July 2, 1968 T. W. ROGERSON ETAL 3,390,548

DRIVING ARRANGEMENT FOR KNITTING MACHINES OR THE LIKE

Filed Nov. 20, 1962 4 Sheets-Sheet 1

Fig. 1.

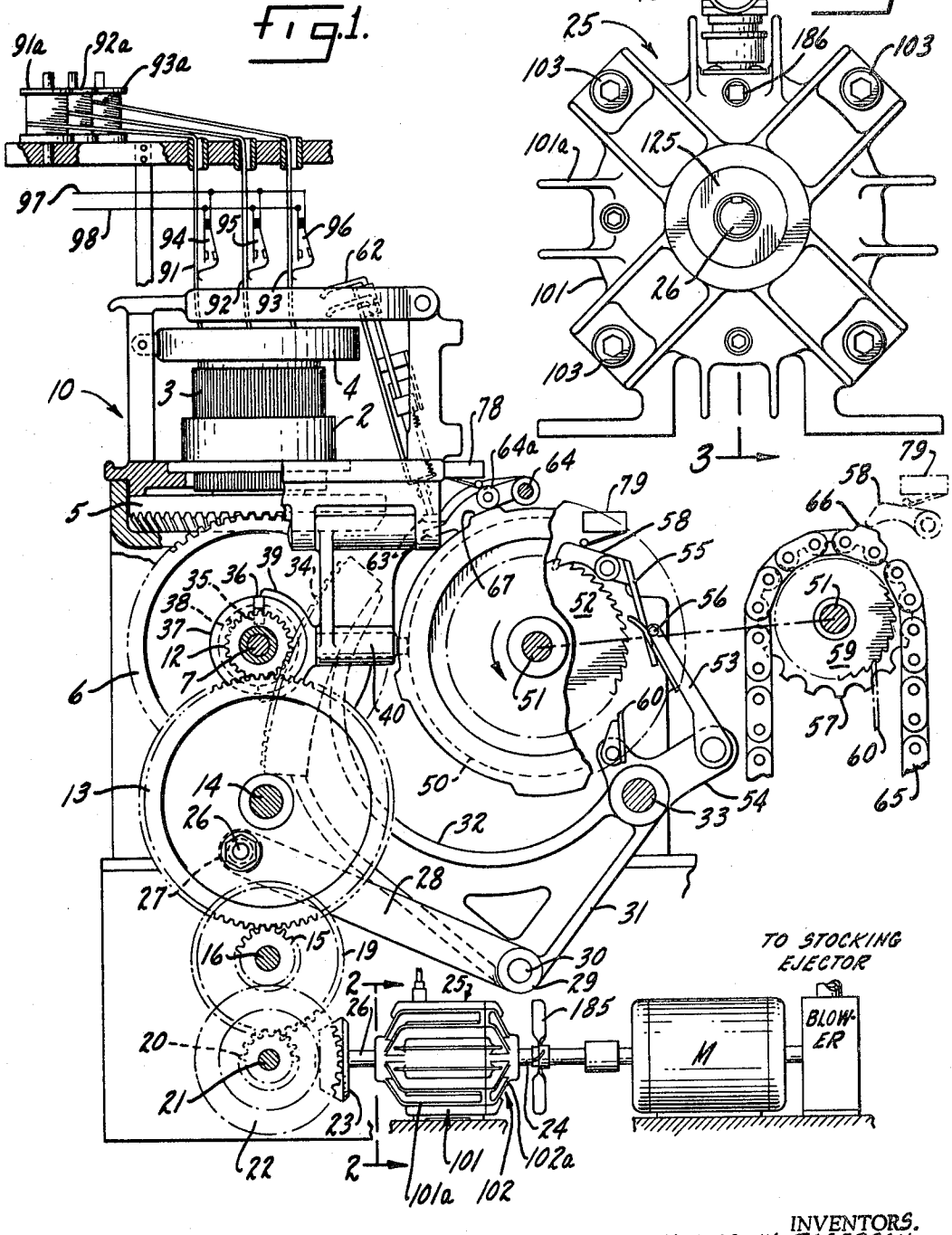


Fig. 2.

INVENTORS.
THOMAS W. ROGERSON
GERALD A. SWEENEY
BY
Attorney.

July 2, 1968 T. W. ROGERSON ETAL 3,390,548

DRIVING ARRANGEMENT FOR KNITTING MACHINES OR THE LIKE

Filed Nov. 20, 1962 4 Sheets-Sheet 2

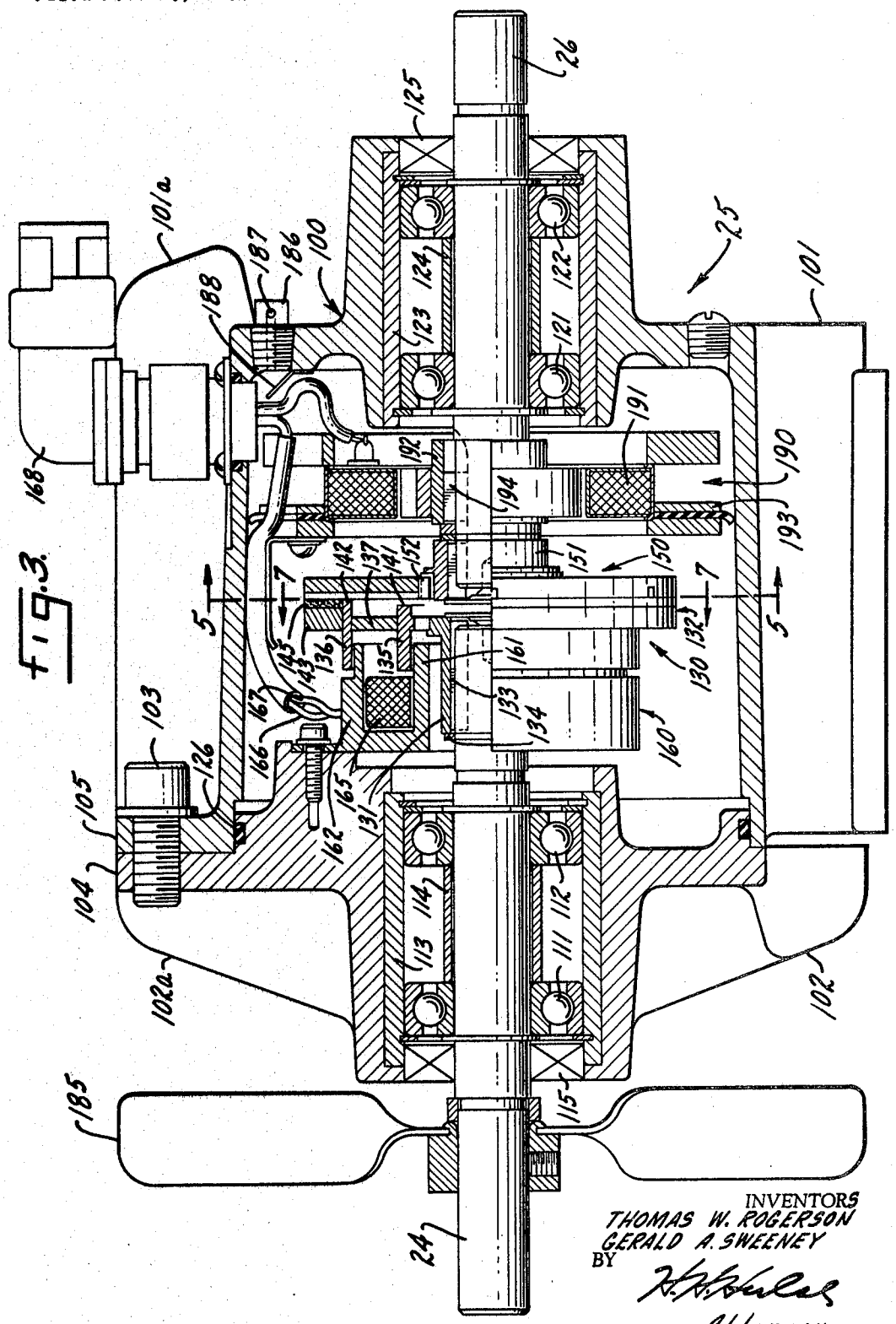


Fig. 3.

