United States Patent [19]

Boettcher et al.

[11] **3,788,575**

[45] **Jan. 29, 1974**

[54] **AUTOMATIC AND SEMI-AUTOMATIC REEL TENDERS**

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[22] Filed: **Apr. 14, 1972**

[21] Appl. No.: **244,065**

Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 100,059.

[52] **U.S. Cl.**..... **242/86.5 R,** 61/72.6, 242/75.3, 242/75.53, 242/86.7

[51] **Int. Cl.**.. **B65h 75/40,** B65h 59/00, B65h 59/38

[58] **Field of Search** 242/86.5, 86.7, 75.3, 75.53; 61/72.6

[56] **References Cited**

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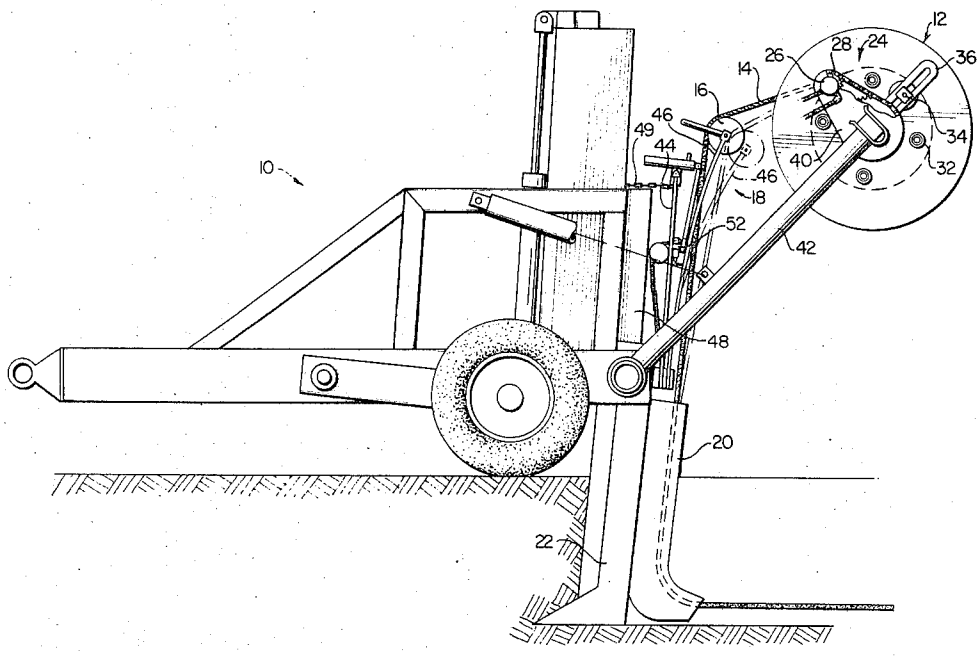
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Primary Examiner—John W. Huckert
Assistant Examiner—Edward J. McCarthy
Attorney, Agent, or Firm—Colton & Stone, Inc.

[57] **ABSTRACT**

An automatic reel tender especially adapted for use in underground cable laying operations employs a positive cable reel drive whose operation is modulated as a function of varying cable tension to match mean cable pay-out with advancement of the cable laying equipment. A hydraulic motor is in positive driving engagement with the cable supply reel and modulation of the same may be effected either by varying motor speed as a substantially instantaneous function of cable tension or by intermittant driving of the same. In either event, a unit-handled mechanical tensiometer is relied upon to sense cable tension.

