal surfaces of the connector housing section 69 defining the passage 133. Liquid is then pumped from the exterior of the flow meter into the chamber 138, as the piston 140 reciprocates, through the slots 77, 74 and 150 and the port 141 of the piston past the check valve 142 and is pumped from the chamber 138 through port 137 past the check valve 136 to the passage of the stinger and into the passage 133.

When the direction of rotation of the motor 33 is subsequently reversed, by reversing the polarity of direct current voltage applied across the conductor 35 and the metal sheath 34 of the cable 32, the direction of rotation of the pawl holder 100 is also reversed. This causes the pawl 104 to rotate the pawl follower in the opposite direction and causes it to move upwardly with respect to the wall member 114 due to its threaded connection therewith. This causes pump cylinder 124 to be moved upwardly until the ports 130 of the stinger 129 are withdrawn from the passage 133. Once the stinger has been raised to the upper posittion illustrated in FIGURE 2, fluid may flow upwardly from the passage 133 through the stinger, the ports 130 of the stinger, and the port 75 and 77 and to the exterior of the flow meter.

The lower end of the passage 133 of the connector housing section 69 communicates with the upper end of longitudinal passage 160 of the next lower housing section 162 which extends upwardly into the connector body section 69 and is theadedly secured thereto as at 163. The housing section 162 has a reduced upper end portion 164 provided with an external annular recess in which is disposed an O-ring 165 which seals between the upper portion 164 and the internal surfaces of the connector body section 69 defining its passage 133. The passage 160 communicates with the passage 167 of a tubular seal member 168 whose upper reduced portion is threadedly secured as at 169 to the housing section 162 and which extends into the longitudinal passage 170 of the next lower housing section 171. The seal member 168 is provided with a pair of external annular recesses in which are disposed the O-rings 174 and 175 which seal between the tubular seal member and the internal surfaces of the body sections 162 and 171, respectively, on opposite sides of an annular chamber 177 defined thereby. The housing section 171 is threaded to the section 162 as at 180 and is

provided with a pair of external annular recesses in which are disposed O-rings **181** which seal between the two body sections. The lower end of the passage **170** communicates with a lateral port **182** of the housing section which opens into the upper end of a longitudinal passage **185** provided by an external longitudinal recess **186** of the body housing section **171** and an arcuate plate **188** secured in fluid tight relationship to the body section as by the screws **189** and any suitable gasket or seal means. The lower end of the passage communicates through the lateral port **190** of the bottom housing section **191** with the upper end of the passage **192** of a duct **193** extending through a longitudinal passage **194** of the housing section **191** and secured thereto, as by welding. The lower end of the passage **192** of the duct communicates through a lateral port **196** of the bottom housing section with an annular chamber or space **200** between the exterior of the bottom housing section and a tubular packer **201**. The cross sectional area of the duct **193** is quite small compared to the cross sectional area of the passage **194** and thus does not unduly restrict or impede fluid flow through the passage. The passages **133**, **160**, **167** and **170**, the port **182**, the passage **186**, the port **190**, the passage **192** and the port **196** thus constitute a continuous passage P through which liquid pumped by the pump piston **140** is transmitted to the packer chamber **200** past the turbine **210** mounted in the main longitudinal passage **211** of the housing section **171**. The lower end of the packer is disposed in an external annular recess **214** defined by the external annular flanges **215** and **216** of the bottom housing section **191** and is rigidly secured thereto by a suitable clamp ring **217**. If desired, the lower end of the packer may also be secured thereto to the housing by any suitable adhesive or sealing agent.

The packer may consist of a preformed resilient tubular element having a maximum diameter approximating the diameter of the bore hole of the well wherein the flow measurement is to be made. The upper end of the packer element is clamped between a serrated surface **219** of the bottom housing section and the outwardly inclined surface **220** of a clamp sleeve **221** and held in compressed seal tight relationship therewith. The clamp sleeve is secured in clamping position by a nut **222** threaded as at **223**, on the bottom housing section.

