May 5, 1964 J. E. BLACK 3,132,295

PRINTING PRESS DRIVE CONTROL SYSTEM

Filed Sept. 14, 1959 7 Sheets-Sheet 1

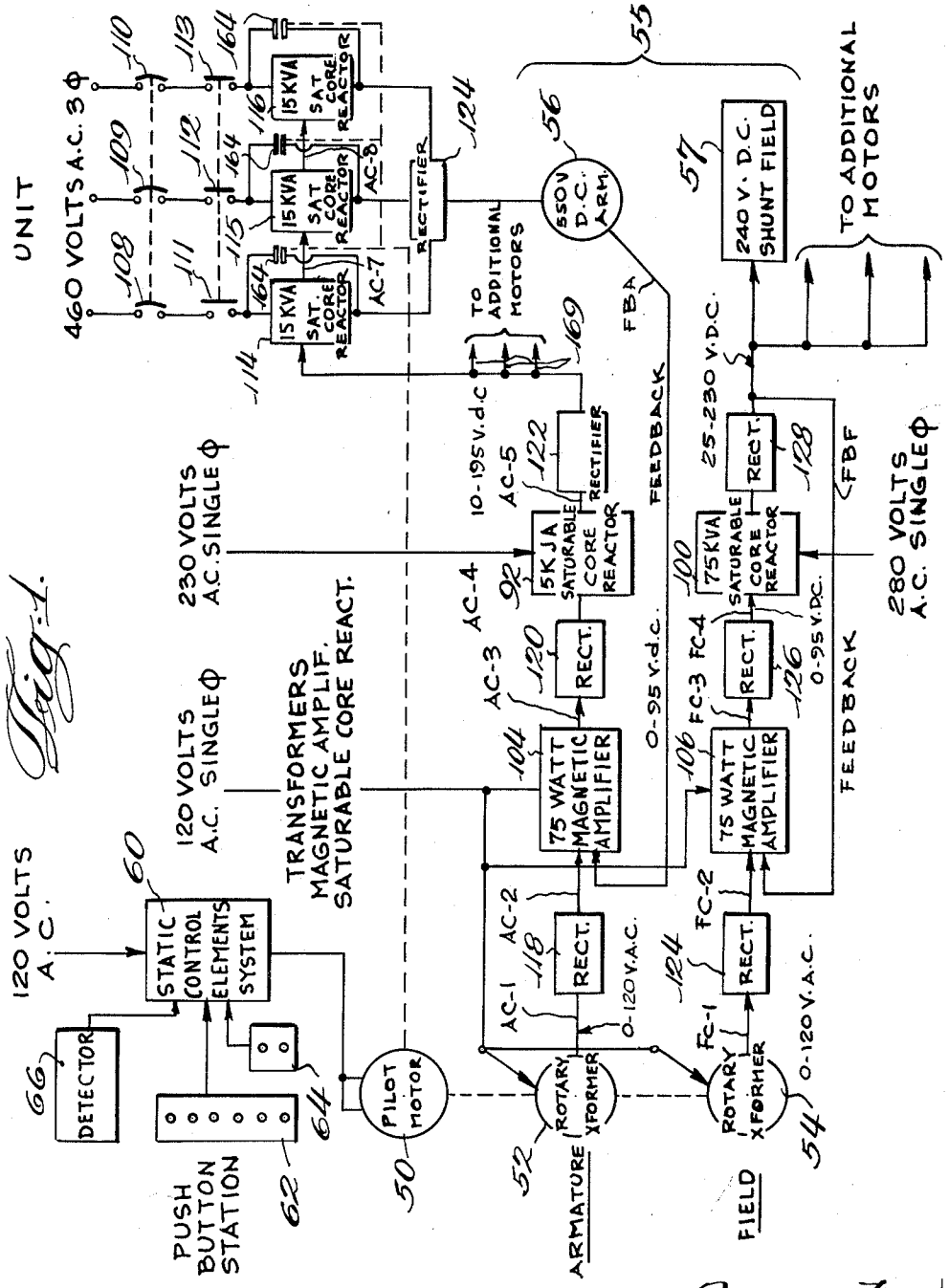


Fig. 1.