22 Claims, 12 Drawing Figures



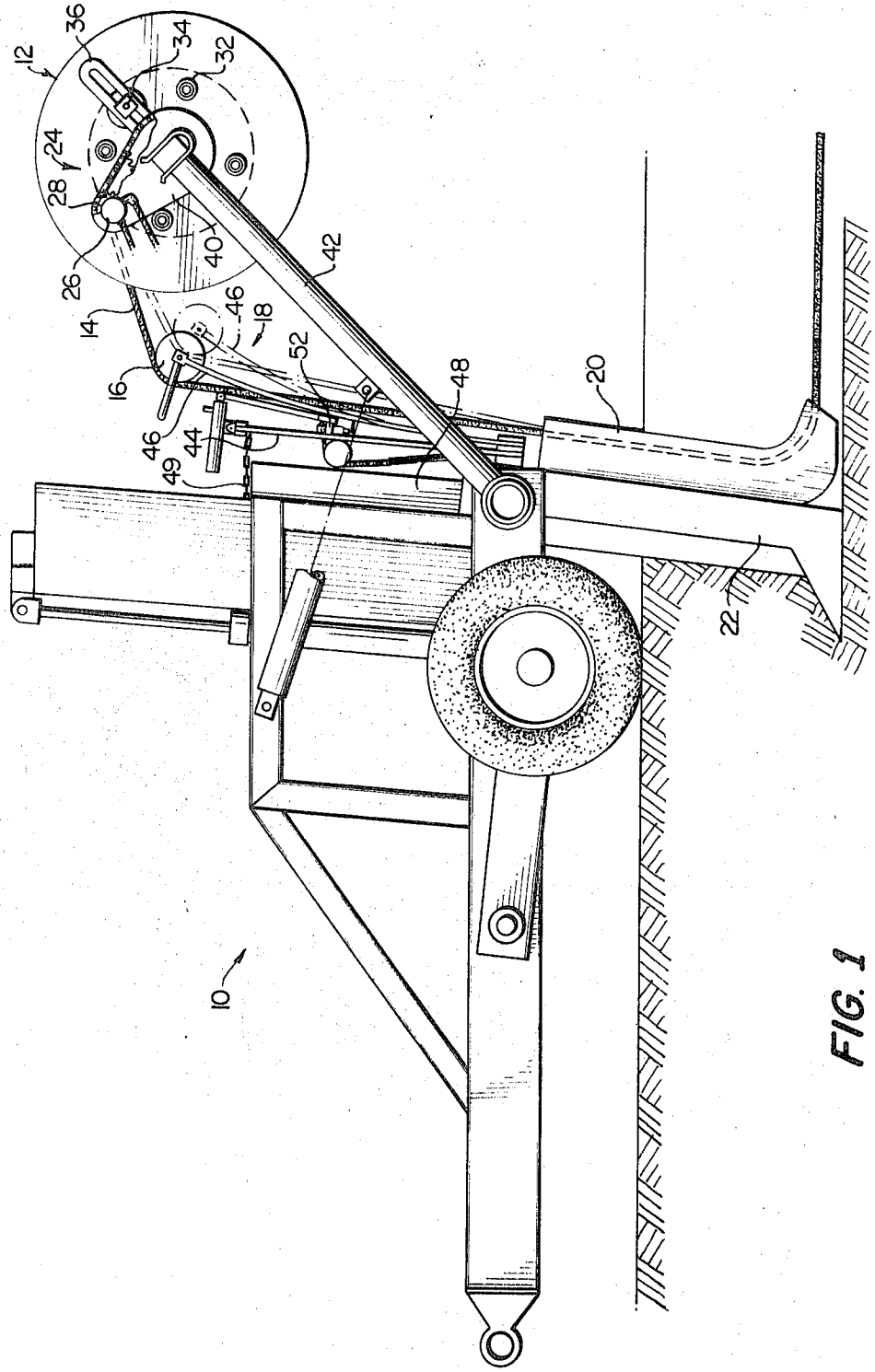


FIG. 1

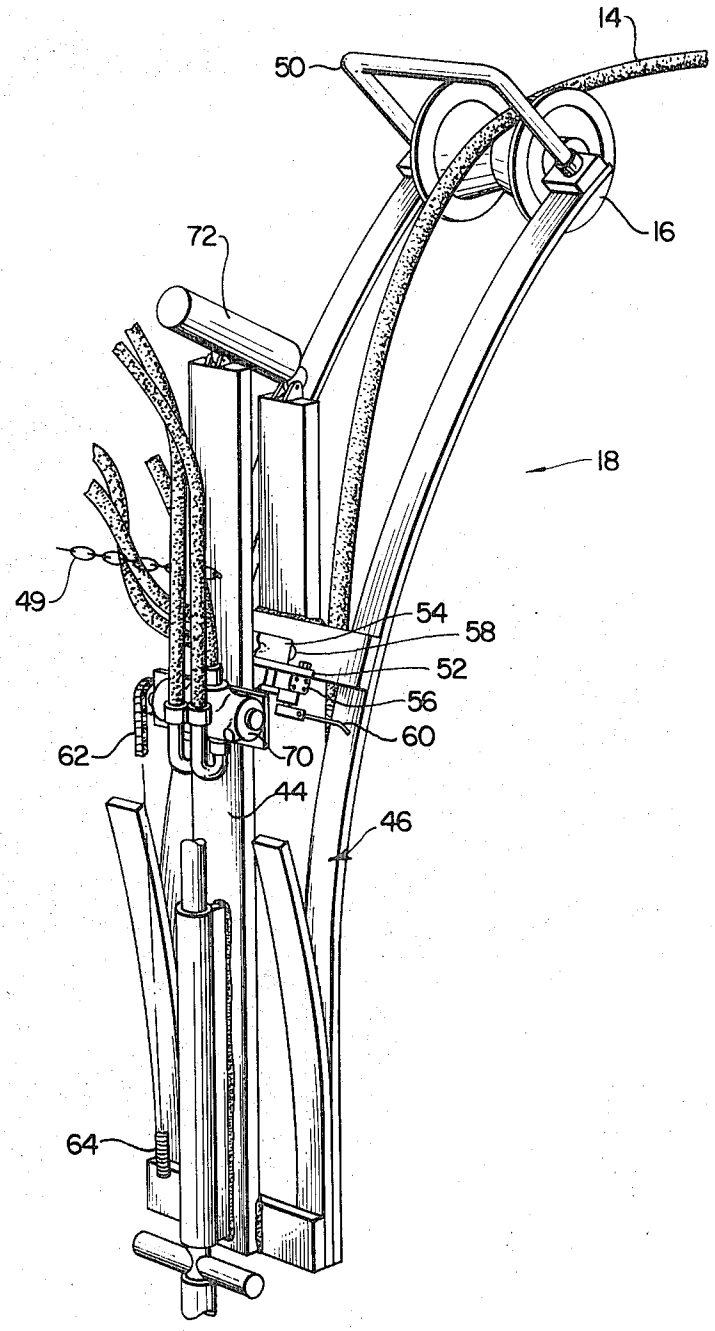


FIG. 2

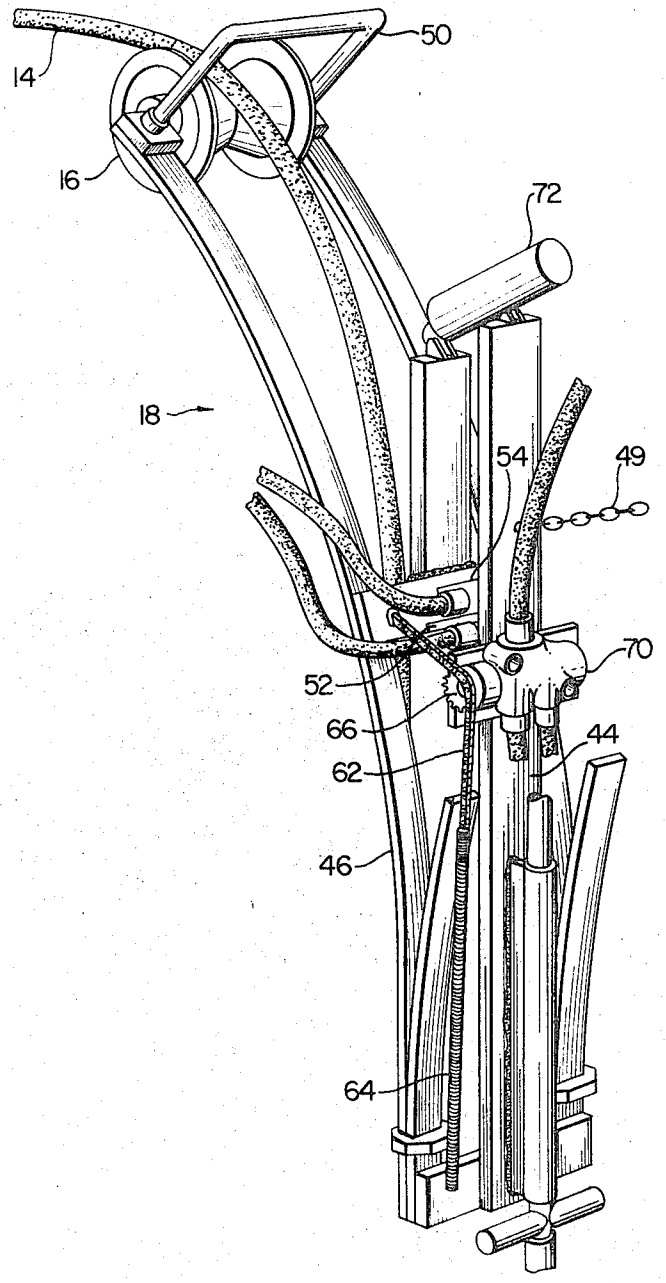


FIG. 3

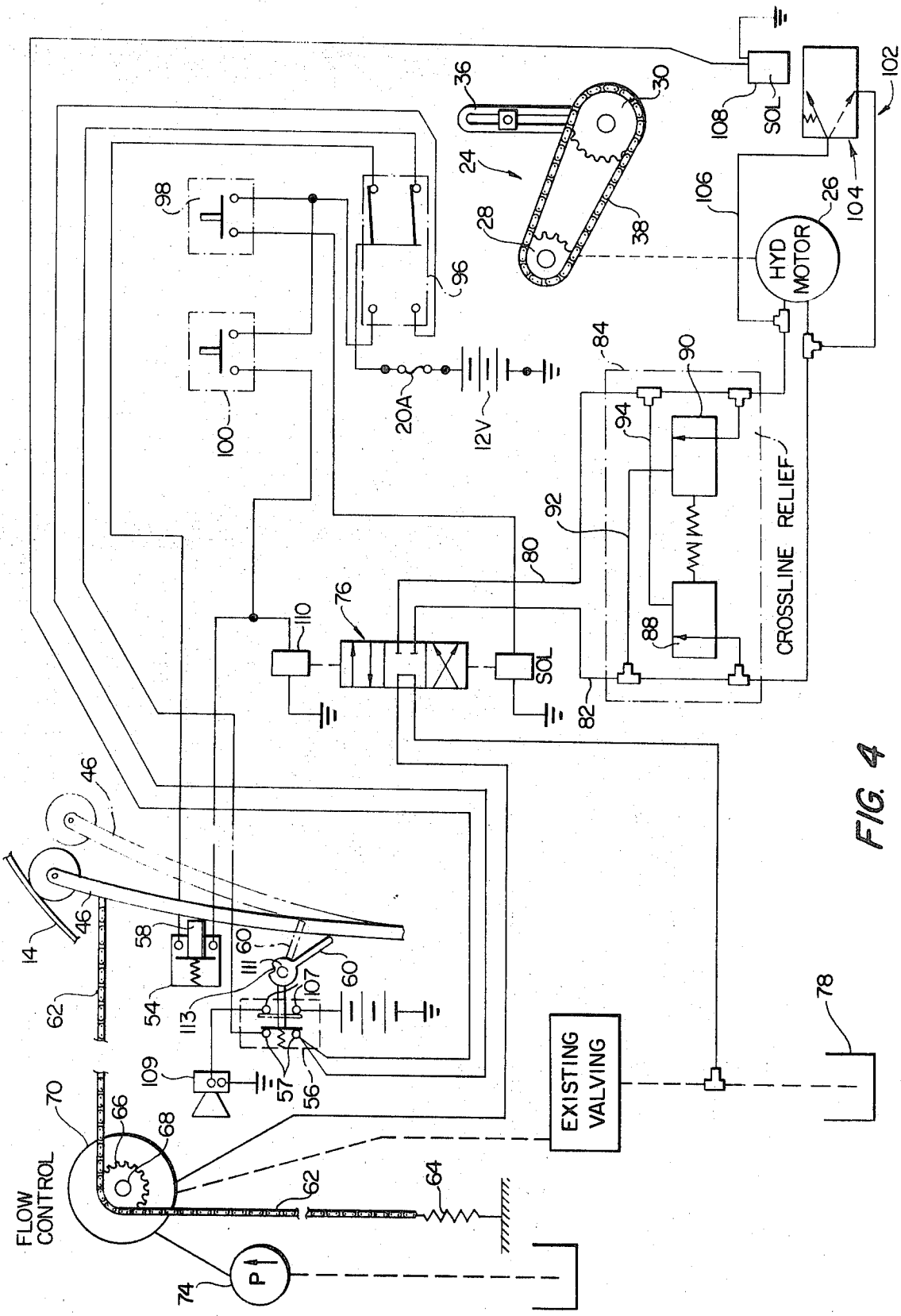

FLOW CONTROL
EXISTING VALVING
HYD MOTOR
CROSSLINE RELIEF
SOL