A turbine assembly **225** which includes the turbine **210** is disposed in the passage **228** of the housing section **171** and includes upper and lower stator deflectors **229** and **230**. The upper stator deflector **229** includes concentric outer and inner sleeves **232** and **233** and two or more helical vanes **234** which extend between and are connected to the two sleeves. The lower stator deflector **230** similarly includes outer and inner sleeves **236** and **237** and a pair of helical vanes **238** connected to and extending between the two sleeves. A spacer ring **240** is disposed between the two outer sleeves **232** and **236**. Upward movement of the outer sleeve **232** of the upper deflector is limited by the engagement of its top annular shoulder with the downwardly facing annular stop shoulder **241** of the housing section **171**. Downward movement of the stator deflectors and the spacer ring is limited by a lock ring **234** threaded in the lower end of the housing section **171** whose top annular shoulder **244** engages the bottom end or shoulder of the outer sleeve **236** of the lower stator deflector.

The turbine **210** includes a tubular sleeve **246** having a plurality of radially outwardly extending vanes **248** and a turbine shaft **249** which extends through the turbine sleeve and is rigidly secured thereto by a pin **250**. The turbine shaft has a reduced needle pivot **251** at its lower end which engages a suitable bearing **252** disposed in an upwardly opening recess of the bearing support or rod **253** threaded in the inner sleeve **237** of the lower stator deflector **230**. The turbine shaft extends upwardly through the upper portion of reduced diameter of the passage **228** of the housing section **171** and is provided at its upper end with a reduced needle pivot **257** which is receivable in the usual conical recess of a bearing **258** mounted in a downwardly opening recess of a bearing support **259** threaded in a suitable bore **260** of the housing section **171**. The upper end of the bearing support **259** is disposed in the passage **170** below the lateral port **182** of the housing section **171** and has an external annular flange **263** provided with an external annular recess in which is disposed an O-ring **264** which seals between the flange and the internal surfaces of the housing section **171** defining the lower end of the passage **170**. Neither the turbine sleeve nor its vanes have any frictional contact with any of the surfaces of the upper and lower stator deflectors and the only frictional force tending to restrain rotation of the turbine shaft is at the points of contact of the needle pivots **238** and **257** with the bearings.

The housing section **171** above the upper stator deflector **229** has a plurality of radially outwardly opening slots or ports **265** through which fluids may flow between the passage **228** and the exterior of the flow meter. The bottom housing section **224** has an intermediate threaded portion **270** threadedly secured in the lower end of section **171** and an upper reduced portion **271** provided with a pair of external annular recesses in which are disposed O-rings **272** and **273** which seal between the reduced portion and the housing section **171** above and below the lateral port **190** which communicates with the lower end of the passage **185**. The housing section **171** is preferably provided with internal recess **275** which opens to the lower end of the recess **188** of the housing section **171** to facilitate flow of fluid between the passage **185** and the port **196** and in order that the port **196** need not be aligned with the lower end of the recess **188**.

The passage **194** of the bottom housing section opens downwardly. A nose **276** which extends downwardly from the lower end portion of the passage is formed of two vanes or blades **277** and **278** whose outer surfaces slope convergently downwardly and provide cam surfaces for guiding the movement of flow meter past obstructions in a flow conductor or well bore.

It will be apparent that the ports **265**, the passage **228** and the passage **194** of the bottom housing section **191** constitute a turbine flow passage T and that fluids flowing through the turbine passage T, due to the provision of the upper and lower stator deflectors cause the direction of rotation of the turbine to vary with the direction of flow of fluids through the turbine passage T. For example, if fluids flow downwardly through the turbine passage T, the upper stator deflector **229** causes the fluids to impinge on the vanes of the turbine in such manner that the turbine is rotated in a counter-clockwise direction, FIGURE 8, and when the fluids are flowing upwardly through the turbine passage T the lower stator deflector causes the liquids to impinge on the vanes of the turbine in such manner as to cause the turbine to rotate in a clockwise direction.