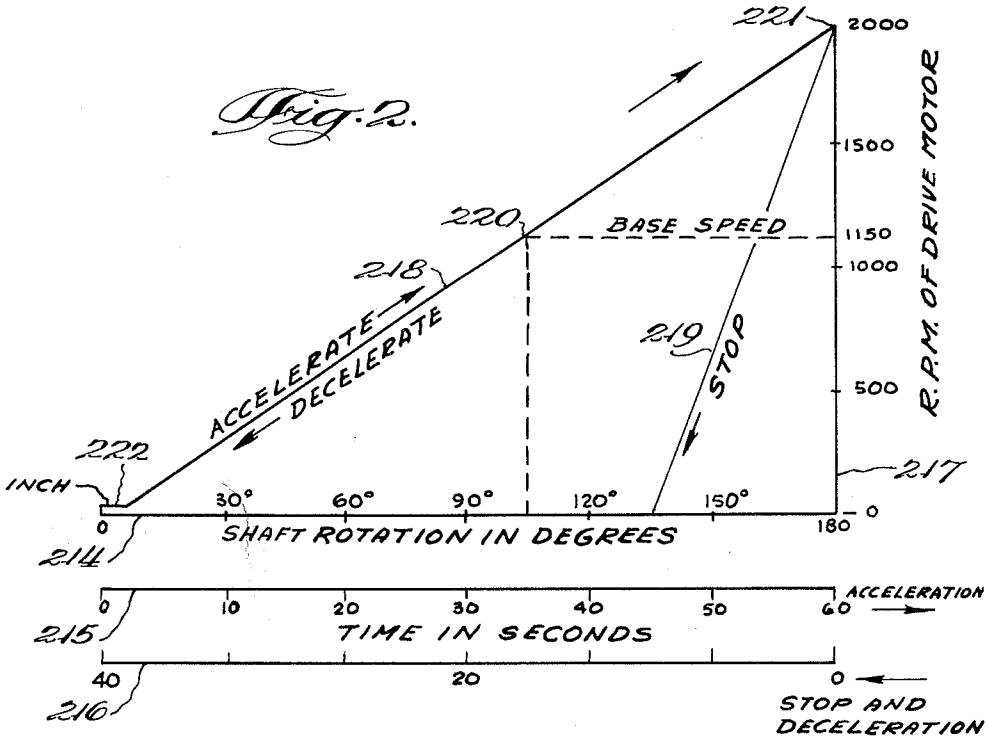
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PRINTING PRESS DRIVE CONTROL SYSTEM

Filed Sept. 14, 1959 7 Sheets-Sheet 2

Fig. 2.



SWITCH	CAM POSITIONS IN DEGREES														
	12	24	36	48	60	72	84	96	108	120	132	144	156	168	180
DETECTOR															
WEB SEVERERS															
REGULATED TENSION															
FASTER LIMIT (N.C.)															
SLOWER LIMIT (N.C.)															
AUTOMATIC ACCELERATION															
AUTOMATIC DECELERATION															
REGISTER CONTROL GO-DOWN															
SHUNTING CONTACTOR															

Fig. 4.

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PRINTING PRESS DRIVE CONTROL SYSTEM