12V
20A
P

FIG. 4

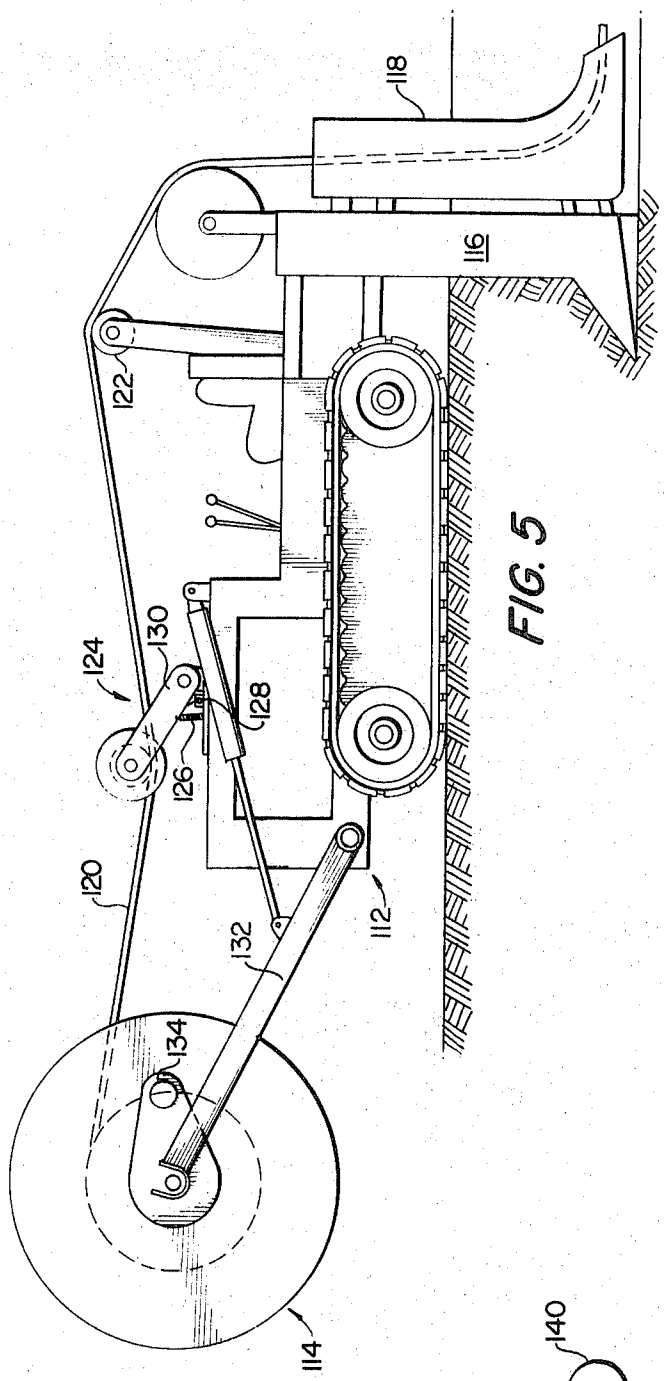

118
116
122
124
130
128
126
120
132
112
134
114

FIG. 5

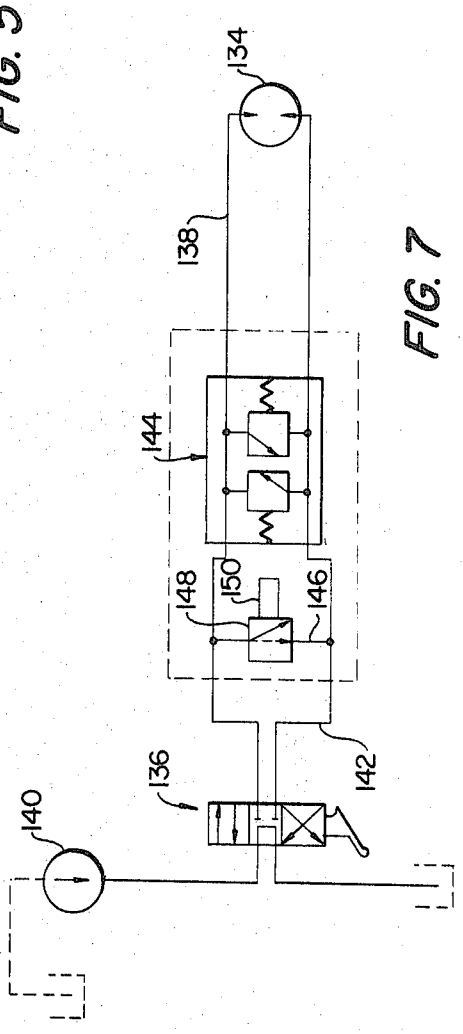

134
138
144
148
150
146
142
136
140

FIG. 7

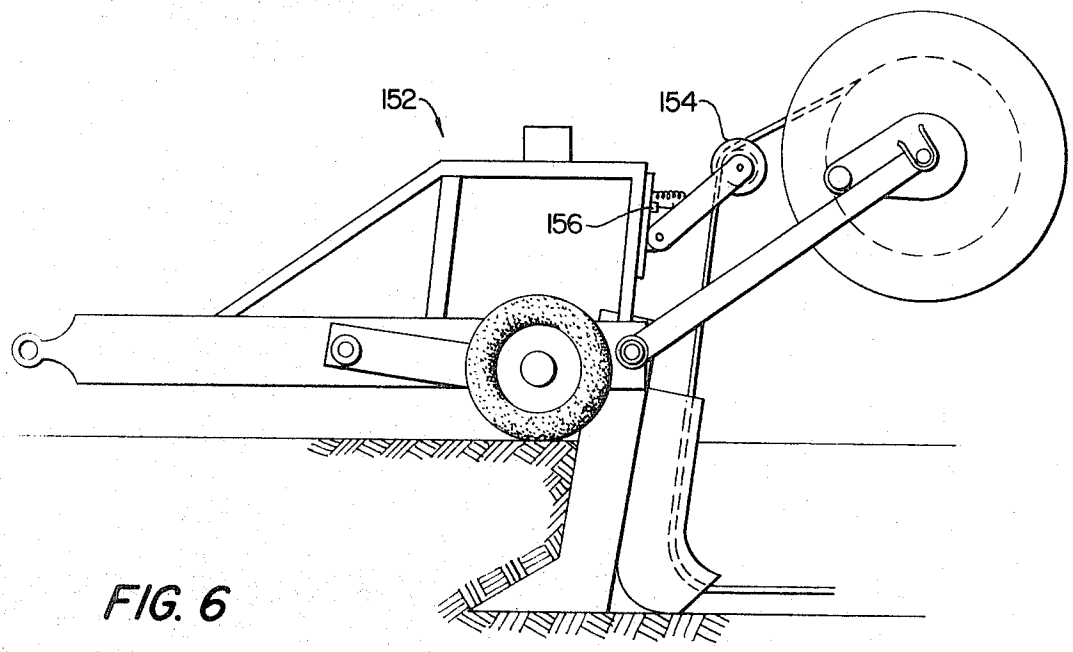
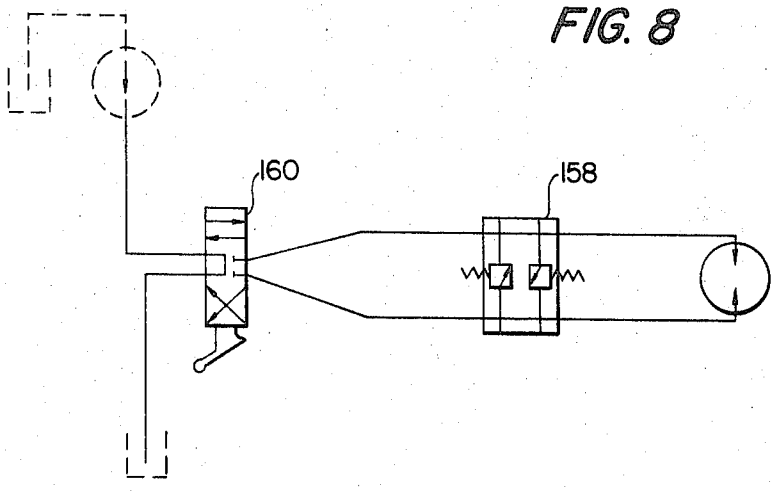