It will thus be seen that the direction of rotation of the turbine varies in accordance with the direction of flow of fluid through the turbine flow passage T, which of course extends through the packer **201**, so that when the flow meter is in a flow conductor or a well bore with its packer **201** in expanded condition closing the annulus between the internal surfaces of the well bore or of the flow conductor and the housing of the flow meter, all fluid flow through the bore at the location of the flow meter must take place through the turbine passage T and causes the turbine to rotate in one direction when the flow is downwardly through the turbine passage and in the opposite direction when the flow is upwardly through the passage. The speed of rotation of the turbine of course varies in accordance with the rate of flow of fluid through the turbine passage.

The turbine shaft **249** has a cylindrical rotor **280** rigidly secured thereto by a pin **281**. The rotor **280** is disposed

in the reduced upper portion of the passage **228** of the housing section **171** above the inner ends of the upwardly opening ports **265** of the housing section **171** so that the rotor **280** itself does not interfere with the flow of fluids through the turbine passage. The rotor has a permanent magnet **282** rigidly secured in an external longitudinal slot thereof. The housing section **171**, which is formed of a non-magnetic substance such as brass, has a pair of upwardly opening recesses **285** and **286** in which are disposed switches **287** and **288**, respectively, which are closable by the magnet **282** of the rotor **280** as it rotates therepast.

The recesses are spaced in predetermined angular relationship relative to each other about the axis of rotation in order that a predetermined relationship or ratio exist between the periods of time elapsing between the closings of the two switches during each revolution of the rotor and turbine. For example, the two switches may be spaced 120 degrees and 240 degrees apart about the axis of rotation of the turbine so that the turbine must rotate 120 degrees after the switch **187** has been closed by the permanent magnet **282** before the switch **188** is closed thereby and then must rotate through an additional angle of 240 degrees before the switch **187** is again closed by the permanent magnet.

Each of the switches **287** and **288** includes a hermetically sealed envelope **290** of glass or the like, a resilient conductive leaf spring or contact **292** of magnetic substance whose lower end is secured to a terminal **293** which extends outwardly of the lower end of the envelope and has a coiled spring portion **294** which engages the bottom shoulder **295** of its bore **285** to resiliently hold the switch assembly in the recess and to establish electric contact with the housing section **171**. The envelope **282** is held against upward movement by an insulator sleeve **297** inserted in the upper end of the bore **285** or **286** whose lower end engages the upper end of the envelope to hold the envelope against upward movement in its bore of the housing section. A terminal **299** extends inwardly through the upper end of the envelope and is connected to the stationary contact **300** of the switch and to a conductor **301** which extends upwardly through the insulator tube. The switch **288** has a resistance **302** associated therewith and connected in series therewith between the upper portion of its terminal **293** and its spring **294**.

The stationary contact **300** of the switches **287** and **288** are connected to the insulated conductor **35** of the cable **32** by suitable conductors which extend through passages or bores of the various housing sections. Contact assemblies **303** and **304** may provide suitable electrical connections for such conductors between adjacent ends of adjacent housing sections. Each contact assembly **303** includes a tubular insulator block **305** disposed in the upper enlarged end portion of the bore **285** or **286** of the housing section **171** with its downward movement being limited by the engagement of its lower end with the upwardly facing annular shoulder **307** of the housing section **171**. The insulator block has an external annular recess in which is disposed an O-ring **308** which seals between the block and the housing section **171**. The metal connector **310** has a dependent stud **311** which is threaded in the upper end of the insulator block **305** and a rounded reduced contact portion **312** which engages an annular contact ring **313** bonded or otherwise secured to an insulator support block **314** press-fitted or otherwise rigidly secured in a suitably recess of the connector housing section **162**. The connector **310** is, of course, of smaller diameter than the internal diameter of the enlarged upper portion of the bore **285** or **286** and is therefore not in contact with the housing section **171** and the conductor **301** is connected to its lower end. The contact ring **313** may be connected to another contact assembly at the opposite end of the connector housing section **162** such as the contact assembly **304** by a conductor **320** which extends through a suitable passage or bore of the housing section **162** and a suitable aperture in an insulator block **322** mounted in a lateral recess **324** of the housing section **162**. The conductor is connected to a movable contact **325** disposed in a bore of the insulator block and which is biased outwardly, by a spring **327** of a suitable non-conductive substance such as plastic. The contact **325** engages a conductor ring **330** bonded in a suitable recess of an insulator ring **331** which in turn is pressed fitted or otherwise secured in the housing section **69**. O-rings such as the O-rings **332** and **333** are disposed in suitable external recesses of one of the telescoped sections of housing section to seal therebetween. The contact ring, of course, has a conductor **335** connected thereto which extends through any suitable passage or bore **335** of the housing section in which the insulator ring **331** is press-fitted and extends to its opposite ends.