INVENTORS
THOMAS W. ROGERSON
GERALD A. SWEENEY
BY
Attorney.

July 2, 1968 T. W. ROGERSON ETAL 3,390,548

DRIVING ARRANGEMENT FOR KNITTING MACHINES OR THE LIKE

Filed Nov. 20, 1962 4 Sheets-Sheet 3

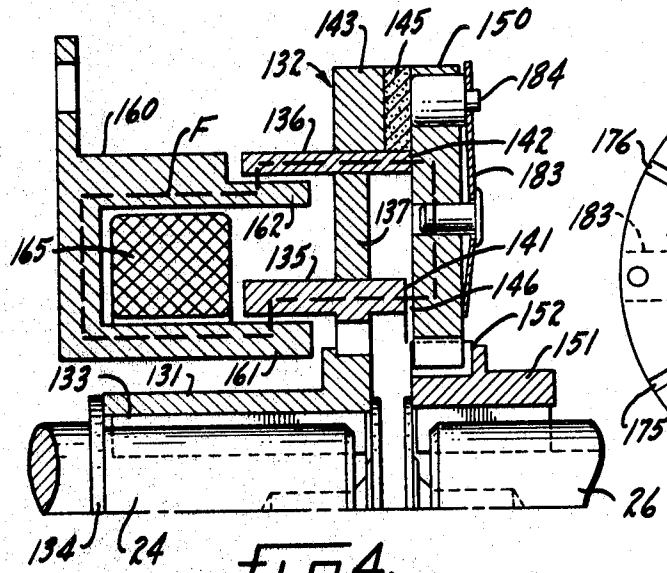


Fig. 4.

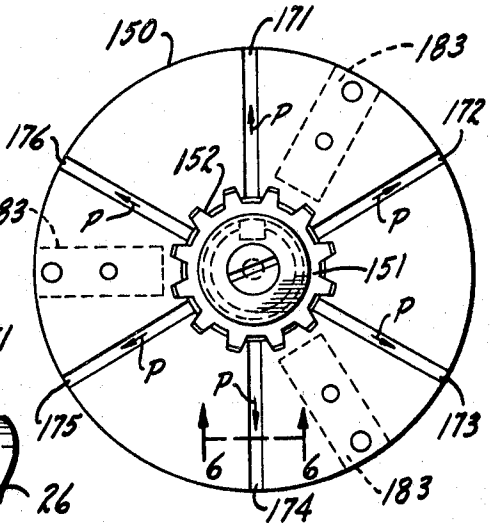


Fig. 5.

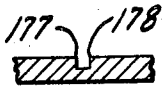


Fig. 6.

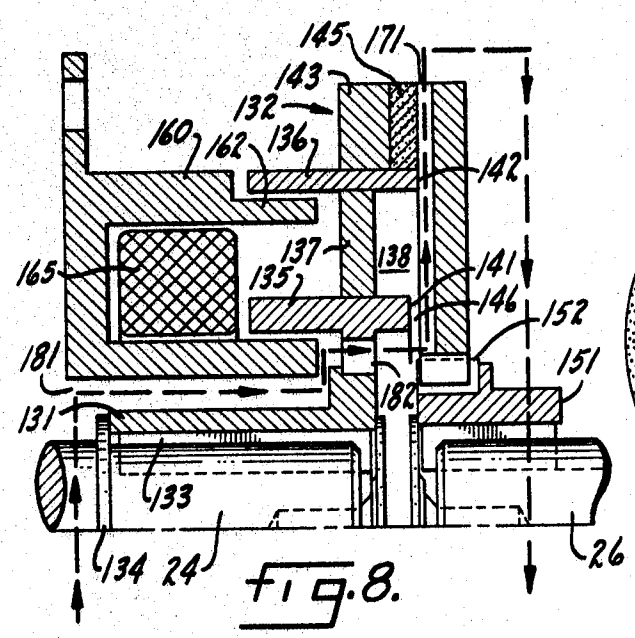


Fig. 8.

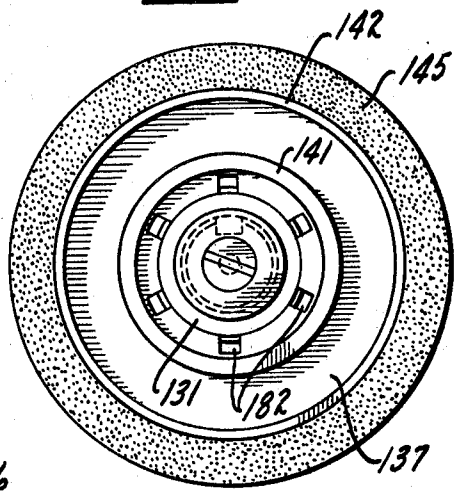


Fig. 7.

INVENTORS.
THOMAS W. ROGERSON
GERALD A. SWEENEY
BY
Attorney.