FIG. 6

FIG. 8



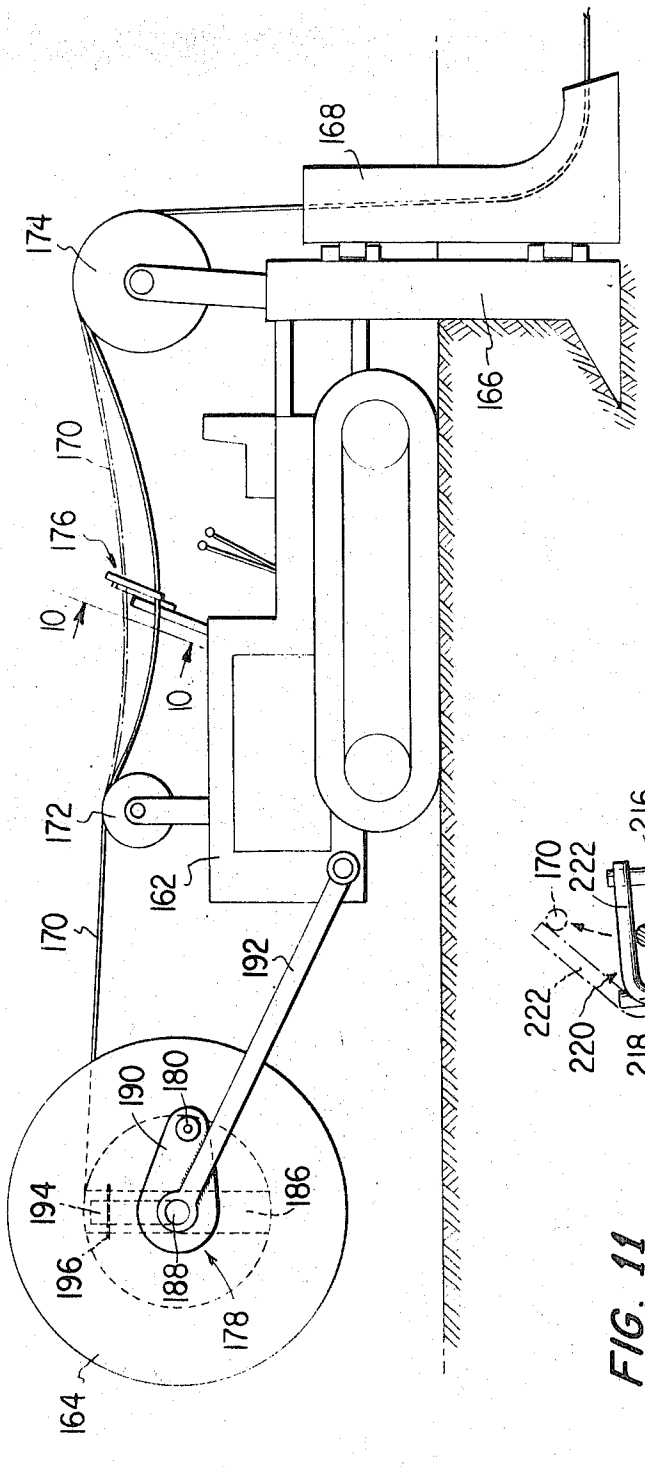


FIG. 9

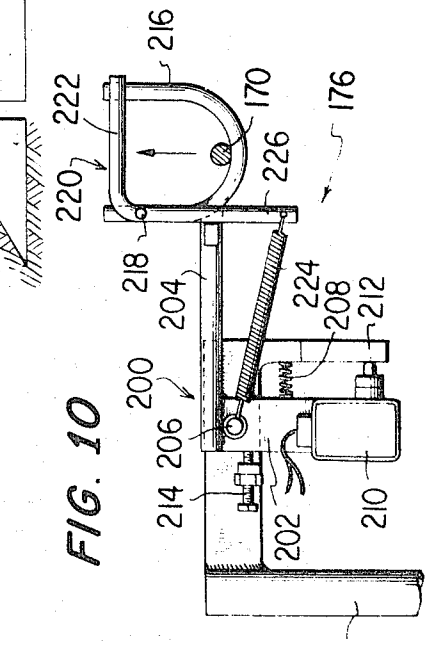


FIG. 10

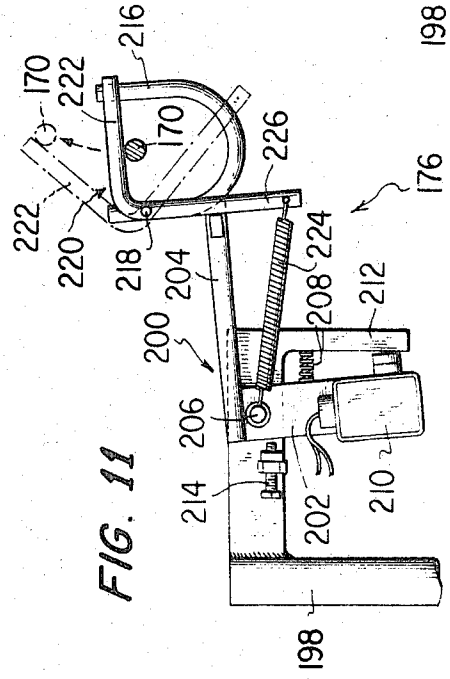


FIG. 11

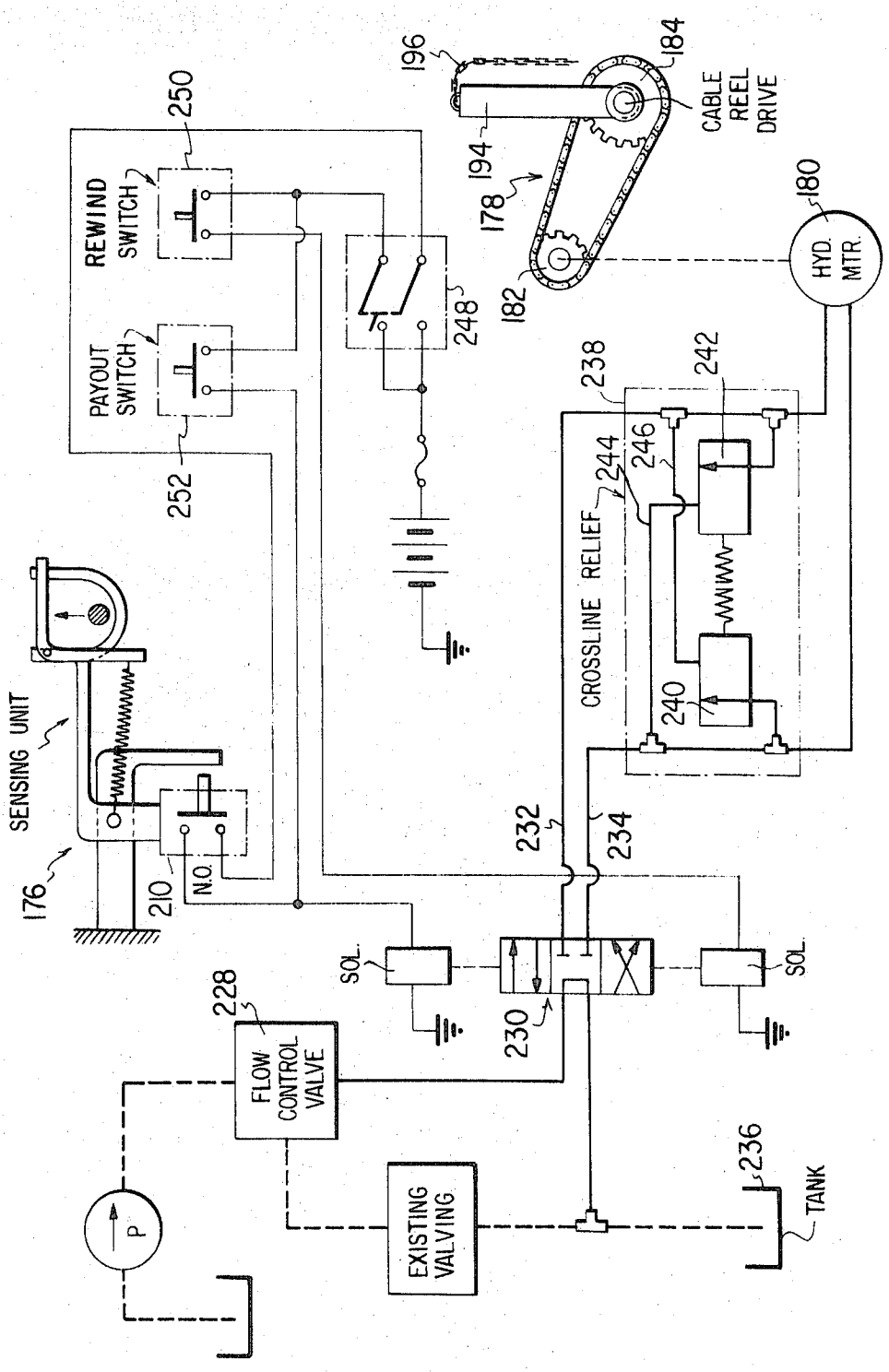

196
184
CABLE REEL DRIVE
250
REWIND SWITCH
194
178
180
HYD. MTR.
PAYOUT SWITCH
248
182
238
242
252
CROSSLINE RELIEF
244
246
SENSING UNIT
240
232
234
176
210
N.O.
SOL.
SOL.
228
230
FLOW CONTROL VALVE
EXISTING VALVING
236
TANK
P

FIG. 12

AUTOMATIC AND SEMI-AUTOMATIC REEL TENDERS

CROSS REFERENCE TO RELATED APPLICATION

This is a continuation-in-part of application Ser. No. 100,059, filed Dec. 21, 1970, abandoned.

BACKGROUND OF THE INVENTION

The manufacturers of underground cable laying equipment wherein cable is buried simultaneously with the formation of a slit trench have long taken advantage of the fact that the buried cable will provide sufficient anchorage to unreel the supply cable. Unfortunately, this same anchorage is normally sufficient to resist the imposition of cable breaking tensions. Such tensions may be applied, for example, in overcoming initial reel inertia or in the common occurrence of an idling supply reel commencing to rotate in the rewind direction as permitted by a slack run between the reel and trench. Additionally, many cables and particularly telephone cables are highly sensitive to applied tensions below the breaking point.

The long standing solution to the problem of excessive cable tension has been the use of an extra man riding with the equipment to manually pay-out the supply reel, as required. Recent attempts to automate this function have involved the use of frictional drives applied, on the one hand, to the cable itself which merely transfers the overtension or cable breakage point and, on the other hand, to the reel rims which not only requires adjusting mechanisms to accommodate different size reels, but, also, fails to take into account the fact that cable reel rims in actual use are seldom round by reason of damage, breakage and the like. In this latter respect, wooden cable reels are normally constructed of the cheapest quality lumber and are routinely handled in a rough manner both in storage and deployment. Cable reels are frequently designed to be reusable and the pick-up and handling of spent reels, particularly as they are dropped onto the ground from a truck, provides almost complete assurance that their most vulnerable portions, the rims, will not present a smooth, circular circumference. Thus one or more "flats" and/or missing rim slats providing a break of several inches in the circular continuity of one or both reel rims, are quite common. Steel reel rims are similarly subject to damage as by peripheral indentions due to droppage.