It will be apparent that although only the housing sections **171**, **162** and **69** have been shown provided with such control assemblies **303** and **304** by way of example, either a contact assembly **303** or a contact assembly **304** may be provided at each connection of two sections of the housing to permit easy assembly and disassembly of the flow meter.

A pair of magnetic shunts **340** and **341** of soft iron or the like are inserted in suitable slots of the housing section **171** between the two bores **285** and **286** to shunt the magnetic flux or field of the magnet from each switch previously closed thereby and cause it to open before the other switch closes as the magnet is moved therepast. For example, if the rotor, which is of brass or other non-magnetic substance, is rotating in a clockwise direction, FIGURE 7, as its magnet moves into radial alignment with the switch **287** its magnetic field or flux causes the switch **287** to close. As the magnet moves toward radial alignment with the shunt **240** its flux or field is immediately shunted from the switch **287** to the shunt **240** whereupon the switch **287** opens. As the magnet continues to move, its magnetic field is shunted through the shunt **241** and then, as it moves into radial alignment with the switch **288**, its field closes the switch **288**. The shunts are disposed between the switches at the locations wherein the switches are positioned close to one another and ensure that either switch which has been closed by the magnet is open before the other switch is closed regardless of the direction of movement of the magnet therepast. The shunts are necessary to permit proper operation of the switches during rapid rotation of the rotor when the rate of flow of fluids through the turbine passage is great.

A relay **350**, FIGURE 11, is also mounted within the motor housing section **22** and includes a coil **351** and a movable contact **352**. A resistance **353** which is connected in series with the coil **351** and the insulated conductor **35** of the cable are also mounted in the motor housing section. The relay coil is connectable across a high voltage direct current source or power supply **354** through a double pole switch **355** when its movable contacts **357** and **358** engage either the stationary contacts **1** or **3**. The stationary contacts **1** and **3** of the switch **355** engageable by the movable contact **357** are connected by the conductors **359** and **360**, respectively, to the power supply **354** while the stationary contacts **1** and **3** engageable by the movable switch contact **358** are connected to the power supply by the conductors **360** and **359**, respectively.

It will be apparent that when the movable contacts of the switch are moved to the positions wherein they engage the stationary contacts **1** or **3**, the relay coil is energized by a relatively high voltage which causes current flow through the relay coil and the contact **352** is moved downwardly out of its normal upper position, FIGURE 11, wherein it engages the stationary contact **365** and into engagement with the lower stationary contact **365** and

into engagement with the lower stationary contact **366** of the relay. One side of the motor **33** is then connected to the insulated conductor **35** of the cable **32** through the movable contact **352** and the conductor **368** while its other side is connected to the other conductor or sheath **34** of the cable through the conductor **369** and the housing of the flow meter.

It will now be apparent that when the switch **355** is in one extreme position wherein its movable contacts **357** and **358** engage their associated contacts **1**, the positive side of the power supply is connected to the insulated cable conductor **35** of the cable and its negative side is connected to the sheath **34**. When the switch is moved to its other extreme position wherein its movable contacts engage the stationary contacts **3**, the negative side of the direct current power supply is connected to the insulated conductor **35** and the positive side to the sheath so that the direction of flow of current through the motor may be reversed by moving the movable switch contacts from engagement with the contacts **1** and into engagement with the contacts **3**, and vice versa.