July 2, 1968 T. W. ROGERSON ETAL 3,390,548

DRIVING ARRANGEMENT FOR KNITTING MACHINES OR THE LIKE

Filed Nov. 20, 1962 4 Sheets-Sheet 4

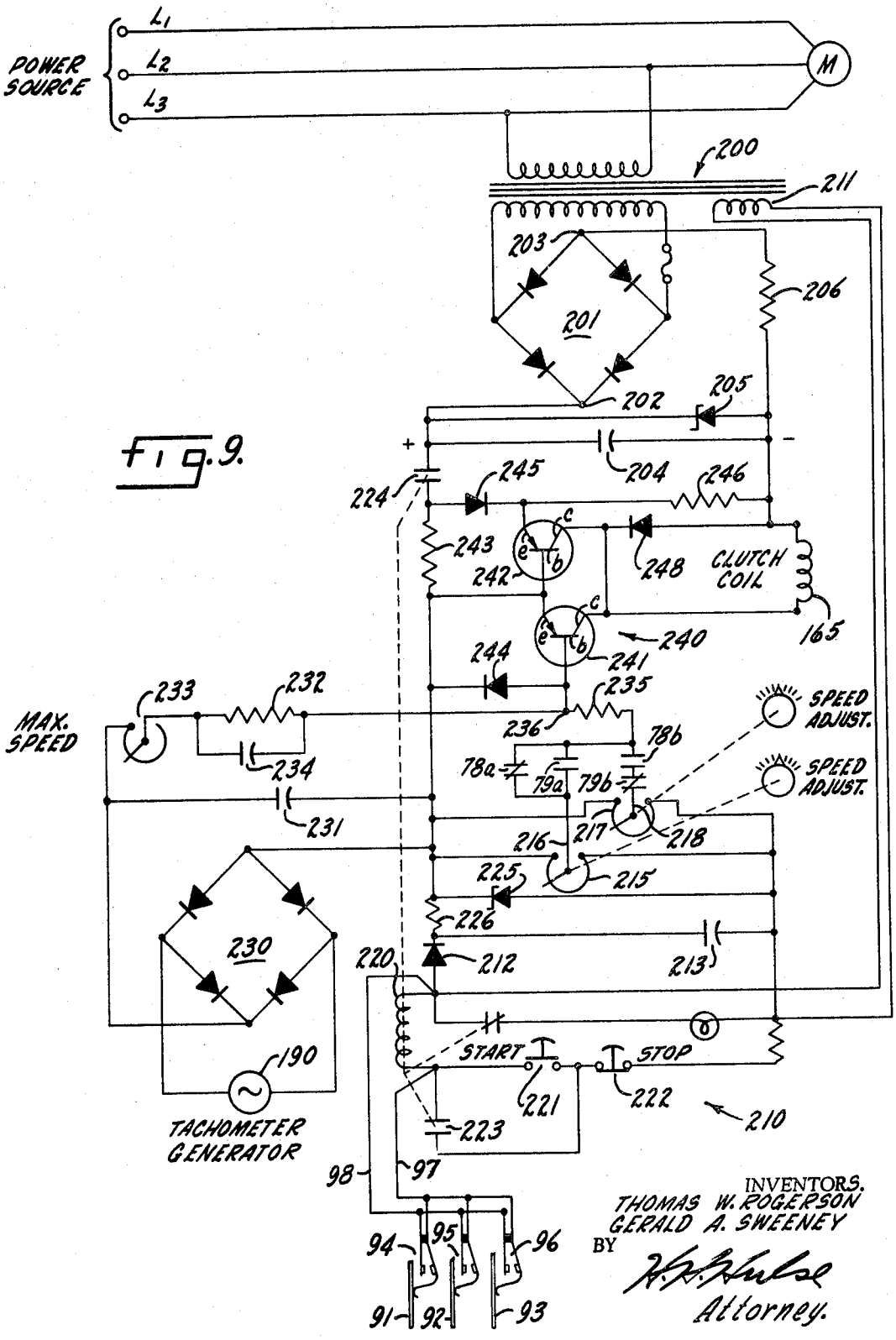


Fig. 9.

INVENTORS.
THOMAS W. ROGERSON
GERALD A. SWEENEY
BY
Attorney.

United States Patent Office 3,390,548 Patented July 2, 1968

3,390,548

DRIVING ARRANGEMENT FOR KNITTING MACHINES OR THE LIKE

Thomas W. Rogerson and Gerald A. Sweeney, Harwinton, Conn., assignors to General Time Corporation, New York, N.Y., a corporation of Delaware

Filed Nov. 20, 1962, Ser. No. 238,968
13 Claims. (Cl. 66—56)

The present invention relates to an electric drive and more particularly to an automatic electrical driving arrangement for a knitting machine or the like.

It has been common practice in the knitting industry to employ variable speed motors having relatively complex control arrangements in order to vary the speed setting to accommodate the machine to different kinds and weights of yarns and to different modes of operation as required during the knitting of the different parts of a stocking. Accurate speed control is necessary to insure maximum output of the machine while, nevertheless, preventing damage to the needles, sinkers and other related parts of the machine. It is particularly desirable that the machine be halted just as promptly as possible following breakage of the yarn or breakage of a thread or other fragile knitting element in order to prevent snowballing of the damage to other parts of the machine and to minimize "down" time. Prior driving end control arrangements for knitting machines have have not been "fail safe" upon cessation of control current, since they have suffered from the effect of inertia and, where plugging or similar techniques have been used to control inertia, they have required the making and breaking of large amounts of electric current. Moreover, it has been difficult to adjust the machine for automatic speed change between successive modes of operation or steps in the production of the knitted article.

It is an object of the present invention to provide a knitting machine drive which is capable of extremely rapid response to a control signal, and which is substantially free of the inertia which characterizes drives of conventional type. Thus, it is an object to provide a knitting machine drive which may be turned off upon breakage of the yarn, a needle or associated knitting element so rapidly as to prevent breakage of other needles in the series. It is a more detailed object to provide a knitting machine drive in which immediate reduction in speed may be secured without necessity for employing "plugging" usually required to overcome inertia and which may be readily "inched" or "jogged" during set-up or adjustment of the machine without necessity for switching or controlling large currents.

It is another object of the present invention to provide a novel arrangement for automatically switching the drive to provide predetermined and automatically maintained speeds in the successive modes of operation, with each of the speeds being easily settable on separate potentiometers mounted on the control panel. It is a related object to provide a novel arrangement for switching the potentiometers without necessity for interposed relay.

It is another object of the present invention to provide a driving arrangement for a knitting machine or the like which is particularly useful where a large number of machines are operated at the same location. In this connection it is an object to provide a driving arrangement for the knitting machine which permits all of the machines to be driven from the same power source usually by means of a line shaft but which, nevertheless, permits the speed at the input of each of the machines to be independently adjustable and automatically maintained in spite of wide variations in the speed of the power source It is a related object to provide a driving arrangement for a plurality of knitting machines in the same room but in which the total amount of dissipated heat is substantially less than that where individually controlled driving motors are used on the machines.

It is still another object to provide a drive for knitting machines or the like which enables the driving speed to be maintained with a high degree of accuracy but which, nevertheless, is independent of the type of driving motor which may be used, thereby enabling motors to be employed which are common to the particular area, regardless of voltage, whether A.-C. or D.-C., and regardless of whether the motor has good or poor speed regulation. Thus it is an object to provide a knitting machine having a built-in coupling mechanism and control circuit but which may be universally used in any part of the world.

It is yet another object related to the foregoing to provide a drive for a knitting machine or the like which is extremely simple, consisting of only two rotating parts under the control of a simple control circuit readily serviced and maintained by local technicians having only a limited amount of knowledge and ability in electronic control techniques. Moreover, the entire control circuit or subassemblies thereof may be fabricated in the form of compact plug-in units so that a new unit may be substituted promptly for a defective one and with the actual servicing being taken care of at a central service center. It is a related object to provide a driving and control arrangement for a knitting machine or the like which is not only simple but which is capable of operating without maintenance for long periods of time, avoiding the common sources of trouble including commutators, slip rings, relay or contactors, all of which are subject to the effects of dirt and wear within a relatively short period of time.

It is still another object of the present invention to provide a variable speed electric drive having speed regulation which is as good and in many cases superior to that of conventional motor drives and which is, in addition, lower in initial cost, particularly in the integral horse power range.

It is an object of the invention, in one of its aspects, to provide a novel and effective oil clutch in which a film of oil is maintained between input and output discs together with means for changing the thickness of the film correctively to maintain a predetermined but adjustable output speed.

It is another object of the invention, in one of its aspects, to provide a drive which utilizes intentional slippage but in which the energy lost in the slippage is constantly and efficiently dissipated so that the device may be operated for long periods of time, where necessary, at high slippage rates, without noticeable wear and without build-up of excessive temperatures.

It is finally an object to provide a clutch control circuit employing transistors which avoids the effects of high reverse voltage and current leakage, particularly where the device is employed in spaces having a high ambient temperature. As one of the features of the control, the power output element may be "locked in" to the power input element so that there is no loss of power through the drive.

Other objects and advantages of the invention will become apparent upon reading the attached detailed description and upon reference to the drawings in which:

FIGURE 1 shows a portion of a knitting machine including a driving arrangement constructed according to the teachings of the present invention.

FIG. 2 is a view taken along the line 2—2 in FIG. 1 showing the end of the oil clutch.

FIG. 3 is a longitudinal section through the clutch taken along the line 3—3 in FIG. 2.

FIG. 4 is a fragmentary section showing the path of flow of magnetic flux.

FIG. 5 is a face view of the armature or output disc looking along the line 5—5 in FIG. 3.

FIG. 6 is a fragmentary section showing the cross section of an oil groove looking along the line 6—6 in FIG. 5.

FIG. 7 is a face view of the rotor or input disc looking along the line 7—7 in FIG. 3.