An even greater deficiency in any frictionally driven supply reel whether the frictional drive be applied to the cable or reel is the practical impossibility of using such a system with the larger type reels where the likelihood of cable breakage is also present. Exemplary are some of the larger cable laying reels in common use which have a wound supply weight of 10,000 pounds on a 9 foot reel. In the case of certain lead sheathed 4 inch diameter 3/0 electrical conductor cable; a loaded 9 foot supply reel weighs 17,000 pounds. The application of a sufficient starting torque through a frictional drive to overcome the stationary inertia of a reel of this size is simply not practical and, in the case of the frictional drive being applied directly to the cable, it will be appreciated that even if the reel inertia could be overcome within practical time limits the total starting torque would be applied to the reel via the cable which is precisely the circumstance to be avoided.

Prior to the instant invention it was thought to be necessary to employ a frictional reel drive as opposed to a positive drive if the obvious disadvantages inhering in the use of an automatic heavy duty clutch were to be avoided. This for the reason that uncontrolled reel rotation, as by its own inertia, must not be allowed to damage the driving mechanism. Similarly, in the case of an uncontrolled increase in cable tension it is desirable that the mechanism for sensing such tension not be damaged.

SUMMARY OF THE INVENTION

The invention, as related to fully automatic reel tenders, is broadly directed to a positive drive mechanism for a supply reel operable as a function of paid-out cable tension. More specifically, a unit-handled tensiometer which may be readily attached to existing equipment provides a mechanical or electrical feedback indicative of cable tension which feedback controls the operation of the drive mechanism.

It will thus be immediately apparent that the broad inventive concept, particularly as regards the unit-handled tension sensing unit per se, possesses obvious utility far beyond the specific environment herein illustrated.

Inasmuch as the massive tension forces involved in commercial cable laying operations present a number of problems not normally associated with other environments where the invention finds utility such as in the recovering of overhead cables or the like; the application of the invention to cable laying equipment has been chosen for illustration.

It is the primary object of the invention to provide a positive pay-out drive for a cable reel which may be operative as a function of cable tension in a fully automatic manner or under the manual control of an operator.

Secondary aspects of the invention reside in the details of driving, sensing, and safety systems as applied to automatic reel tenders while a tertiary aspect relates to semi-automatic reel tenders employing sensing and safety features similar to those utilized with the automatic reel tenders.

The positive drive derives from a hydraulic motor and related circuitry, including a hydraulic overload relief with dynamic braking capability, which may be installed directly on existing cable laying equipment. The unit-handled tensiometer may also be installed on existing equipment and the incorporation of these two subassemblies with conventional idle reel cable layers may thus be economically effected to convert the same into either automatic or semi-automatic reel tenders as disclosed herein.

A preferred embodiment of the invention includes a hydraulic, cable over-tension relief feature while in an alternate construction a mechanical, cable over-tension relief is incorporated with the mechanical tensiometer.

The use of a hydraulic motor insures that sufficient torque will be available to overcome stationary reel inertia. The hydraulic overload relief is constituted by a cross-over relief which not only dumps excessive system pressure to reservoir during normal motor operation but, also, permits the motor to act as a pump and provides dynamic braking for inertial reel rotation following termination of the positive drive in response to a cable slack condition as sensed by the tensiometer.

DESCRIPTION OF THE DRAWINGS

FIG. 1 is a side elevation of a trailing cable layer incorporating an automatic reel tender in accordance with one embodiment of the invention;

FIG. 2 is a detail perspective illustrating the tensiometer mounting of FIG. 1;

FIG. 3 is a similar perspective view taken from the opposite side of FIG. 1;

FIG. 4 is a schematic representation of the tensiometer, cable reel drive and associated circuitry for converting an idle reel cable layer into an automatic reel tending cable layer in accordance with one aspect of the invention;

FIG. 5 is an elevational depiction of a tractor mounted cable layer in accordance with a second modification of the invention;

FIG. 6 is a side elevation of a trailing cable layer employing a tensiometer similar to the type shown in FIG. 5;

FIG. 7 is a hydraulic diagram of the reel driving circuit of FIGS. 5 and 6;

FIG. 8 is a simplified hydraulic circuit lacking the hydraulic cable over-tension relief feature that may be substituted for the circuit of FIG. 7;

FIG. 9 is a side elevational view of a tractor mounted cable layer incorporating a further embodiment of the invention;

FIG. 10 is an elevational view of the tensiometer as viewed along line 10—10 of FIG. 9 illustrating a slack cable condition;

FIG. 11 is a similar view illustrating, in solid lines, a normal tensioned cable position for actuating the reel drive mechanism and, in phantom, the operation of the mechanical cable over-tension relief mechanism; and

FIG. 12 is a schematic representation of the sensing unit, cable reel drive and associated circuitry necessary to convert an idle reel cable layer into the automatic reel tending cable layer of FIG. 9.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

A preferred embodiment of the automatic reel tender wherein both the cable supply reel and tensiometer are mounted on a towed cable layer is illustrated in FIGS. 1–4.

In FIG. 1 is illustrated, in cable laying position, a trailed cable layer **10** adapted to be towed in conventional manner by a traction unit, not shown. Cable layer **10** includes a cable supply reel **12** from which cable **14** is paid out to pass over idle pulley **16** of a unit-handled tensiometer **18** and thence through a conventional cable guide **20** trailing a conventional slit trencher **22.** The run of cable **14** across tensiometer pulley **16** is desirably maintained between the solid and dotted line positions of FIG. 1 through the coaction of tensiometer **18** and a positive cable reel drive **24.** The cable reel is driven by an hydraulic motor **26** whose maximum cable pay-out capacity, as determined by the drive chain connected sprockets **28, 30,** exceeds the cable laying rate of the equipment.

Reel **12** is illustrated in FIG. **1** as comprising a conventional wooden reel from which one tie bolt **32** has been removed for receipt in a tie bolt opening thereof a reel pin adapter **34** whose outer threaded end is removably secured to a reel anchor bar **36** rigid with sprocket **30.** Motor output sprocket **28,** drive chain **38** and reel anchor sprocket **30** are mounted within housing **40** rigidly supported at the outer end of one of lift arms **42** just outboard of reel **12.** Reel **12** is, of course, mounted for rotation on the usual reel axle shaft bridging the ends of lift arms **42** but the rotation thereof about the axis of the axle shaft is positively controlled by cable reel drive **24** through the interconnection of reel anchor bar **36** with the reel via reel pin adapter **34.**

Tensiometer **18** includes an upstanding, rigid mast **44** to the lower end of which is secured a normally bowed leaf spring assembly **46** mounting, at the upper free end thereof, the idle pulley **16.** The unit handled tensiometer may be secured to the cable layer frame as by welding or the like of mast **44** adjacent the lower end thereof, to frame structure **48** to position idle pulley **16** in spaced relation to the cable supply reel. A chain **49** interconnected between the upper end of mast **44** and the cable layer frame completes the tensiometer mounting. A rigid guide loop **50** constrains cable **14** to a desired path across pulley **16** enroute to cable guide **20.** The unstressed condition of leaf spring **46** is illustrated in solid lines in FIGS. **1** and **4,** while the phantom line position indicates the usual relationship of parts during a cable laying operation wherein the degree of rearward spring assembly flexure is a function of cable tension. Thus, as will be apparent from FIG. **1,** idle pulley **16** is biased by leaf spring assembly **46** to guide cable **14** in an arcuate path from supply reel **12** to cable guide **20.** As cable tension increases, the path of the cable run starts to straighten between the supply reel and cable guide with a concomitant flexure of the leaf spring assembly toward the phantom line position of FIGS. **1** and **4.** Thus, leaf spring assembly flexure is a direct function of cable tension and, in the embodiment of FIGS. **1–4,** both electrical and mechanical feedbacks from the varying positions of the leaf spring assembly are used to control cable pay-out.

A switch mounting bracket **52,** rigid with mast **44,** mounts a pair of microswitches **54, 56** whose actuation is controlled by flexing movement of leaf spring assembly **46** into and out of engagement with switch actuators **58, 60.** Switch **54** is the hydraulic motor control switch and is a normally closed switch held open by leaf spring assembly **46** engaging switch actuator **58** in the unstressed solid line position of FIGS. **1** and **4.** Thus, with insufficient tension in cable **14** to flex the leaf spring assembly, switch **54** remains open and hydraulic motor **26** is not energized. This would be the situation upon cessation of cable laying operations. Switch **56** is normally open with respect to its motor control terminals **57** (FIG. **4**) but is held closed with respect to terminals **57** by leaf spring assembly **46** engaging switch actuator **60** in all positions of leaf spring flexure falling within normal cable laying operating parameters. Switch **56** will not go closed until actuator **60** has rotated approximately 30° from the position of FIG. **2** as the leaf spring assembly flexes beyond the phantom line position of FIGS. **1** and **4** which would indicate some emergency condition wherein cable tension is increasing without limit. Such a condition would be exemplified by a failure of the hydraulic control circuit to supply fluid to motor **26** so that continued forward movement of the cable layer would impose supply reel pay-out forces directly on cable **14.** When this occurs, switch **56** goes open and the hydraulic motor is short circuited so that the motor simply acts as a recycling

pump as will be more fully explained in connection with the circuit diagram of FIG. 4.