When the switch is in the position wherein its movable contacts **357** and **358** are in the positions wherein they engage the middle or intermediate stationary contacts **2**, the conductor **35** is connected to one side of the input circuit of the monitor and indicator equipment **371** through the conductor **372** and movable switch contact **357** and the sheath is connected to the other side of the monitor and indicator equipment through the conductor **373**, the movable switch contact **358** and the conductor **374**. The monitor and indicator equipment includes a source of relatively low voltage, for example, three volts, which is applied across the input circuit whenever such input circuit is closed by either one of the switches **187** and **188** since the relay coil **351**, which now also has the low voltage applied thereto, will not move its contact **352** downwardly out of engagement with the stationary contact **365** when energized by such low voltage. The stationary contact **365** of the relay is connected to the stationary contacts **300** of the rotor operated switches **287** and **288** through a conductor **376**, a unidirectional conducting device, such as a diode **378**, a conductor **379**, a resistance **380** and the conductor **381**. The switch **287** when closed connects the conductor to the sheath **34** through its terminal **293**. The switch **288** when closed connects the conductor to the sheath through its terminal **293**, a resistance **395** and the spring **295** and it will thus be apparent that a smaller current will flow through the input circuit when the switch **288** is closed than when the switch **287** is closed. A resistance **384** is connected between ground and the common connection of the diode **378** and the resistance **384** by the conductors **385** and **386** to suppress any sparking between the contacts of the relay.

In use, the flow meter **20** is lowered through a flow conductor, such as the tubing of a well whose lower end is positioned above the bottom of the well bore, to a position in the well bore whereat it is desired to discover the direction and measure the rate of flow of fluids in the well bore.

During the movement of the flow meter in the well, the switch **355** may be in its middle position wherein its movable contacts **357** and **358** engage stationary contacts **1** or **3**, or may be in an open position wherein its movable controls do not contact any of its stationary contacts. As a result the resilient tubular packer is in the retracted position illustrated in FIGURES 1 through 5. When the flow meter is positioned at the desired location in the well bore below the lower end of the tubing, the switch is moved to one of its operative positions, for example, the position wherein its movable contacts engage the stationary contacts **1**. The coil **351** of the relay **350** is then energized and moves its contact **352** downwardly into engagement with its stationary contact **366**. The pump motor **33** is thus energized and pumps fluids through the pump passage P into the chamber **200** between the packer **201** and the housing. The packer is expanded by the fluid until it engages the internal surfaces defining the well bore and closes the annular space between the housing **21** and the well bore between the opposite open ends of the turbine passage.

If the fluids in the well bore are now flowing upwardly at the location of the flow meter, they flow through the turbine passage and past the turbine and cause the turbine to rotate in a clockwise direction, FIGURE 8. During each such clockwise rotation of the turbine, the rotor is also rotated through 360 degrees and the magnet **282** in moving momentarily and successively closes the switches **287** and **288**. Since the circuit of the switch **288** has the resistance **302** connected therein the current in the signal input circuit of the Monitor and Indicator Equipment across the conductors **372** and **374**, will be of greater amplitude when the switch **287** is closed than when the switch **288** is closed, as is illustrated in FIGURE 12. In addition, the pulses **287***a* and **288***a* produced when the switches **287** and **288**, respectively are closed, have the time and the amplitude relationships illustrated in FIGURE 12 since when the magnet moves in a clockwise direction, FIGURE 7, and closes the switch **287**, it rotates only through 120 degrees into radial alignment with the switch **288** and closes it and then rotates through 240 degrees until it again closes the switch **287***a*. As a result, the two time intervals between each pair of signal pulses during successive closings of the two switches are different and indicate the direction of rotation of the turbine.