FIG. 8 is a fragmentary view showing the path of oil flow within the clutch.

FIG. 9 is a schematic circuit diagram showing the means for controlling the clutch output speed.

While the invention has been discussed in connection with a preferred embodiment, it will be understood that we do not intend to be limited to the embodiment shown but intend, on the contrary, to cover the various alternative and equivalent constructions included within the spirit and scope of the appended claims.

Turning now to FIGURE 1, there is disclosed at **10** a portion of a knitting machine incorporating a drive mechanism in accordance with the present invention. A machine of this type is disclosed in detail in Larkin Patent 2,422,568, issued June 17, 1947, and to which cross reference is made. In the knitting machine of Patent 2,422,568 means are provided for regulating the speed of the machine during each of the successive operations required in forming the knitted product. Speed variations are obtained through the medium of electronic control devices acting upon the electric motor which serves as the power source for the machinery, particularly a potentiometer actuated directly from the pattern drum of the machine.

The cam ring **2** of the knitting machine, in the present instance, is held stationary and is rigidly secured to the top frame of the knitting machine. The knitting or needle cylinder **3** is of the rotary type and is adapted to rotate about a vertical axis within the cam ring **2**. The sinker ring mechanism is illustrated generally at **4**. The needle cylinder **3** is provided with an integral bevel gear **5** which meshes with and is rotated by a bevel gear **6**, which latter is fixedly mounted for rotation with the horizontal shaft **7**. The shaft **7** is rotatably mounted in suitable bearings in opposite side frame members (not shown). Loosely mounted for rotation about the axis of the shaft **7**, is a gear **12** which meshes with a spur gear **13** which is rotatably mounted on a fixed stub shaft **14**. The gear **13**, in turn, meshes with a pinion **15** which is fixed to a jack shaft **16** suitably journaled in the machine. Secured to the jack shaft **16** is a second spur gear **19** which meshes with a spur gear **20**. The spur gear **20** is secured to a take-off shaft **21**. Mounted on the take-off shaft **21** is a bevel gear **22** which meshes with a bevel pinion **23**. The latter is secured to the output shaft **26** of a variable speed coupling **25** constructed in accordance with the present invention having an input shaft **24**.

It will be apparent that the gear train as thus far described, and the needle cylinder **3**, rotate at a relatively slow rate of speed which depends upon the gear ratio. However, as described in detail in the above patent, provision is also made for oscillating the gear **5** as an alternative to continuous driving. For this purpose the gear **13** carries a crank pin **26** to which is secured one end **27** of a pitman **28**, the opposite end **29** of the pitman carrying a pin **30** which engages one arm **31** of a gear segment lever **32**. The lever **32** is mounted for oscillatory movement on a shaft **33**. At the left hand end of the lever **32** a gear segment **34** is provided which engages a gear similar to the gear **12** on shaft **7** but which is not visible in the drawing. It will suffice to say that for selecting between the two conditions of continuous and oscillatory movement a shift mechanism is provided operated by a shifting fork. Thus there is provided a sleeve **37** which carries a key **36** which is sliable in a slot **35** formed in the

gear **6**. The sleeve **37** has a peripheral groove **38** which is engaged by a shifting fork **39** having a shifting lever **40**. Thus when the gear **12** is coupled to the hub of the gear **6** the needle cylinder **3** rotates continuously but when the companion gear is coupled to the hub, the rocking movement of the gear sector **34** causes the needle cylinder to oscillate back and forth. Selection of the two modes of operation is brought about by cam plates secured to the peripheral surface of a pattern drum **50** mounted on a shaft **51** which is rotatably mounted in the framework of the machine. Secured to the shaft is a ratchet wheel **52**. For advancing the ratchet wheel a pawl **53** is provided mounted upon a lever **54** which is secured to the oscillating shaft **33**.

Means are, however, provided for disabling the pawl **53**, lifting it clear of the ratchet wheel **52** so that the pattern drum does not rotate continuously but is advanced only in accordance with a predetermined program. Thus there is provided a kick-out arm or latch **55** which is pivotally mounted on the frame of the machine and which operates against a pin **56** which projects laterally from the pawl **53**. The position of the latch **55** is controlled by the links of a pattern chain which is constantly driven at a slow rate of speed. Referring to the drawing, it will suffice to say that a sprocket or chain wheel **57** is provided which is directly connected to a second ratchet wheel **59** which is engaged by a pawl **60** oscillated by a lever **32**. Trained about the sprocket wheel **57** is a pattern chain **65** having cams **66** secured at predetermined points along its length. These cams are in the path of movement of an arm **58** forming a part of the latch **55** which controls the action of a pawl **53**.

Thus as the lever **32** rocks back and forth, reciprocation of the pawl **60** causes rotation of the ratchet wheel **59** accompanied by movement of the pattern chain **65**. Whenever one of the cams **66** engages the arm **58**, of latch **55**, the pawl **53** is lowered into working engagement with the ratchet wheel **52**, thus stepping the pattern drum **50** forwardly in accordance with a predetermined pattern of movement.

It may, incidentally, be noted that means operated by the pattern drum are provided for changing the yarn. This is accomplished by yarn change fingers **62** which engage lift levers **63** pivotally mounted on a cross shaft **64**. The shaft **64** carries a cam follower **64***a* which rides on cams **67** formed on the periphery of the pattern drum.

In the above patent a potentiometer was provided in the machine having a rotor and stator which were separately adjustable by cam members in the machine. However, in accordance with one of the aspects of the present invention, separate manually settable reference elements are provided in the control circuit for establishing predetermined speeds and program cams or the like are provided on the pattern chain **65** and pattern drum **50** for operating limit switches for switching between the reference elements. Thus, associated with the cam follower **64***a* which rides on the drum **50**, there is provided a limit switch **78** having contacts **78***a*, **78***b*. Similarly, associated with the arm **58** which rides on the chain, there is provided a second switch **79** having contacts **79***a*, **79***b*. The manner in which all of these contacts are employed to effect a change in the driving speed will be apparent when considering the control circuit covered in a subsequent paragraph. For the present it will suffice to say that the pattern chain and pattern drum together serve to switch the driving mechanism thereby to change the operating speed of the machine. Directing attention next to the upper portion of FIG. 1, means are provided for feeding strands of yarn into the machine and for detecting breakage of any one of the strands. In the present instance three strands indicated at **91**, **92**, **93** are fed from bobbins **91***a*, **92***a*, **93***a*. Associated with the strands are switches **94**, **95**, **96** which are connected to disabling lines **97**, **98** and which are so constructed that when breakage occurs the switch contacts close thereby to produce a short circuit across the lines **97**, **98**. Such short circuiting is utilized to bring

about immediate disabling of the drive mechanism and stoppage of the machine so that damage to the machine is minimized.

At the lower right of FIG. 1 is disclosed a stocking ejector apparatus. As is well known to those skilled in the knitting art, the purpose of such apparatus is for pneumatically ejecting a finished product.

Up to the present time, and to the best of our knowledge, machines of the type disclosed herein utilized a separate motor for product ejecting purposes other than the motor used for the variable speed drive. Furthermore, it is also well known that it is desirable to have the blower operating motor developing a constant speed in order to maintain a constant eject force within the blower. Thus it can be appreciated that the variable speed drive motor was unsuitable for such application as any alteration of its speed altered the eject conditions within the blower.

By the example arrangement of the variable speed drive of the instant invention (FIG. 1) only a single constant speed drive motor is required whereby a variable speed and eject function is efficiently obtained. Moreover, the drive motor benefits from the cooling effect given off by the blower unit due to its convenient location adjacent thereto. Thus the single drive motor serves a dual function which results in a reduction of overall expense and affords sought after compactness.