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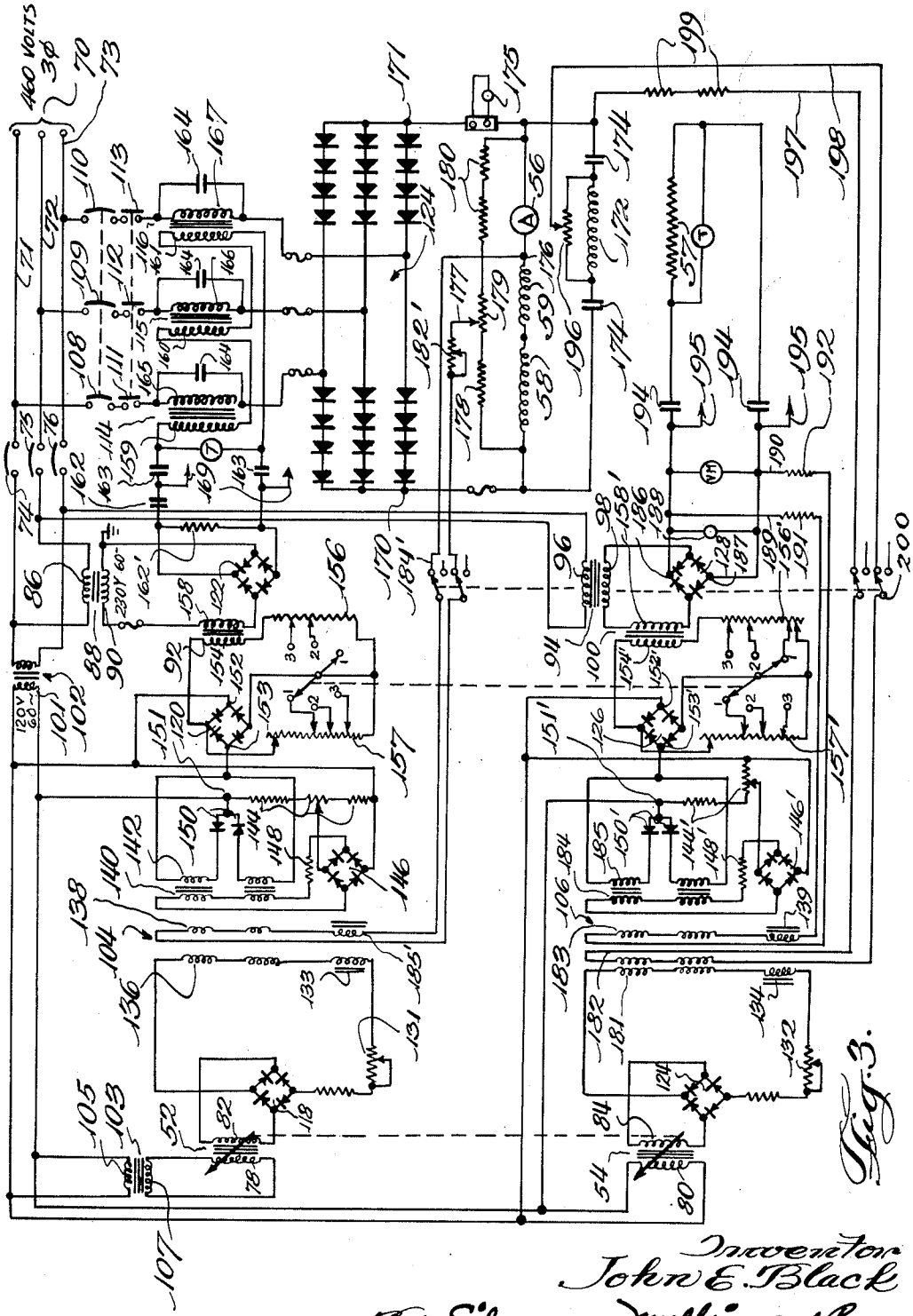


Fig. 3.

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PRINTING PRESS DRIVE CONTROL SYSTEM

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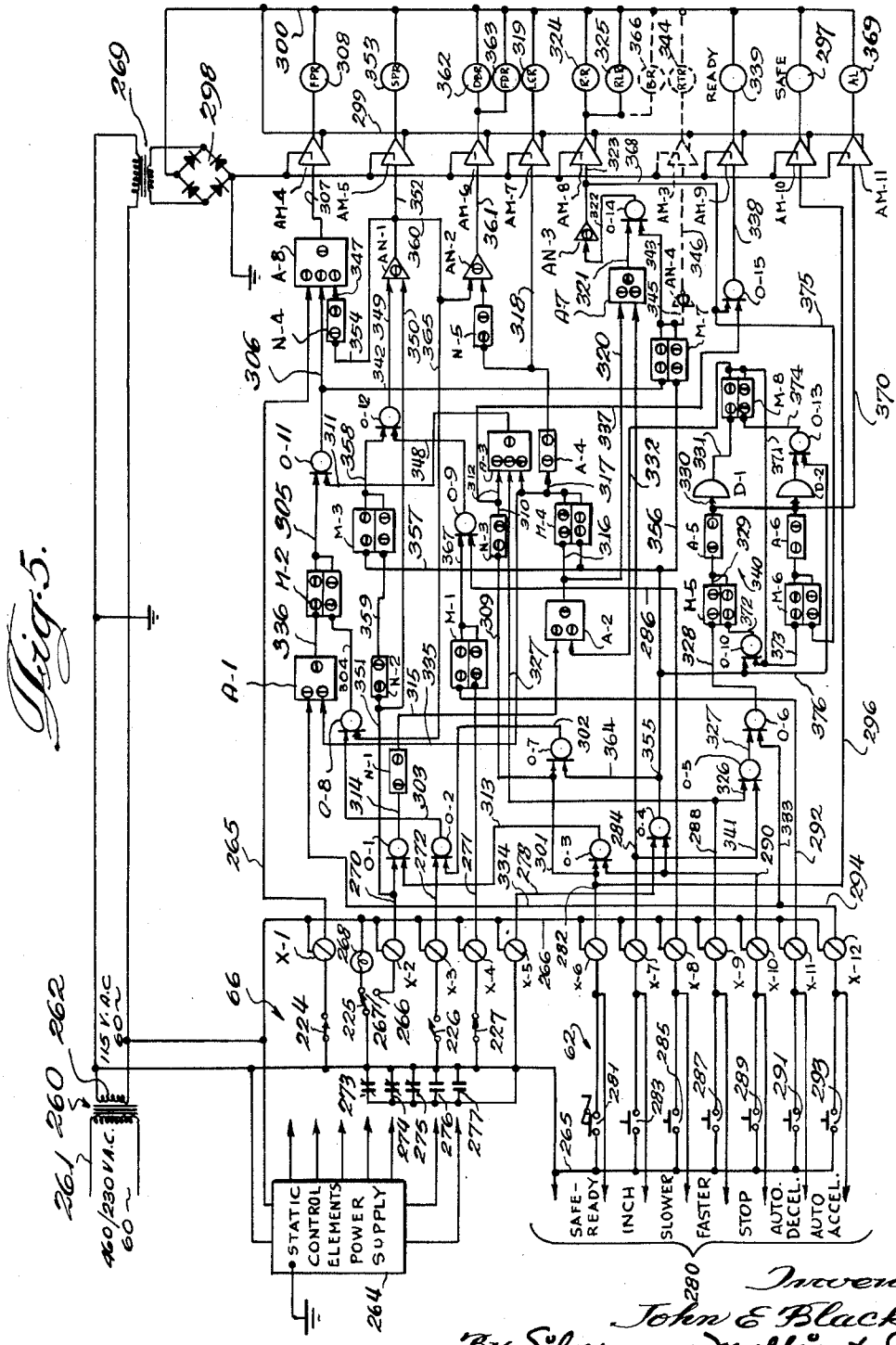