The speed of rotation of the turbine will, of course, vary directly in accordance with the rate of flow of fluids through the turbine passage and thus the rate of flow of fluids in the well bore at the location of the flow meter is easily determined by the monitor and indicator equipment which may include any suitable recorder and rate of flow indicating devices operable responsive to the signals. The monitor and indicator equipment may also include an oscilloscope for providing a continuous visual indication of the signals in the signal input circuit of the monitor and indicator equipment so that the operator may immediately know that the fluids in the well at the location of the flow meter are flowing upwardly. If the rate of flow of the fluids is very rapid, the turbine and the rotor of course rotate very rapidly and if the magnetic shunts **240** and **241** were not provided, the switch **287** would not open before the switch **288** closed due to the fact that the magnetic field of the magnet would tend to maintain it closed until it had moved a substantial distance out of radial alignment with the switch **287** and due to the inertia of the switch. The shunt **240**, however, shunts the magnetic field away from the switch **287** as the magnet **282** moves out of radial alignment therewith. In addition, the shunt **241** will prevent the magnetic flux from actuating the switch **288** until the magnet **287** moves into radial alignment with the switch **288**. Thus both shunts tend to prevent the simultaneous closure of the two switches which could occur at very high speeds of rotation of the turbine and the rotor.

When the direction and the rate of flow of the well fluids at a particular location in the well bore has been determined by the monitor and indicator equipment, the switch **355** is moved to the position wherein its movable contacts **357** and **358** engage its stationary contacts **3** and the relay coil **351** is again energized by a high voltage and moves its contact **352** again downwardly. This time, however, the direction of flow of electric current through the motor **33** is reversed from that when the switch contacts **357** and **358** engage the stationary contact **1**, and the rotor rotates in its opposite direction to move the stinger **129** upwardly whereupon the fluid trapped in the chamber **201** is free to flow outwardly and the packer retracts to its retracted position from its

expanded position. A predetermined short interval of time after the movement of the switch **355** to the position wherein its movable contacts engage a stationary contact **3**, and the packer has retracted, the contacts **357** and **358** are again moved to the contacts **2** or intermediate open positions and the packer is then moved in the well to another position. The movable contacts **357** and **358** are moved to the contacts **1** to cause the pump to expand the packer. If the fluids in the well bore are now flowing in a downward direction through the turbine passage, the direction of rotation of the turbine and the rotor is counter clockwise, FIGURES 7 and 8, and the amplitude and time relation of the pulses **288***a* and **287***a* is that illustrated in FIGURE 12 wherein the signal of the smaller amplitude **288***a* caused by the closing of the switch **288** precedes the signal **287***a* caused by the closing of the switch **287** during each complete revolution of the turbine.

It will thus be seen that since the time intervals between the signals produced by the successive closings of the two switches **287** and **288** vary in accordance with the direction of flow of the fluids the direction as well as the rate of flow of fluids through the turbine passage and is easily determined by the use of only two switches **287** and **288**.

The packer **201** is of course expanded many times during its useful life and will, after prolonged usage, tend to lose some of its resilience so that its lower portions sag or fold as at **400**. Since the packer is located about the lower end portion of reduced external diameter of the flow meter housing, such fold is free to move inwardly or encountering internal obstructions during the upward movement of the flow meter in the well and is not damaged due to such contact as could occur if the housing therebelow were of larger external diameter as would be necessary if the turbine were located in the housing above the packer.

In addition, it is desirable for the packer to be disposed about the lowermost end portion of the flow meter housing preferably of smaller external diameter than the portion thereof above the packer in order that should the packer rupture or be ruptured by engagement with internal obstructions of the well tubing or the well bore, the lower portions of such ruptured packer are free to hang downwardly of the lower end of the housing and are not likely to wedge between the housing and the well tubing or the well bore and prevent upward removal of the flowmeter which they might if the packer were mounted about an intermediate portion of the housing.

The foregoing description of the invention is explanatory only, and changes in the details of the construction illustrated may be made by those skilled in the art, within the scope of the appended claims, without departing from the spirit of the invention.