Turning attention next to the construction of the coupling **25** which is set forth in longitudinal section in FIG. 3, it will be noted that it includes a housing **100** having a cup shaped portion **101** and an end bell **102**, the two sections being clamped together by machine screws **103** engaging mated flanges **104**, **105**, respectively. Extending from the left hand end of the machine is the input shaft **24** and extending from the right hand end of the machine, and alined therewith, is the output shaft **26**. The input shaft is journaled in spaced bearings **111**, **112** so as to be capable of supporting an overhanging load. In the present instance the bearings are mounted in a sleeve **113** and are spaced apart by a spacer **114** which engages the inner races. For the purpose of preventing escape of lubricant along the shaft, an oil seal **115** is provided which may be of any suitable type, commercially available. Similarly, the output shaft **26** is supported on bearings **121**, **122** mounted in a sleeve **123** and separated by a spacer **124**, sealing being taken care of by a seal **125**. The housing is intended to be operated approximately half full of oil or other viscous fluid capable of efficient lubrication and cooling. An O-ring **126** is preferably interposed between the portions **101**, **102** of the housing to provide an effective seal.

In carrying out the present invention, a driving disc or rotor is secured to the input shaft and a driven disc, or armature, is secured to the output shaft, with means for setting up a variable magnetic flux between them, thereby to regulate the output torque and speed. Turning attention first to the rotor, which has been indicated at **130**, it includes a hub **131** mounting a disc portion **132**, the hub being secured to the shaft by a key **133** and locked against endwise movement by any suitable means, preferably snap rings such as the ring **134** seated in a shallow groove formed on the shaft. The disc **132** is of composite construction including coaxial sleeves **135**, **136** of magnetic material spaced apart by a nonmagnetic annulus **137** to form separate annular poles **141**, **142**. Surrounding the sleeve **136** is a further annulus **143** to which is cemented, or otherwise secured, an annular friction member **145**.

Cooperating with the rotor **130** is an armature **150** mounted on a hub **151** providing a freely slidable splined connection **152**. The armature is preferably made of soft steel or other permeable magnetic material, completing the magnetic circuit between the poles **141**, **142** on the rotor previously referred to.

For the purpose of establishing a flow of flux through the poles, a stationary annular electromagnet **160** is provided having poles **161**, **162** thereon which axially overlap, and have a close spacing with respect to the pole members **135**, **136** on the rotor. The magnet **160** is of "U" cross section accommodating an annular coil **165** to which current is conducted by leads **166**, **167** leading to a connector **168** outside of the machine.

It will be apparent from FIG. 4 that the flux, indicated at F, passes from the electromagnet through the annular poles **135**, **136** for magnetic attraction of the armature which is free to move on its central spline connection **152**, the amount of force being dependent upon the current flow through the winding. Preferably the friction material **145** is made flush with the outer pole **142** while the inner pole is undercut to provide a small amount of clearance **146** on the order of a few thousandths of an inch.

In accordance with one of the aspects of the present invention, sharp edged, radial grooves are formed in the face of the armature for the purpose of conducting the oil to the faces which are in engagement and to provide an escape path for the oil film as the magnetic attraction is increased with resulting increase in rotational drag. Thus, referring to FIGS. 5 and 6, radial grooves **171–176** are cut in the face of the armature spaced at equal angles. Each of the grooves defines edges **177**, **178** which are preferably relatively sharp and each of the grooves is of square cross section, having an area which may be on the order of .01 square inches. It should be here pointed out, however, that similar grooves **171–176** may be formed in the friction member **145** (instead of armuature **150**) and through the outer edge of annular pole **142** to provide for the above explained oil circulation without departing from the spirit of the invention.

For the purpose of admitting the oil to the inner ends of the grooves **171—176**, the magnet **160** is so dimensioned with respect to the hub **131** as to provide an annular oil passageway **181**, and openings **182** are formed in the rotor at spaced intervals (see FIGS. 3, 7 and 8). As the input shaft turns, and assuming flow of current through the electromagnet, drag torque is applied to the armature so that it too begins to turn. As will be set forth in greater detail in connection with the control circuit, the current through the coil under starting conditions is high and the attractive force on the armature is correspondingly great so that the film tends to be squeezed out from between the engaging surfaces resulting in a high value of transmitted torque and with immediate acceleration of the output shaft to a speed approaching the desired value. Simultaneously, the centrifugal force, acting upon the oil in the armature grooves, causes oil to be discharged radially outward along the path P shown in FIGS. 5 and 8. Because the grooves are in multiple, having substantial total area, a large volume of fluid is conducted. For example, in the case of a practical coupling having a rating of ½ hp, the rate of flow may be on the order of approximately 50 cubic inches per minute when rotating at 1800 r.p.m. It is to be noted that, while the oil conducting grooves are formed in the output disc rather than the input disc, the output disc is immediately effective on start-up and has the advantage of rotating thereafter at a maintained speed. The clearance at the pole face **141** augments the grooves in providing replenishment of the fluid to the space **138** (FIG. 8).

Conversely, when prompt shutoff is required the current in the coil **165** is immediately dropped to zero by the control circuit to be described, thereby releasing the magnetic attractive force upon the armature. To insure prompt separation, the armature preferably carries a set of three separator springs **183** having separator buttons **184** which engage the rotor face (see FIG. 5). One of the spring assemblies is shown in FIG. 4, wherein a rivet passes through a hole at the lower portion of spring **183** and is pressed into a hole provided in the armature **150**. The button **184** loosely fits in a second hole provided at the upper portion of armature **150**. Button **184** is fixed to the upper portion of spring **183**. With the coil **165** in energized condition, button **184** is drawn toward the friction

member 145 (as shown) thereupon tending to straighten spring 183. Such action causes a pressure build-up at the rear of button 184. Upon de-energization of coil 165, the magnetic attractive force is released, whereupon springs 183 apply their stored energy at the rear of buttons 184 and positively disengage the armature 150 from the friction member 145. Thus it can be appreciated that immediate separation is effected and any possible adhesion condition is prevented. The pressure of the fluid in the grooves is also effective to cause the armature to move away from the rotor, greatly increasing the thickness of the film between them so that negligible torque is transmitted to the output shaft. In accordance with one of the aspects of the invention it will be noted that the armature is axially quite thin and of low mass so that the inertia of the output element is kept to a low value. The net result is that when current is turned off the output shaft stops with little overtravel. This is to be contrasted with conventional driving arrangements either in the form of motors or in the form of a clutch of the eddy current type in which there is substantial inertia and hence substantial overtravel which must be arrested by "plugging" or similar techniques.

Our observations show that the oil in the device performs a number of different functions. Not only does it lubricate the interface between rotor and armature to prevent wear but it also serves to provide a frictional drag torque which varies more or less inversely with respect to the film thickness. The arrangement is such that a thin film is available on starting for maximum accelerating or break-away torque and a thick film is established promptly upon stopping to provide prompt torque cut-off. In addition, the relatively large amount of fluid which is pumped by the centrifugal force serves efficiently to carry away the energy of slippage in the form of heat which is conducted to the housing of the device. Thus, notwithstanding the fact that the clutch is only half filled with oil, the entire inner surface of the housing is thermally coupled to the oil by scrubbing action.

Means are provided at the outside of the housing for carrying away this conducted heat. In the present instance the portions 101, 102 of the housing have integrally molded fins 101*a*, 102*a* which are in register with one another providing longitudinal air channels having a large total surface area over which air is forced by a fan, indicated at 185, secured to the input shaft. For safety's sake, the end member 102 may be provided with a cup shaped shield which fits over the fan so as to protect against contact with the whirling blades or, if desired, a shield may be provided which is sufficiently deep so as to enclose not only the fan but also an input drive pulley which may be secured to the shaft adjacent the fan and in absence of a separate driving motor.