Fig. 5.

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May 5, 1964 J. E. BLACK 3,132,295

PRINTING PRESS DRIVE CONTROL SYSTEM

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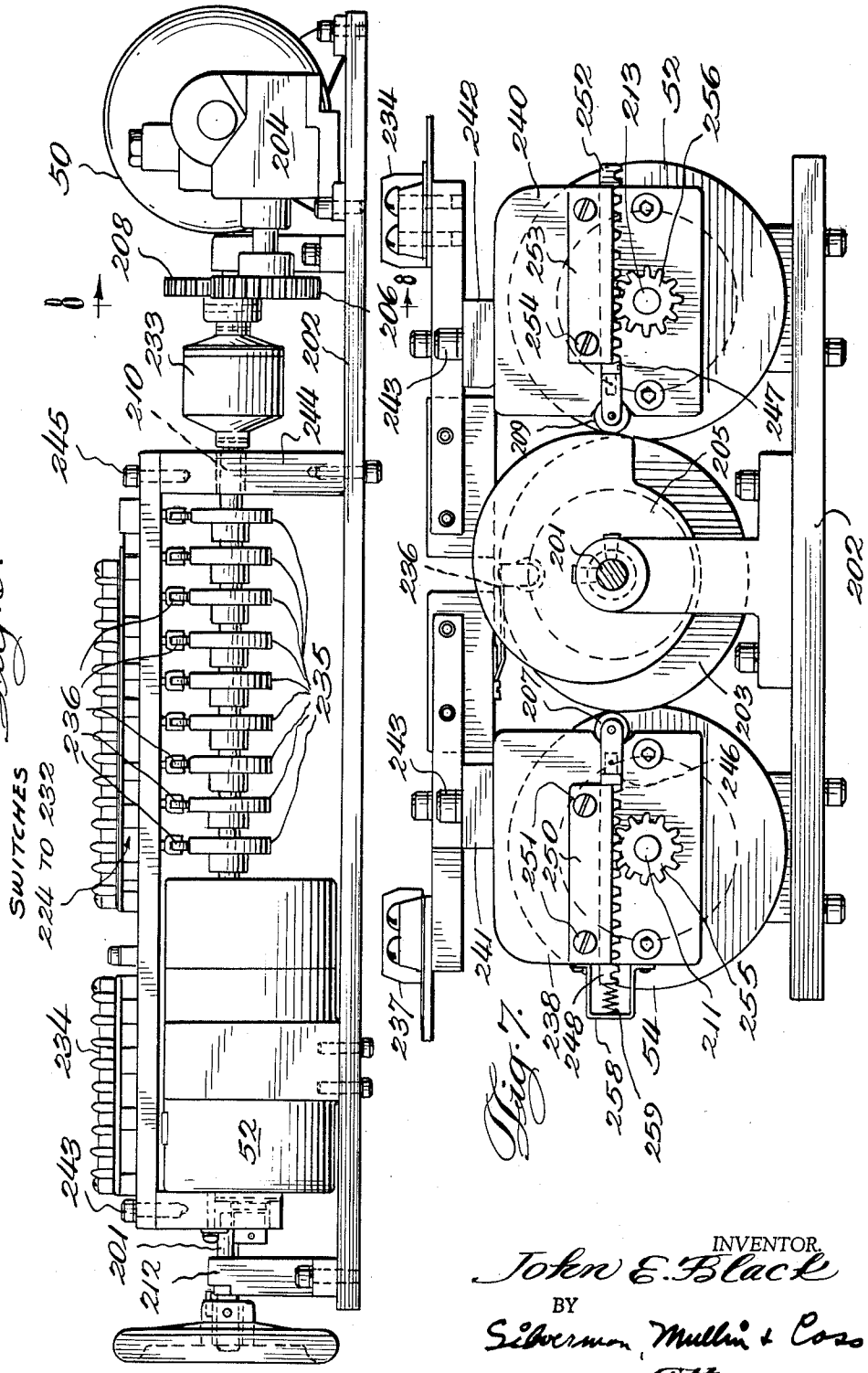