What is claimed and desired to be secured by Letters Patent is:

1. A flow meter including: an elongate housing having a longitudinally extending turbine passage opening to the exterior of the housing at the lower end of said housing, said housing having a lateral port communicating said turbine passage to the exterior of said housing intermediate longitudinally spaced ends of said turbine passage; a turbine in said turbine passage below said lateral port and rotatable by fluids flowing through said turbine passage; rotor means mounted in said turbine passage above the inner end of said lateral port and out of the path of flow of fluids through said turbine passage, said rotor means being rotatable by said turbine and having a magnet movable about the axis of rotation of said rotor means; a pair of switches carried by said housing adjacent said rotor means and spaced from each other about the axis of rotation of said rotor means, the distances between the two switches about the axis of rotation of said rotor means being unequal, said switches being closable successively by the magnetic field of said magnet during each rotation of said rotor means for providing signals indicating the rate of flow of fluids through said turbine passage; one of switch means being connected in a circuit of greater resistance than the other; a tubular expansible packer mounted on said housing below said turbine and about a lower end portion of said housing, said lower end portion of said housing and the portion thereof below said packer being of smaller external diameter than the portions thereof above said packer, said packer and said housing providing a cylindrical packer chamber; pump means mounted in said housing above said turbine passage; means for selectively transmitting fluid pumped by said pump means from the exterior of said housing above said packer to said packer chamber to expand said packer and permitting flow of fluids from said packer chamber; and magnetic shunt means carried by said housing between said switches for shunting the magnetic field of said magnet from said switches to cause them to open immediately upon movement of the magnet therepast.

2. A flow meter including: an elongate housing having a longitudinally extending turbine passage opening to the exterior of the housing at the lower end of said housing, said housing having a lateral port communicating said turbine passage to the exterior of said housing intermediate longitudinally spaced ends of said turbine passage; a turbine in said turbine passage rotatable by fluids flowing through said turbine passage; rotor means mounted in said turbine passage out of the path of flow of fluids through said turbine passage, said rotor means being rotatable by said turbine; a magnet carried by said rotor means and movable about the axis of rotation of said rotor means by said rotor means; a pair of switches mounted on said housing adjacent said rotor means and in the path of movement of the magnetic field of said magnet, said switches being spaced from each other about the axis of rotation of said rotor, one distance between the two switches about the axis of rotation of said rotor means being shorter than the other distance between the two switches about said axis of rotation, said switches being closable successively by the magnetic field of said magnet during each rotation of said rotor means for providing signals indicating the direction and rate of flow of fluids through said turbine, at least one magnetic shunt means mounted on said housing between said switches at a location within said one distance between the two switches for shunting the magnetic field of said magnet from at least one of said switches to cause it to open immediately upon movement of the magnet therepast, one of said switches being connected in a circuit of greater resistance than the other; a tubular expansible packer mounted on said housing between said lateral port and the lower end of said housing, the lower end of said housing and the portion of said housing on which said packer is mounted being of smaller external diameter than the portions of the housing above said packer, said packer and said housing providing a cylindrical packer chamber; pump means mounted in said housing; and means for selectively transmitting fluids pumped by said pump means from the exterior of said housing to said packer chamber to expand said packer and permit flow of fluids from said packer chamber.

3. A flow meter including: an elongate housing having a longitudinally extending turbine passage opening to the exterior of the housing at the lower end thereof, said housing having a lateral port communicating said turbine passage intermediate its ends with the exterior of said housing; a turbine in said turbine passage below said lateral port and rotatable by fluids flowing through said turbine passage; rotor means mounted in said turbine passage above the inner end of said lateral port and out of the path of flow of fluids through said turbine passage, said rotor means being rotatable by said turbine; means carried by said housing and responsive to the rotation of said rotor means for providing signals indicating direction

and rate of flow of fluids through said turbine passage, said housing having a lower end portion of reduced external diameter; a tubular expansible packer mounted on said housing below said turbine and about said lower end portion of said housing, said lower end portion of said housing and the portion of said housing below said packer being of smaller external diameter than the portions of the housing above said packer, said packer and said housing providing a cylindrical packer chamber; and pump means mounted in said housing above said turbine passage; said housing having bypass means providing a bypass passage from the exterior of said housing above said packer past said rotor means and said turbine to said packer chamber for transmitting fluid pumped by said pump means from the exterior of said housing to said packer chamber to expand said packer.