For the purpose of venting the housing to prevent the build up of pressure therein as the fluid is brought up to operating temperature, a breather plug 186 is provided above the oil level having a breather opening 187 and which is protected against loss of fluid by an internal shield or baffle 188.

In accordance with one of the aspects of the present invention, for the purpose of monitoring and automatically controlling the output speed, a tachometer is provided within the housing adjacent the armature disc 150. The tachometer, indicated at 190, includes a stator 191 and rotor 192. The stator is clamped in place within the structure by a retaining ring 193 while the rotor is keyed to the shaft on a key 194. The tachometer is of the commutatorless type producing an output voltage and frequency which varies directly with speed. Briefly stated, the stator 191 includes a toroidal coil between annular core pieces having fingers bent inwardly and interspersed with one another to define a plurality of stator poles. The rotor is permanently magnetized with pairs of poles integrally related to the fingers on the stator. Thus when the rotor is in a reference position flux is caused to flow through the coil in one direction and when the rotor is advanced through an incremental distance, flux is caused to flow through the coil in the opposite direction thereby generating an A.-C. wave. Integrating the tachometer into the construction makes it unnecessary to provide a separate housing and outboard mounting for the tachometer, reducing the cost to a fraction of that formerly necessary. In addition the tachometer is protected and both the control leads and tachometer leads which lead to the control unit may be run through the connector 168 simplifying the installation.

In accordance with the invention improved means are provided for automatic maintenance of the output speed in spite of wide variations in the speed of the input shaft. More specifically, the current from the tachometer generator is bucked against an adjustable source of reference current to produce a net input current to a transistor amplifier having the clutch coil in its output circuit so that a corrective change is made in the clutch current when there is any tendency for the speed to change. Thus, upon a slight drop in the output of the tachometer, current through the clutch coil is increased and any slight excess in output of the tachometer causes the clutch current to decrease with the result that the output speed is maintained constant within close limits.

Turning to the control circuit as set forth in FIG. 9, attention may be directed first to the power supply set forth in the top portion of the diagram. Assuming that the motor M is supplied with three phase current via lines L1, L2 and L3, voltage is taken from two of the lines, passed through a step down transformer 200 into a bridge rectifier 201 having output terminals 202, 203 of the polarity indicated. The output voltage is filtered by a capacitor 204. The voltage is maintained constant by a Zener 205 having a series resistor 206.

For producing a selectable reference voltage, a reference voltage source 210 is provided as shown at the foot of the diagram. Alternating current is conveniently obtained from a winding 211 which may be wound on the transformer 200. The output is rectified by a diode 212 and filtered by a capacitor 213. To enable selection of reference voltage, a plurality of potentiometers are provided, in the present instance a first potentiometer 215 having an output terminal 216 and a second potentiometer 217 having an output terminal 218.

To turn the power on and off a relay 220 is provided having a start switch 221, a stop switch 222, and contacts 223, 224. Pressing the start switch energizes the relay, with contacts 223 sealing in to maintain the relay closed. To turn off the circuit, momentary pressing of the stop button drops out the relay.

In order to make the reference voltage independent of fluctuations in line voltage, a Zener voltage regulator is provided including a Zener diode 225 and series resistor 226 connected as shown.

Means are provided for converting the output of the tachometer to A.-C. feedback voltage for bucking against the selected reference voltage. For this purpose the tachometer generator is connected to a bridge rectifier 230, the output of which is filtered by capacitor 231. Both legs of the circuit are provided with a series or "droop" resistor for limiting the current flow. Thus, in series with the tachometer generator circuit, the feed-back current is limited by a resistor 232 having a rheostat 233 connected in series therewith for adjustment of "maximum" speed. In parallel with the resistor 232 is a capacitor 234 to stabilize the circuit, particularly in the face of sudden changes in output of the tachometer generator. In the reference leg of the circuit, a resistor 235 is provided in series with the switch terminal. It will be seen, then, that the tachometer circuit and reference circuit, each with a series resistance, are in parallel with the input terminal 236 of the amplifier stage.

For the purpose of responding to the differential current and for producing an amplified signal which is ap-

plied to the clutch coil, an amplifier **240** is provided having direct coupled transistors **241, 242**. The emitter of the first transistor has a resistor **243** and is directly connected to the base of the second. Both emitters are supplied from the positive terminal **202** of the power supply and the collectors are jumpered together and returned to the negative terminal **203** of the power supply with the clutch coil **165** in series therewith. A diode **244**, polarized as shown, is connected across the base-emitter, or input, circuit of the first transistor to protect the latter against reverse overvoltage.

To insure that the output current may be reduced to zero upon shutoff, particularly under high ambient temperature conditions, means are provided for applying a small amount of positive bias to the base of the second transistor. This is accomplished by employing a constant voltage drop diode **245** or "stabistor" in the emitter circuit of the transistor **242** with the circuit being completed through a series resistor **246**. Upon flow of current from the power supply through diode **245** and resistor **246** a constant voltage drop occurs through the diode, making the base slightly positive with respect to the emitter.

Finally, to prevent the transistors from being injured by the inductive kick from the clutch coil **165** when the latter is deenergized, the coil is short-circuited by a diode **248**.

While the operation of the circuit described above will be apparent to one skilled in the art, it may be described briefly as follows. It will be assumed that the clutch input shaft is being turned at a certain nominal speed by the motor, that a load is connected to the output shaft, that the first potentiometer **215** is in the active position, and that sufficient current is flowing through the clutch coil so that a predetermined output speed is obtained. In the event that the output load drops slightly resulting in a tendency for the output speed to increase, the net input current applied to the base of the first transistor decreases slightly, thereby decreasing its current output which is fed to the emitter and base of the transistor **242** whereupon the output of transistor **242** is decreased. Then the load current of the two transistors which flows through the clutch coil **165** tends to decrease slightly, reducing the drag torque so that there is a corrective, slight increase in speed of the output shaft and restoring a condition of equilibrium. A corrective change in the same direction takes place upon any tendency for the speed of the input shaft to increase, for example, as a result of a sudden increase in line voltage.

The converse takes place when there is a decrease in the output speed from the desired equilibrium value due to added loading or a drop in the line voltage supplying the motor. Under such conditions the resulting unbalance between the tachometer circuit and reference circuit causes a slight increase in the current flowing through the base circuit of the transistor **241**, increasing the emitter current and thereby slightly increasing its current output which is fed into the emitter and base of the transistor **242** whereupon the output of transistor **242** is increased. Then the load current of the two transistors which flows through the clutch coil **165** tends to increase slightly, increasing the drag torque so that there is a corrective, slight decrease in the speed of the output shaft that restores a condition of equilibrium.

It is one of the characteristics of conventional transistors, particularly where of the germanium type, and particularly under high temperature conditions, that the transistor output circuit is conductive even where the input current is zero. The presence of the stabistor **245** in the circuit insures that under zero input conditions there will be sufficient positive bias on the base with respect to the emitter so that the current through the clutch coil will be substantiallly zero.

By using the above described combination of clutch and control circuit, the speed regulation may be held to within approximately 2% or better in spite of variations in input speed over a wide range.