In one exemplary application the leaf spring assembly is constructed to yield to the approximate phantom line position of FIG. 1 under an applied cable tension of approximately 4 pounds under which conditions switch 54 is closed and motor 26 is driving supply reel 12 in the pay-out direction. It is only upon a substantial further increase in applied cable tension, as on the order of 10 pounds for example, that leaf spring assembly 46 flexes well beyond the phantom line position of FIG. 1 to allow switch 56 to open and short circuit the motor.

A third feed-back from the flexed position of leaf spring assembly 46 is effected, mechanically, through a sprocket chain 62 which has one end anchored to the leaf spring assembly while the other end thereof is interconnected with a rigid anchor adjacent mast 44 through a tension spring 64. Sprocket chain 62 is in driving engagement with a sprocket 66 rigid with adjusting shaft 68 of a conventional priority type, pressure compensated flow regulator 70 which is in hydraulic circuit with motor 26. Rotation of adjusting shaft 68 as a consequence of leaf spring flexure modulates fluid flow to motor 26 thus adjusting the pay-out speed of supply reel 12 as will be more fully explained in the description of FIG. 4.

A one-way damping cylinder 72 is interconnected between mast 44 and leaf spring assembly 46 to damp movement of the leaf spring assembly toward the mast while permitting free, undamped flexing movement of the leaf spring assembly away from the mast (to the right as viewed in FIG. 1).

The complete motor control circuit and the manner in which the same is related to tensiometer 18 is illustrated in FIG. 4. The existing hydraulic circuitry normally associated with a conventional cable layer is indicated in dotted lines and the priority type flow regulator 70 is in circuit therewith to divert variable proportions of the output from pump 74 to a conventional solenoid operated valve 76 controlling the input to motor 26 and to reservoir 78. When valve 76 is closed, as shown in FIG. 4, flow through the valve is dumped to reservoir. Upon closure of switch 54, valve 76 is activated to pressurize line 80 and communicate line 82 with reservoir to rotate motor 26 in the pay-out direction.

A cross-line relief 84 is connected across lines 80 and 82 to provide a hydraulic pressure relief and dynamic braking feature for the positive drive system. The cross-line relief includes differentially biased relief valves 88, 90 which may, for example, be set to relieve 400 p.s.i. and 1,500 p.s.i., respectively, as applied from the motor side of the valves. Relief valve 90 is operative when motor 26 is being driven to dump excessive pressure surges in line 80 to reservoir via cross-over line 92 and conduit 82. When cable tension decreases to open switch 54 and block the motor control circuit at valve 76; reel 12 continues to rotate under its own inertia which, of course, rotates the rotor of motor 26 causing the same to act as a pump. It is at this point that relief valve 88 comes into play by yielding to recycle pressurized fluid from line 82 through cross-over line 94 and back to the intake of the motor/pump. This has a dynamic braking effect on reel 12 as the kinetic energy of rotation is dissipated, primarily through heat losses, at relief valve 88.

A further advantage in the cross-line relief arrangement is that it permits cable to be manually unreeled at a controlled tension which, in the case of the illustrated parameters, would be approximately 12 pounds. In such situation, the motor again acts as a pump and is relieved through cross-over line 94. This is particularly advantageous in certain emergency situations such as in the case of a complete power loss.

A conventional double pole, double throw toggle switch 96 and manually operable rewind and pay-out switches 98, 100 are provided whereby valve 76 may be manually rather than automatically controlled. As will be apparent, switches 98 and 100 may be brought into circuit for manually controlling the reversible operation of motor 26.

A hydraulic cable over-tension relief 102 is built into the motor circuit to provide an unrestricted short circuit across the motor in contradistinction to the cross-line or hydraulic overload relief 84 which includes resistances in the cross-over lines. A conventional solenoid operated valve 104 alternately blocks and opens a short circuit 106 across motor supply and exhaust conduits 80, 82 on the motor side of the cross-line relief 84. Valve 104 is spring biased toward the open, dotted line position of FIG. 4 but is held in the upper closed position of FIG. 4, blocking short circuit flow through lines 106, by the energization of solenoid 108 controlled by microswitch 56. Thus should cable tension increase beyond normal limits, i.e., sufficient to flex leaf spring assembly 46 past the dotted line position of FIGS. 1 and 4; the leaf spring moves out of engagement with switch actuator 60, switch 56 opens across terminals 57 to deenergize solenoid 108 and valve 104 opens (dotted line position of FIG. 4) to short circuit motor 26 so that continued reel rotation simply pumps fluid about circuit 106.

In operation, and assuming the solid line position of FIGS. 1 and 4 wherein cable layer 10 is stationary and cable 14 is under substantially zero tension; as cable layer 10 starts to move forwardly, cable tension increases to flex leaf spring assembly 46 toward the dotted line position of FIGS. 1 and 4.

Immediately upon movement of leaf spring 46 away from the solid line position; switch 54 goes closed to energize solenoid 110 and communicate motor 26 with pump 74 via valve 76 and motor supply line 80 while exhausting motor 26 via line 82 to reservoir. Simultaneously, flow control valve 70 is adjusted via sprocket 66 to deliver a greater proportion of the pump output to motor supply line 80. Flow control valve 70 is a commercially available unit known as a priority type flow regulator and manufactured by Fluid Power Systems, a division of AMBAC Industries, Inc. of Wheeling, Illinois under Model designation 13–15–3.

Under normal operating conditions of less than 10 pounds cable tension for example, flexure of leaf spring assembly 46 past the dotted line position of FIGS. 1 and 4 does not take place and actuator 60 of switch 56 remains in contact with the leaf spring to keep switch 56 closed across terminals 57 energizing solenoid 108 and blocking short circuit flow around motor 26 at valve 104. As the cable laying operation proceeds, instantaneous increases in cable tension are reflected by an increased input to motor 26 as the deflection of leaf spring 46 rotates adjusting shaft 68 to direct a greater proportion of pump flow through control valve 76 to the motor. One-way damping cylinder 72 damps the re-

turn of leaf spring **46** toward the solid line unstressed condition while tension spring **64** insures that valve control adjusting shaft **68** will faithfully reflect the damped return of the leaf spring to decrease fluid input to the motor as cable tension decreases. If the advance of cable layer **10** be terminated, the unwinding inertia of reel **12** slacks cable **14,** leaf spring assembly **46** returns to the solid line position of FIGS. **1** and **4** to open switch **54** deenergizing solenoid **110** and allowing self centering valve **76** to divert all flow to reservoir thus blocking motor lines **80, 82.** The inertial movement of reel **12** is then damped by recirculation flow through cross-line relief **84** as already explained. This is the normal mode of operation.

Under conditions of increasing cable tension beyond normal operating parameters such as, for example, if a failure of solenoid **110** should result in blocking flow through motor lines **80, 82** while the cable layer is still advancing; leaf spring assembly **46** will deflect beyond the phantom line position of FIGS. **1** and **4** thus allowing switch **56** to open terminals **57** to thereby deenergize solenoid **108** and permit valve **104** to assume its normal open position opening short circuit **106** around motor **26.** Continued advancement of the cable layer will then result in continued unwinding movement of reel **12** via the tension applied thereto through cable **14** while motor **26** acts as a recirculating pump. This short circuit **106** allows the continued advancement of the cable layer with the imposition of a lesser cable tension than would be realizable if the cross-line relief section of the circuit were relied on for the function since it includes the previously discussed resistance factors desirable for dynamic braking.

Simultaneously with the opening of terminals **57** in switch **56,** auxiliary terminals **107** are closed to sound an alarm, herein illustrated as a horn **109,** to alert the operator to stop advancement of the traction unit.