4. A flow meter including: an elongate housing having a longitudinally extending turbine passage opening to the exterior of the housing at the lower end thereof, said housing having a lateral port communicating said turbine passage intermediate its ends with the exterior of said housing; a turbine in said turbine passage below said lateral port and rotatable by fluids flowing through said turbine passage; rotor means mounted in said turbine passage above the inner end of said lateral port and out of the path of flow of fluids through said turbine passage, said rotor means being rotatable by said turbine; means carried by said housing and responsive to the rotation of said rotor means for providing signals indicating direction and rate of flow of fluids through said turbine passage, said housing having a lower end portion of reduced external diameter; a tubular expansible packer mounted on said housing below said turbine and about said lower end portion of said housing, said lower end portion of said housing and portions of said housing below said packer being of smaller external diameter than the portions of the housing above said packer, said packer and said housing providing a cylindrical packer chamber; and pump means mounted in said housing above said turbine passage; said housing having bypass means providing a bypass passage from the exterior of said housing above said packer past said rotor means and said turbine to said packer chamber for transmitting fluid pumped by said pump means from the exterior of said housing to said packer chamber to expand said packer, said bypass means including a duct extending longitudinally in said turbine passage below said turbine and having a cross-sectional area substantially smaller than the cross-sectional area of said turbine passage whereby flow of fluids through the tubing passage is not obstructed by said duct.

5. A flow meter including: an elongate housing supportable at one end by a flexible member having a pair of conductors insulated from one another, said housing having a longitudinally extending turbine passage opening to the exterior of the housing at the lower end thereof, said housing having a lateral port communicating said turbine passage intermediate its ends with the exterior of said housing; a turbine in said turbine passage below said lateral port and rotatable by fluids flowing through said turbine passage; rotor means mounted in said turbine passage above the inner end of said lateral port and out of the path of flow of fluids through said turbine passage, said rotor means being rotatable by said turbine; a pair of switches carried by said housing adjacent said rotor means and spaced from each other about the axis of rotation of said rotor means, the distances between the two switches about the axis of rotation of said rotor means being unequal, said switches being connectable to said conductors and responsive to the rotation of said rotor means for providing signals indicating direction and rate of flow of fluids through said turbine passage, said rotor means having a magnet, said switches being closable by the magnetic field of said rotor means as said rotor rotates therepast; a pair of spaced magnetic shunt means carried by said housing adjacent said rotor means and spaced from each other about the axis of rotation of said rotor means, each of said shunt means being located adjacent an associated switch and spaced therefrom a distance shorter than the distance from the other shunt means, said shunt means being located between said switches within the shorter distance between the two switches about the axis of rotation of said rotor means, said magnetic shunt means shunting the magnetic field of said magnet from said switches to prevent simultaneous closure of said switches, said housing having a lower end portion of reduced external diameter; a tubular expansible packer mounted on said housing below said turbine and about said lower end portion of said housing, said lower end portion of said housing and the portions thereof below said packer being of smaller external diameter than the portions of the housing above said packer, said packer and said housing providing a cylindrical packer chamber; pump means mounted in said housing above said turbine passage and energizable by current transmitted to the pump means through said conductors; and means for transmitting fluids pumped by said pump means from the exterior of said housing above said packer to said packer chamber to expand said packer, said switches being connectable in parallel across said conductors, one of said switches having a resistance connected in series therewith between said conductors whereby any circuit through said conductors and said one of said switches is of greater resistance than such circuit of the other of said switches.

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