In accordance with one of the aspects of the present invention, a novel contact arrangement is employed including both normally open and normally closed contacts in the switches **78, 79** to permit switching between the potentiometers **215, 217** directly without use of an interposed relay. Thus, we provide in switch **78** normally closed contacts **78*a*** and normally open contacts **78*b***, and we also provide, in switch **79**, normally open contacts **79*a*** and normally closed contacts **79*b***. Contacts **78*a*, 79*a*** are arranged in parallel with one another and connected in series with the output terminal **216** of potentiometer **215**. The remaining contacts **78*b*, 79*b*** are connected in series with one another and in series with output terminal **218** of potentiometer **217**. As a result, potentiometer **217** is connected in the circuit only when switch **78** is actuated and when switch **79** is in its normal, or non-actuated position. Under such conditions it will be apparent that contacts **78*b*** are closed so that a circuit is completed to potentiometer **217** through the normally closed contacts **79*b***, whereas the contacts associated with the potentiometer **215** are both open circuited.

Referring briefly to the other possible conditions, it will be apparent that when neither switch is actuated, potentiometer **215** is in the circuit via normally closed contacts **78*a***. When only switch **79** is actuated, potentionmeter **215** is again in the circuit since the closure of contacts **79*a*** and opening of contacts **79*b*** is simply redundant. Finally, it will be apparent that when both switches **78** and **79** are actuated the circuit to potentiometer **215** is set up through closure of contacts **79*a***, with the circuit to the potentiometer **217** being opened by opening of contacts **79*b***. In short, the contacts in the two switches are connected to perform a logic function, with the potentiometer **217** being connected in the circuit only during one of the four possible switch conditions.

The ability of the device to maintain the speed constant at an adjusted value is particularly important in a knitting machine where operation at maximum efficiency requires a certain operating speed for certain operating parameters, notably the type and gauge of the yarn being used. The drive is well suited for use in those areas where wide swings in line voltage are encountered or where wide changes in input speed may occur, as where water power is being utilized as the power source. To take a practical case it may be assumed that the desired output speed is 1800 r.p.m. and that the available speed at the input shaft is a nominal 2200 r.p.m., with substantial variation possible below this value. Using the present control arrangement the speed of the input shaft would have to drop more than 18% to below 1800 r.p.m., before there would be any reduction in output speed below the set value. Consequently, knitting machines employing the present invention may be sent to any country of the world independently of the kind of power available with assured efficiency of the operation of the machine, provided only that the input speed does not fall below a stated minimum.

The clutch and control circuit, comprising a system, have a short "time constant," i.e., are capable of responding immediately to changes in the operating conditions. Thus, upon breaking the yarn in the knitting machine, causing momentary short circuiting of the relay coil, the resulting dropout removes power from the clutch with practically no overtravel due to inertial effects and without necessity for resorting to "plugging." The circuit may be readily inched or jogged by holding the start button down and releasing the stop button in short pulses.

Control over the entire speed range is achieved using low values of control current so that conventional and inexpensive circuit components may be used permitting compact unit, or "plug in," construction. Because of the small amount of current drawn by the control system, the voltage across the power supply output terminals **202,**

203 may be regulated by the low cost Zener diode 205 and series resistor 206 which are optional.

The amount of heat dissipated by the control circuit is negligible. Moreover, where operating conditions are such that a constant high degree of slippage in the variable drive unit must be employed, resulting in a high rate of energy transferred to the cooling fluid, the cooling air may be vented from the work space or a heat exchanger may be used for recirculating the cooling fluid and for maintaining it at a relatively low temperature.

The control system is so simple as to enable servicing by relative untrained personnel, particularly where "plug in" units permit simple substitution of the circuit or subassembly.

While the mechanism whereby torque is transmitted through the oil film is a matter for continued investigation, it would appear that a thin film of moderately viscous oil or the like, because of internal friction between the oil molecules, tends to resist shearing force. Thus when the rotor rotates with respect to the armature at a certain slip speed and where the film is only a few molecules thick, it will be apparent that there must be a high speed of slip between adjacent molecules which is accompanied by a high reactive force, i.e., a high torque. However, where the rotor and armature are more widely spaced with a thick film between them, the same relative speed of slip between the discs is accompanied by a relatively low speed of slip between adjacent molecules. Hence the reactive force, or torque, is reduced. In short, when the current to the coil 165 is reduced, oil from the grooves 171–176 feeds between the disc faces to reduce the transmitted torque.

Wear is negligible in the instant variable drive construction due to the opposed surfaces being at all times during operation swept and cooled by oil. It has been experienced over extended periods of operation that the sleeve 136, which is flush with the friction material, and the armature face tend to wear a trivial amount. However, such wear has no influence on the engaging surfaces and the desired torque characteristics remain constant when varying loads are applied over extremely long periods of operation.

It is one of the features of the present drive system that it is "fail safe" in operation. Thus the driving torque is not only instantly terminated as a result of thread breakage, or the breakage of any other element in the machine causing thread breakage, but the drive is turned off as a result of failure of control current, the effects of which are simply to cut off current flow in the transistors which supply current to the clutch coil 165. Thus the system is to be contrasted with systems in which deceleration or cut-off requires control current in the form of brake or "plugging" current.

It is to be understood that the following claims are intended to cover all of the generic and specific features of the invention herein described, and all statements of the scope of the invention, which, as a matter of language, might be said to fall therebetween.

Having described our invention, what we claim as new and desire to secure by Letters Patent is:

1. In a drive system for a knitting machine having a program mechanism including a pattern chain and pattern drum having cams thereon for defining successive steps in the completion of a knitted stocking or the like, the combination comprising a source of rotative power having a speed at least as high as the maximum speed required by the machine, a variable speed coupling interposed between the source and the machine, said variable speed coupling including input and output discs having an associated electromagnet so arranged that the coupling force and hence the torque transmitted by the coupling varies by the amount of current flowing through the coil, a tachometer coupled to the output disc for producing a speed signal, reference means having first and second reference terminals for producing two levels of reference signal, an amplifier having an input and an output with the input being coupled to the tachometer and reference terminals and the output being connected to said electromagnet, chain and drum switches associated with the chain and drum respectively for operation by the cams thereon, each of said switches having normally open and normally closed contacts directly interposed between the reference terminals and the input of the amplifier for activating a selected one of the reference terminals depending upon the existing settings of the switches.

2. In a drive system for a knitting machine having a program mechanism including a pattern chain and pattern drum provided with cam surfaces for separating the operation into a succession of steps as required to complete the successive portions of a stocking, the combination of a source of rotative power having a speed at least as high as the maximum speed required by the machine, a variable speed coupling interposed between the source and the machine, said variable speed coupling including input and output discs and an associated electromagnet so arranged that the clutching force varies in accordance with the amount of current flowing through the electromagnet, a tachometer associated with the output disc for producing a speed signal, means including reference terminals for providing a plurality of reference signals at different but adjustable signal levels, an amplifier having its input coupled to the tachometer and the reference terminals and having its output connected to said coil, switches associated with the pattern chain and pattern drum respectively for operation by the cams thereon, said switches having contacts connected in predetermined combination to said reference terminals for directly connecting said reference terminals to the amplifier in succession to establish a programmed succession of equilibrium speeds.

3. In a drive system for a knitting machine having a program mechanism including a pattern chain and pattern drum having cams thereon for defining successive steps in the completion of a knitted stocking or the like, the combination comprising a source of rotative power having a speed at least as high as the maximum speed required by the machine, a variable speed coupling interposed between the source and the machine, said variable speed coupling including input and output discs having associated electromagnet so arranged that the coupling force and hence the torque transmitted by the coupling varies by the amount of current flowing through the coil, a tachometer coupled to the output disc for producing a speed signal, reference means having first and second reference terminals for producing two levels of reference signal, an amplifier having an input and an output with the input being coupled to the tachometer and reference terminals and the output being connected to said electromagnet, chain and drum switches associated with the chain and drum respectively for operation by the cams thereon, each of said switches having normally open and normally closed contacts directly interposed between the reference terminals and the input of the amplifier, the normally closed contact of one of the switches being connected in parallel with the normally open contact of the remaining switch to provide a circuit to one of said reference terminals and the remaining contacts of the switches being connected in series with one another to provide a circuit to the second reference terminal so that said second reference terminal is effective only when one of said switches is solely actuated and ineffective under all other conditions.