Fig. 6.

Fig. 7.

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PRINTING PRESS DRIVE CONTROL SYSTEM

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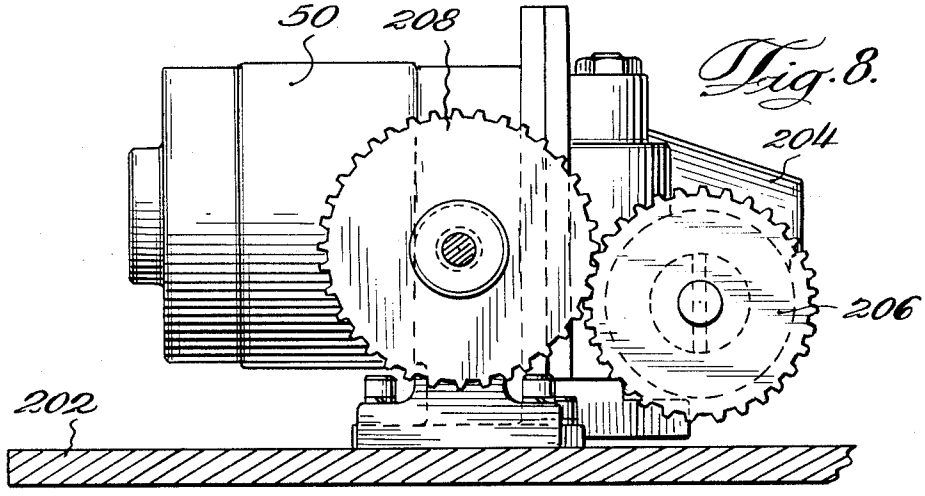


Fig. 8.

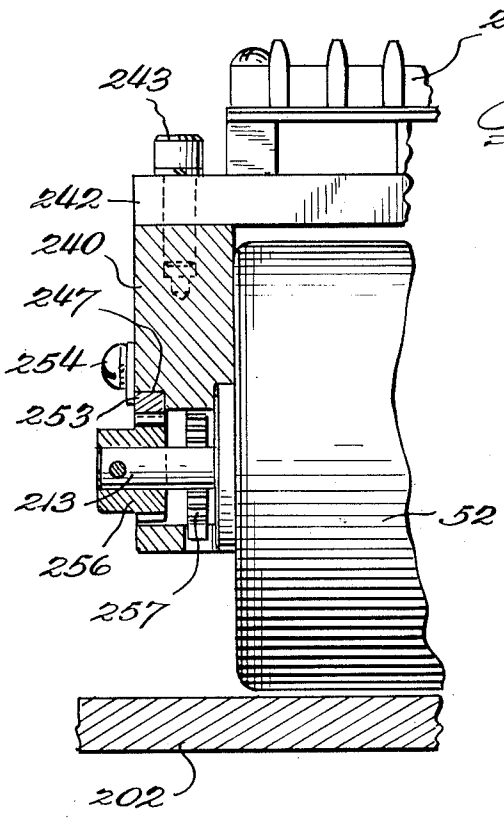


Fig. 9.