In the absence of the wiring for an alarm circuit, as just described, switch **56** may simply include a pair of stops at the position of terminals **107.** It will be apparent that the wire trigger switch actuator **60** and its interconnected rotary actuator **111** are biased for movement toward the dotted line position of FIG. **4** and so dimensioned that recess **113** permits the contacts **57** to be opened only after the deflection of leaf spring assembly past the phantom line position of FIG. **4.**

The semi-automatic reel tenders shown in FIGS. **5** and **6** retain the positive cable reel drive feature as well as the cross-line and cable over-tension relief feature described in connection with FIGS. **1–4** but rely upon manual control of the hydraulic motor driving the supply reel as will be apparent from the abbreviated circuit configuration of FIG. **7.**

The semi-automatic reel tender shown in FIG. **5** includes a tractor **112** having a forwardly mounted supply reel **114,** a rearwardly mounted slit trencher **116** and a trailing cable guide **118.** During the course of a normal cable laying operation as illustrated in FIG. **5,** the run of cable **120** is desirably maintained deflected from a straight line run between supply reel **114** and idle pulley **122** by an idle sensing pulley or tensiometer **124** which is biased to deflect cable **120** by a tension spring **126.** A normally open microswitch **128** is held closed by the idle sensing pulley support arm **130** within the normal cable tension operating parameters as selected by the bias of spring **126** and permitted to go open as arm **130** moves upwardly in response to increasing cable tension to approach a straight line run between reel **114** and idle pulley **122.** The cable reel mounting to the ends of lift arm **132** and the positive drive thereof by hydraulic motor **134** is identical to that described in connection with FIGS. **1–4.** The control of power fluid to motor **134** is via a manually controlled, normally centered valve **136** as shown in FIG. **7.** Thus, manual actuation of valve **136** to move the control spool downwardly from the position of FIG. **7** places motor supply conduit **138** in communication with pump **140** and vents exhaust line **142** to reservoir. The configuration and operation of cross-line relief **144** is identical with that described in connection with FIG. **4** as is the operation of the cable over-tension relief defined by the short circuit conduit **146** which is normally blocked by solenoid operated valve **148** whose operation is identical to that of valve **104** in FIG. **4.** In further explanation, the cable over-tension relief valve acts, in effect, as a "deadman" control in that it is a biased, normally open valve to establish flow through short circuit **146** and is held closed by the energization of solenoid **150** when cable tension is normal (as in FIG. **5**) and switch **128** is held closed by arm **130.** When cable tension increases to elevate arm **130,** as when the operator holding valve **136** to establish flow communication with motor **134** fails to take note of increasing cable tension, switch **128** opens deenergizing solenoid **150** and valve **148** goes to the dotted line position of FIG. **7** thus short circuiting the reel drive motor.

The semi-automatic control features of the trailed cable layer **152** shown in FIG. **6** are identical with those of FIG. **5** and the hydraulic circuitry is that shown in FIG. **7.** The only distinction is in the rearward mounting of the supply reel and the positionment of idle sensing pulley **154** to hold the normally open switch **156** closed under condition of normal cable tension. Switch **156,** of course, controls the energization of the cable over-tension relief solenoid **150** (FIG. **7**).

A hydraulic schematic of a further simplified semiautomatic version of the invention is illustrated in FIG. **8** wherein the cable over-tension relief has been omitted and the cross-line relief **158** performs this function in addition to its dynamic braking function, as previously described. The circuit of FIG. **8** may be substituted for that of FIG. **7** as applied to either of the embodiments shown in FIGS. **5** and **6** with the obvious modifications that the cable tension sensing pulleys **124, 154** and their associated switches **128, 156** are eliminated.

In operation of the embodiment shown in FIG. **8,** positive reel rotation is effected by manual manipulation of control valve **160** and cable over-tension is relieved via the cross-line relief **158** albeit at the sacrifice of relieving at a lower tension through a short circuit across the motor which does not include the resistance built into the cross-line relief as will be explained in greater detail with regard to an identically functioning cross-line relief in FIG. **12.**

A further embodiment of a fully automatic reel tender is illustrated in FIGS. **9–12** and differs from that of FIGS. **1–4** primarily in the details of the tensiometer and the substitution of a mechanical cable over-tension relief. The mechanical over-tension relief is primarily to protect the tensiometer from damage rather than to effect continued cable over-tension relief which is provided for by a hydraulic cross-line relief.

The automatic reel tender depicted in FIG. **9** includes a tractor **162** having a forwardly mounted cable

supply reel **164**, a rearwardly mounted slit trencher **166** and a trailing cable guide **168**. During the course of a normal cable laying operation as illustrated in FIG. **9**, the run of cable **170** between idlers **172, 174** is desirably maintained between the solid and dotted line positions through the coaction of a tensiometer **176** and a positive cable reel drive **178**. The cable reel is driven by a single speed hydraulic motor **180** whose cable pay-out capacity, as determined by the drive chain connected sprockets **182, 184** exceeds the cable laying rate of the equipment. Reel **164** is herein illustrated as a conventional steel reel having the usual aligned diametral straps **186** having aligned openings formed therein for the receipt of reel mounting shaft **188**. Drive mechanism **178** is mounted in housing structure **190** rigidly supported on one lift arm **192** just outboard of one reel strap **186**. A drive strap **194** is integrally secured to driven sprocket **184** as by an integrally related sleeve or the like for rotation therewith and includes means for securing the same to the adjacent reel strap **186** which is herein illustrated as a chain **196** having one end thereof secured to the distal end of drive strap **194**. Chain **196** may be wrapped about reel strap **186** and secured in any desired manner to positively couple reel **164** to the output shaft of hydraulic motor **180**.

Tensiometer **176** includes a support frame **198** adapted for rigid securement to tractor **162**, as by welding or the like, intermediate idlers **172, 174**. A generally L-shaped bracket **200** including a depending switch mounting arm **202** and a generally horizontal arm **204** extending beneath cable **170** is mounted for limited pivotal movement about the axis of pivot **206** between the positions shown in FIGS. **10** and **11** under the opposed influences of the varying tension in cable **170** sensed as a function of the variable catenary path between idlers **172, 174** and a return compression spring **208**. Normally open microswitch **210**, carried on bracket arm **202**, is adapted to be closed upon counterclockwise rotation of bracket **200** to the FIG. **11** position by engagement with an arm **212** depending from frame **198** which engagement, also, limits the permissible counterclockwise movement of bracket **200**. An adjustable stop **214** limits return clockwise movement of the same under the bias of spring **208** to that position shown in FIG. **10**. The outer end of arm **204** includes an integral U-shaped cable guide **216** upon one leg of which is pivotally mounted, at **218**, an L-shaped overload release member **220** one of whose arms **222** is biased to bridge the open end of cable guide **216** by a tension spring **224** reacting between the other leg **226** thereof and an extension of fixed pivot **206**.

Springs **208** and **224** are differentially biased to yield upon the application of upward force components as transmitted thereto by a decrease in the path length or slack condition of cable **170** between idlers **172** and **174** which decrease in slack condition or path length is a direct function of increasing cable tension. In one exemplary application, springs **208** and **224** are selected to yield in response to applied cable tensions of **4** and **10** pounds, respectively, as applied thereto by cable **170** moving upwardly against overload release arm **222**. Thus, assuming the solid line, cable slack condition of FIGS. **9** and **10**, the reel **164** stationary and a trenching operation in progress; the slack run will be taken up and cable **170** will move upwardly toward the dotted line position of FIG. **9** and the solid line position of FIG. **11** as a function of increasing cable tension. As cable tension reaches 4 pounds, the upward force component acting through overload release member **220** overcomes the bias of spring **208** to pivot bracket **200** counterclockwise about pivot **206** and close switch **210** to drive reel **164** in a manner which will be subsequently explained. Since the driven pay-out speed of reel **164** exceeds trenching speed, the solid line slack condition of FIG. **9** will be restored allowing spring **208** to return bracket **200** to the position of FIG. **10** thus opening switch **210** and stopping the reel drive until cable tension again increases to 4 pounds. Because of its much higher bias, spring **224** acts as a rigid link in the sequence of movements just described and only comes into play should some emergency condition, such as failure of the reel drive circuit, produce an uncontrolled increase in cable tension. Upon such an occurrence, as cable tension passes 4 pounds the tensiometer is in the solid line position of FIG. **11** and, in the absence of an overload release feature, the tensiometer would ultimately be destroyed. When cable tension reaches **10** pounds, spring **224** yields and overload release member **220** assumes the dotted line position of FIG. **11** releasing cable **170**.

The motor control circuit and the manner in which the same is related to tensiometer **176** is illustrated in FIG. **12**. The existing hydraulic circuitry normally associated with a conventional cable layer is indicated in dotted lines and a flow control valve **228** is positioned in circuit therewith to divert flow to a conventional solenoid operated valve **230** which controls the input to hydraulic motor **180**. When valve **230** is closed, as shown in FIG. **12**, flow through valve **228** is dumped to reservoir. Upon closure of switch **210** carried on tensiometer **176**, valve **230** is activated to pressurize line **232** and communicate line **234** with reservoir **236** to rotate motor **180** in the pay-out direction.

A cross-line relief **238** is connected across lines **232** and **234** to provide a pressure relief and dynamic braking feature for the positive drive system. The cross-line relief includes differentially biased relief valves **240, 242**, which may, for example, be set to relieve 400 p.s.i. and 1,500 p.s.i., respectively, as applied from the motor side of the valves. Relief valve **242** is operative when motor **180** is being driven to dump excessive pressure surges in line **232** to reservoir via cross-over line **244** and conduit **234**. When cable tension decreases to open switch **210** and block the motor circuit at valve **230**; reel **164** continues to rotate under its own inertia which, of course, rotates the rotor of motor **180** causing the same to act as a pump. It is at this point that relief valve **240** comes into play by yielding to recycle pressurized fluid from line **234** through cross-over line **246** and back to the intake of the motor/pump. This has a dynamic braking effect on reel **164** as the kinetic energy of rotation is dissipated, primarily through heat losses, at relief valve **240**.