4. In a drive system for a knitting machine having a program mechanism including a pattern chain or the like for separating the operation into a succession of steps as required to complete the successive portions of a stocking, the combination of a source of rotative power having a speed as least as high as the maximum speed required by the machine, a variable speed coupling interposed between the source and the machine, said variable speed coupling including input and output shafts arranged end to end and having input and output discs respectively for clutching the shaft together, electromagnetic means in the cou-

pling including a coil so arranged that the clutching force and hence the torque transmitted by the coupling varies in accordance with the amount of current flowing through the coil, a tachometer coupled to the output shaft for producing a speed signal, means for producing a plurality of selectable reference signals, an amplifier having its input connected for response to the net value of the speed signal and a selected one of the reference signals, said amplifier having its output connected to said coil so that an equilibrium speed tends to be established at the output shaft depending upon which of the reference signals is selected, and means operated by the program mechanism in the knitting machine for selecting the reference signals in succession so that the knitting machine is operated at different speeds during successive steps in its operation.

5. In a drive system for a knitting machine having a program device including a pattern drum or the like for causing the machine to operate in successive modes as required to complete the successive portions of a stocking or other knitted article, the combination comprising a source of rotative power having a speed at least as high as the maximum speed required by the machine, a variable speed coupling inserted between the source and the machine, said variable speed coupling including input and output shafts having clutch discs thereon together with electromagnetic means including a coil for varying the amount of slippage between the discs, a source of speed signal including a tachometer coupled to the output shaft, a source of reference signal providing a plurality of predetermined signal levels, an amplifier having its input connected for response to the net value of said signals and having its output connected to said coil so that the current in the coil is caused to be correctively varied to maintain an equilibrium speed of the output shaft, and switch means operated in unison with movement of the pattern drum for selecting the level of the reference signal required for each mode of operation of the machine.

6. A drive system for a knitting machine having a thread break detector comprising, in combination, a source of rotative power having a speed at least as high as the maximum speed required by the knitting machine, a variable speed coupling interposed between the power source and the knitting machine, said variable speed coupling including alined input and output shafts having cooperating discs at the ends thereof, at least one of said discs having a pair of annular magnetic poles and the companion disc being made of magnetic material, means including an electromagnet for magnetizing said poles, a tachometer on the output shaft for producing a speed signal, means for producing a reference signal, an amplifier having its input responsive to the net signal and having the electromagnet in its output circuit so that the current through said electromagnet is correctively varied upon any tendency of the speed of the output shaft to vary from the desired speed, and means for disabling said electromagnet upon operation of the thread break detector in the knitting machine, the disc on the output shaft being constructed and arranged to have minimum inertia for producing substantially immediate stoppage on the output shaft when thread breakage occurs.

7. A circular knitting machine including knitting instrumentalities, pattern means for controlling said instrumentalities to vary the character of the knitted fabric, at least one accessory, and common drive means for said instrumentalities, pattern means, and said accessory, said drive means including a constant speed prime mover and variable clutch means operable to vary its drive ratio in response to electronic signals fed thereto, means connecting said instrumentalities and pattern means to said prime mover through said clutch means, means connecting said accessory to said prime mover independently of said clutch means, and a control circuit connected to said clutch means and responsive to said pattern means to feed an electronic signal to said clutch means and thereby to control the operating speed of said knitting instrumentalities and pattern means without affecting the speed of said accessory.

8. A circular knitting machine according to claim 7 including a tachometer coupled to the output of said clutch means to feed an electronic signal to said clutch counteracting the signal from said control means when said clutch means attains the desired drive ratio.

9. A circular knitting machine according to claim 7 wherein said pattern means comprises a first device driven continuously with said knitting instrumentalities and a second device driven intermittently, the drive of said second device being initiated by an element of said first device, said control circuit including an electronic component rendered operative upon initiation of the drive of said second device to feed a signal to said clutch means which reduces the output speed thereof.

10. In a circular knitting machine for knitting tubular fabric, a constant speed prime mover, a control circuit, a clutch coupled to said prime mover and operable to vary its output speed in predetermined relation to an electronic signal fed thereto by said control circuit, knitting instrumentalities driven by the output of said clutch including a rotary needle cylinder, needles in said cylinder, control means to selectively displace said needles axially in said cylinder, and yarn feeders actuatable selectively to produce tubular knitted fabric on said needles, and pattern means operable to actuate in a selected sequence elements of said control circuit to feed different electronic signals to said clutch to drive said knitting instrumentalities at different speeds, said pattern means also being operable to operate said control means and yarn feeders to knit a complete tubular fabric.

11. In a knitting mill, a plurality of circular knitting machines, and a common constant-speed prime mover for said machines, each machine including knitting instrumentalities, pattern means for controlling said instrumentalities to vary the character of the knitted fabric, and variable clutch means operable to vary its drive ratio in response to electronic signals fed thereto, means connecting said instrumentalities and pattern means to said prime mover through said clutch means, and a control circuit connected to said clutch means and responsive to said pattern means to feed an electronic signal to said clutch means and thereby to control the operating speed of said knitting instrumentalities and pattern means.

12. In a drive system for a knitting machine having knitting instrumentalities and auxiliary means, the combination comprising a substantially constant speed driving motor having a speed which is at least as great as the maximum desired speed of operation of the machine, a two-ended shaft driven by the motor, a variable speed drive coupling interposed between the shaft at one end thereof and the motor, said drive couplings including a housing having input and output shafts arranged therein end to end, input and output clutch discs at the ends of the shafts for transmission of torque between them, said housing including a charge of oil that is constantly supplied between the clutch discs, electromagnetic means for varying the force between the clutch discs thereby to vary the thickness of the oil film therebetween and consequently the torque applied to the output shaft, and means connected to the other end of the motor driven shaft for operating said auxiliary means when the variable speed drive is in operation.

13. In a drive system for a knitting machine having knitting instrumentalities and means for pneumatically ejecting a finished product, the combination comprising a substantially constant speed driving motor having a speed which is at least as great as the maximum desired speed of operation of the machine, a variable speed drive coupling interposed between the shaft of the motor and the machine, said drive coupling including a housing having input and output shafts arranged therein end to end, input and output clutch discs at the ends of the

shafts for transmission of torque between them, said housing including a charge of oil so that oil is constantly supplied between the clutch discs, electromagnetic means for varying the force between the clutch discs thereby to vary the thickness of the oil film therebetween and consequently the torque applied to the output shaft, said housing including a tachometer on the output shaft for producing a speed signal, means for producing a reference signal, amplifier means responsive to the net value of the speed and reference signals for controlling energization of the electromagnet thereby to maintain the output speed of the coupling constant notwithstanding variations in loading of the output shaft, and a blower connected to the motor shaft for producing an air blast for ejecting the knitted product of the machine.

References Cited

UNITED STATES PATENTS

2,747,105	5/1956	Smith	192—84
2,796,222	6/1957	Frankel	192—84
2,817,220	12/1957	Mahler et al.	66—56
2,864,248	12/1958	Wiesinger	66—56
2,966,783	1/1961	McKibbin et al.	66—56
3,055,470	9/1962	Pierce	192—84
3,092,984	6/1963	Kramer et al.	192—84
2,422,568	6/1947	Larkin	66—56
2,788,104	4/1957	Mason	192—84
3,055,475	9/1962	Pitts	192—84

MERVIN STEIN, *Primary Examiner.*

R. FELDBAUM, *Assistant Examiner.*