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PRINTING PRESS DRIVE CONTROL SYSTEM

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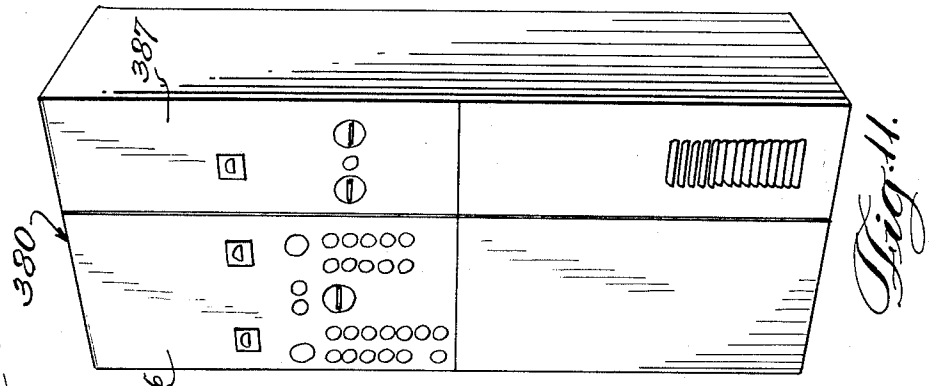


Fig. 11.

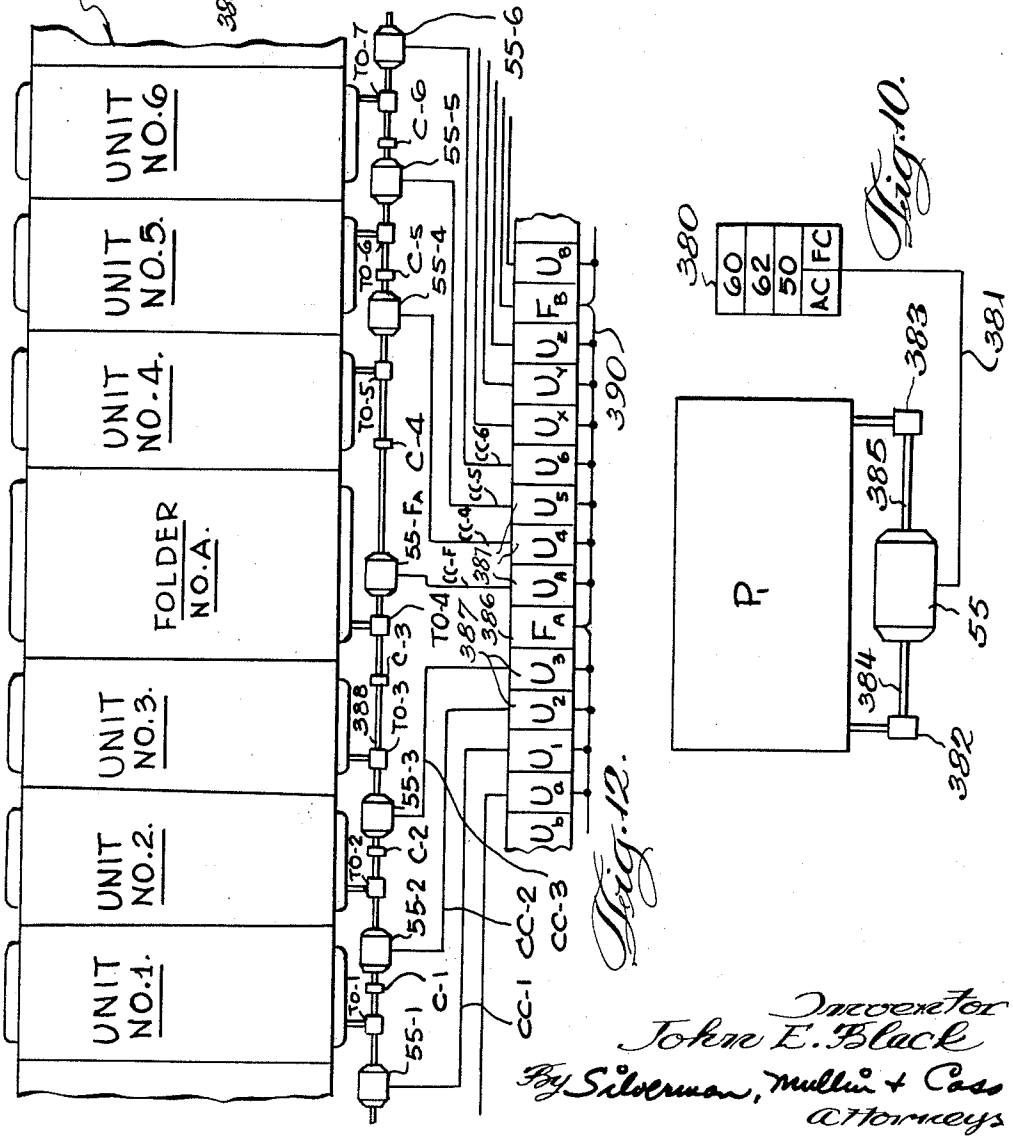


Fig. 12.