A further advantage in the cross-line relief arrangement is that it permits cable to be manually unreeled at a controlled tension which, in the case of the illustrated parameters, would be approximately 12 pounds. In such situation, the motor again acts as a pump and is relieved through cross-over line **246**. This is particularly advantageous in certain emergency situations such as in the case of a complete power loss.

A conventional double pole single throw toggle switch **248** and manually operable rewind and pay-out switches **250, 252** whereby valve **230** may be manually

rather than automatically controlled completes the circuit description of FIG. **12.** As will be apparent, switches **250** and **252** may be brought into circuit for manually controlling the reversible operation of motor **180.**

In operation, and assuming the solid line position of FIG. **9** and the circuit condition of FIG. **12,** as cable tension increases tensiometer bracket **200** pivots counterclockwise to close switch **210** and energize solenoid valve **230** whose spool moves downwardly, as viewed in FIG. **12,** to pressurize line **232.** Motor **180** then rotates reel **164** to restore the slack condition of FIG. **10** at which time switch **210** opens to block lines **232** and **234.** The inertial rotation of reel **164** is dynamically braked by the pumping action of motor **180** recycling fluid through relief valve **240** and cross-over line **246** and, thereafter, when cable tension again increases the sequence of events just described is repeated.

We claim:

1. In combination with a vehicle mounted cable layer including a cable supply reel and a cable laying guide, the improvement comprising; a rotary hydraulic motor for rotating said reel; geared drive means comprising a sprocket chain and a sprocket gear intercoupling said rotary hydraulic motor and cable supply reel; a fluid circuit having supply and exhaust lines and a source of fluid pressure for operating said motor; control means for controlling rotation of said reel by said motor; said control means including valve means for controlling said supply and exhaust lines; said fluid circuit including first and second cross-over fluid lines interconnecting said supply and exhaust lines at positions intermediate said valve means and motor; said first cross-over line including pressure relief means for short circuiting said motor to relieve excessive pressure on one side of said motor when said source of fluid pressure is in fluid communication with said motor; and said second cross-over line including pressure relief means for short circuiting said valve means to effect dynamic braking of the motor connected reel when fluid communication between said source of fluid pressure and motor is blocked at said valve means.

2. The combination of claim **1** including a third fluid line interconnecting said supply and exhaust lines for short circuiting said motor; said control means including a tensiometer for sensing cable tension; and cable over-tension control means responsive to a first cable tension range for blocking short circuit flow through said third fluid line and to a higher cable tension range for establishing short circuit flow.

3. The combination of claim **2** including fluid flow control means in fluid circuit between said pressure source and motor; and first feedback means interconnecting said tensiometer and fluid flow control means for proportioning fluid flow to said motor as a function of cable tension.

4. The combination of claim **3** including second feedback means intermediate said tensiometer and valve means for blocking and establishing fluid flow through said supply and exhaust lines as a function of cable tension.

5. The combination of claim **4** wherein said first feedback comprises a mechanical feedback and said second feedback comprises an electrical feedback.

6. The combination of claim **1** including means for manually operating said valve means; a third fluid line interconnecting said supply and exhaust lines; and cable over-tension control means for controlling flow through said third line as a function of cable tension.

7. An automatic reel tender, comprising; a portable vehicle supporting a cable supply reel; cable guide means mounted on said vehicle defining at least one variable cable run between said supply reel and a point of cable use; power means in positive driving engagement with said reel for concomitantly varying cable tension and the path length of said cable run; sensing means mounted on said vehicle for sensing cable tension as an inverse function of cable run path length; and control means responsive to said sensing means for controlling said power means.

8. An automatic reel tending cable layer, comprising; a cable laying vehicle including subterranean cable laying equipment; a cable supply reel carried by said vehicle; said cable laying equipment including cable guide means defining at least one variable cable run between said supply reel and a subterranean location; power means in positive driving engagement with said supply reel; sensing means mounted on said vehicle for sensing variations in said path length; and control means responsive to said sensing means for controlling operation of said power means in response to variations in said path length.

9. The cable layer of claim **8** wherein said sensing means comprises a tensiometer mounted adjacent said cable run for deflecting movement thereby in response to a decrease in said path length; and said tensiometer being biased for movement in a direction opposite to said deflecting movement whereby increases in said path length are reflected by movement of the tensiometer in said opposite direction.

10. The cable layer of claim **9** wherein said power means comprises a rotary hydraulic motor; said control means including first hydraulic and electric control circuits; and said first electric control circuit including switch means responsive to movement of said tensiometer for controlling said first hydraulic circuit.

11. The cable layer of claim **10** wherein said first hydraulic control circuit includes a source of hydraulic pressure, supply and exhaust lines interconnecting said source of pressure with said motor, and a valve for blocking and establishing flow through said supply and exhaust lines; a second hydraulic control circuit interconnecting said supply and exhaust lines for short circuiting said motor in response to uncontrolled increases in cable tension; a valve in said second hydraulic control circuit for selectively blocking and establishing short circuit fluid flow therethrough; and a second electrical control circuit responsive to movement of said tensiometer for operating said last named valve.

12. The cable layer of claim **9** wherein said tensiometer comprises a leaf spring assembly supporting a cable guide; and said cable run engaging said cable guide.

13. The cable layer of claim **9** wherein said tensiometer comprises a cable guide mounted for pivotal deflecting movement about a fixed pivot axis.

14. A reel tending cable layer comprising; a cable laying vehicle including subterranean cable laying equipment; a cable supply reel carried by said vehicle; a cable extending from said supply reel to a subterranean location; said cable laying equipment including cable guide means defining at least one variable cable run between the supply reel and subterranean location; a rotary hydraulic motor in positive drive transmitting engagement with said supply reel; a source of hydraulic

pressure; supply and exhaust lines interconnecting said source of pressure and said motor; a valve controlling said supply and exhaust lines for controlling the operation of said motor; and at least one valved fluid conduit interconnecting said supply and exhaust lines.

15. The cable layer of claim **14** wherein said rotary hydraulic motor is geared to said supply reel; and at least two valved fluid conduits interconnect said supply and exhaust lines.

16. The cable layer of claim **15** including three valved fluid lines interconnecting said supply and exhaust lines; one valve in one of said fluid lines being biased to open communication between the supply and exhaust lines; sensing means mounted on said cable layer for sensing a range of normal operating variations in the path length of said variable cable run; and circuit means responsive to said range of normal operating variations for overriding said bias to maintain said one valve closed.

17. A cable layer incorporating an automatic reel tender, comprising; a portable vehicle, a cable supply reel carried by said vehicle, subterranean cable laying equipment carried by said vehicle; said cable laying equipment including cable guide means defining at least one unsupported cable run between said supply reel and a subterranean location; power means for varying the path length of said unsupported run; sensing means mounted on said vehicle for sensing a decrease in said path length; means responsive to said sensing means for activating said power means to increase said path length and reduce cable tension; and said sensing means including a cable engaging arm biased to a position intersecting a vertical plane containing said run.

18. The cable layer of claim **17** wherein said power means includes a prime mover; and a geared connection between said prime mover and said supply reel.

19. A cable layer incorporating an automatic reel tender, comprising; a portable vehicle, a cable supply reel carried by said vehicle, subterranean cable laying equipment carried by said vehicle; cable guide means for guiding a cable from said supply reel to a subterranean location; said guide means defining at least two spaced cable guides between said reel and said subterranean location; a cable wound on said reel and engaging said spaced cable guides defining therebetween an unsupported cable run; power means for varying the path length of said unsupported cable run between a minimal run defined by a straight line between the cable engaging portions of said guides and a longer run as defined by a catenary suspension of said run between said guides; sensing means including a rigid support bracket mounted on said vehicle between said guides; said sensing means further including a cable engaging arm mounted for compound pivotal movement relative to said support bracket between a first cable tension sensing position overlying the longer catenary suspension of said cable and a second overload relief position pivotally displaced therefrom; and control means responsive to said sensing means for activating said power means to increase the path length of said run.

20. A cable layer incorporating an automatic reel tender, comprising; a portable vehicle; a cable supply reel, subterranean cable laying equipment carried by said vehicle; cable guide means carried by said vehicle for guiding a cable from said supply reel to a subterranean location; a fluid motor; a positive driving connection between said motor and said reel; tension sensing means carried by said vehicle for sensing cable tension; and control means responsive to said sensing means for driving said motor in the reel pay-out direction.

21. The cable layer of claim **20** wherein said guide means include spaced cable guides for supporting an unsupported cable run therebetween between the supply reel and said underground location; and said sensing means including means for detecting a decrease in cable slack between said spaced cable guides.

22. The cable layer of claim **21** wherein said fluid motor includes pressure and exhaust lines; a fluid pump; said control means including valve means for selectively communicating pump pressure to said pressure line and blocking said pressure and exhaust lines; and cross line relief means for intercommunicating said pressure and exhaust lines between said valve means and motor whereby said motor may act as a pump to recycle fluid under the influence of inertial reel rotation when said pressure and exhaust lines are blocked at said valve means.

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