Fig. 10.

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United States Patent Office 3,132,295 Patented May 5, 1964

3,132,295

PRINTING PRESS DRIVE CONTROL SYSTEM

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Filed Sept. 14, 1959, Ser. No. 839,892
6 Claims. (Cl. 318—163)

This invention relates generally to printing press drives and more particularly is concerned with a system in which the source of rotary power comprises a D.C. motor and which has novel and improved control means therefor.

The type of presses with which the invention is concerned comprise large, high speed installations in which printing plates are applied to rotary cylinders or the matter to be printed is etched into the cylinders, and the cylinders are inked and rotated relative to elongate moving webs of paper to which the impressions carried by the printing cylinders are applied. Such presses produce newspapers, color supplements for newspapers, magazines and the like at web speeds which approach 2000 feet per minute, and usually include equipment which is required to trim and cut, fold and assemble the resulting products, all in perfect synchronism with the printed impressions. Obviously color presses are required to print upon the web with as many as four different impressions.

The requirements of the drive and control for such presses, exclusive of requirements of registration of impression and lateral positioning of the web are manifold. Such requirements have in the past rendered drives and controls complex, expensive, difficult to install and maintain, and subject to many other disadvantages. Not the least of these disadvantages were the almost universal use of switches, relays and controls depending upon the inter-engagement of electrical contacts, either by impact or wiping. The difficulties inherent in depending upon mechanical engagement of electrical contacts are well-known and these include sparking dangers, high costs of maintenance and repair, unreliability, expensive original cost, etc.

One of the important objects of the invention is the provision of a system whose nature is such that there is no need for mechanical engagement between electrical contact means, the control being accomplished with a minimum of moving parts and through the use of completely encapsulated static control elements of the type described in Ramey Patents 2,717,965, 2,770,737, 2,783,315 and the like.

In order to provide a basis for a full understanding of the invention, the requirements of press drives will preliminarily be discussed, prior to entering upon a detailed explanation of the preferred embodiment of the invention. In considering these requirements, it should be appreciated that the most important objects of the invention are concerned with meeting these requirements in a manner which is more efficient, simpler, more economical, and more effective than previously believed possible. These general objects are stated at this point of the discussion so that they may be kept in mind as an important purpose of the invention, there being other objects specifically directed to some of the details of the drive and the controls which will be stated hereunder.

One of the most important factors which must be also borne in mind is that in previous press drives the control has not been as complete as herein, this being most important to flexibility of the system and efficiency of its use. This increased degree of control extends over the entire range of speed of the drive and is what makes this system so desirable. Other press drives provide control, but not to the same degree, and hence provide many of the disadvantages which have caused difficulties with previous apparatus.

The requirements of press drives may be generally considered as comprising the following:

(*a*) The typical newspaper installation may have from one to several press units, each of which may have from two to ten heavy motors driving the various printing rolls or cylinders and folding equipment, all of the motors being coupled for rotation in unison. The movements of the press which will be described hereinafter must take into consideration overcoming inertia and friction, and the proper application of power for moving and stopping all of these motors and equipment operated by them in accordance with predetermined programs or commands controlled by the pressman.

(*b*) The tensioning of the web must be controlled at different operating conditions of the press.

(*c*) The registration and lateral adjustment equipment must be coordinated with the operation of the press so that the control means operated by the registration equipment does not interfere with the normal proper functioning of the press during certain conditions of operation thereof.

(*d*) The characteristics of the particular drive motors operating at various speeds must be built into the control equipment so that the requirements of power are met for the various conditions of movement of the press.

(*e*) The various safety factors which have become accepted as vital to press operation must be built into the control either for completely manual or completely automatic control.

(*f*) The control must provide for the following conditions which are concerned with efficient and practical operation of the press:

(1) Safe-ready
(2) Inch
(3) Slower
(4) Faster
(5) Stop
(6) Automatic Decelerate
(7) Automatic Accelerate
(8) Detecting

The "safe-ready" condition is one in which the speed of the press is fixed or clamped at a given rate by means of a manually operated switch. From this condition, the press speed can be decreased to zero but cannot be raised. From any speed to which the press has been decreased, under safe-ready condition, the press can only be decreased in speed or stopped. Once stopped, on safe-ready condition the press cannot be started until the condition is manually removed.

The safe-ready condition is required for safety of personnel who may be working on the press and wish to keep the same from running, or where a condition is discovered which is to be corrected while the press is running at a certain slow speed, it being desired that the speed be not increased by operation of any other control means.

The "inch" condition is one in which the press is run by manually closing a switch, but at a very slow rate, and only so long as the switch is closed. This is required for set-up work, for testing, for accurate positioning of parts of the press for maintenance and repair, and the like. The press can be operated to move the web therethrough in very small increments through this condition. This condition can be used also to permit the press to run for a time prior to high speed, to thread the same, to check impression and the like.

The "slower" condition is one in which the speed of the press is to be decreased from a high rate by manually operating a control element, such as a switch. In the system of the invention, deceleration occurs automatically at a predetermined rate which is built into the system.

The "faster" condition is one in which the speed of the press is to be increased from a lower value to maximum, through the manual operation of a control element, such as a switch. The acceleration occurs at a rate which is built into the system and in the apparatus of the invention, one which is different from the deceleration rate or slower condition.

In the cases of both conditions described above, the speed of the press may be chosen and fixed at any desired value by the operator merely by de-activating the particular control element when the speed has been reached at which it is desired to maintain operation of the press.

The "stop" condition is an emergency measure and is one in which it is desired to bring the press to a full stop in as short a time as possible, and without damaging any parts of the press or the control system.

The "automatic deceleration" condition is one in which, through the actuation of a suitable control element such as a manual switch, the press speed is decreased along a predetermined function of deceleration to a particular speed somewhat faster than inching, and the press remains at that speed, as determined by suitable limit switch means. In most presses when a new roll of paper is to be connected to the web, the press is slowed down, the reel carrying the new roll is rotated at a circumferential speed which is substantially the linear speed of the web as it is being stripped from the expiring roll, and at a suitable instant, the new end is pasted to the moving web which immediately commences stripping the paper from the new roll. The speed at which this is done is controlled by the said limit switch means.

The "automatic accelerate" condition is one in which by manual operation of a suitable control element such as a switch, the press will increase its speed to a maximum pre-set speed point automatically, along an acceleration function substantially identical with that referred to in connection with the "faster" condition described above. Maximum achieved speed here is controlled by a suitable limit switch which is adjustable to any predetermined value. The difference between this condition and the "faster" condition is that the acceleration caused by the "faster" condition occurs only so long as the control element is actuated, that is, so long as the operator holds the switch closed, for example. In "automatic acceleration" the actuation of the control element starts the cycle and the drive accelerates without any further function being performed. If the control element is a switch, the operator presses it once, releases it, and the acceleration automatically occurs until the pre-set maximum is reached.

The "detecting" conditions are provided through the medium of automatic controls which are for the purpose of establishing the "stop" condition above described if the web breaks or other similar contingency arises. For example, there may be a normally open switch riding the web which is closed if the web should discontinue through breakage or the like.

(g) Several other requirements of control and drive might be included in this discussion, such as for example, the basic need for turning the power on and off, operating the braking means for stopping the motors, switching various parts of the circuits into and out of the system, and the like.

A control system and drive must provide for all of these conditions, and the invention herein does so in novel and improved manners.

It has long been known that the best control of printing press drives is achieved through the use of drive motors operating on direct current. Since power companies have been supplying alternating current power only for the past several decades, alternating current drives have principally been used. The disadvantages of such drives are well-known, and include many basic difficulties which are not capable of being overcome without going to direct current motors. Alternating current motors operate at high efficiency only between about 90% and 100% of maximum speed, and hence it is necessary to have separate drive systems for low speed operation such as the "inching" condition described above. Alternating current motors do not have dynamic braking characteristics inherent in direct current motors, and hence separate braking systems are required. In alternating current motors, speed varies with load, and horsepower varies with speed, hence variations in press operation such as impression, inking and the like will affect speed regulation. Also, if the motor is overloaded, reduction of speed will further overload the motor, while in direct current motors the overloading of the motor is automatically obviated by the motor slowing down itself. Another bad feature of alternating current motors is that for all speeds below maximum, the unused energy must be dissipated in the form of heat, either through a secondary resistance bank, eddy-current clutch or similar device. There are switching problems, heating and ventilating problems and the like.

Some efforts have been made since the development of large water-cooled, mercury-arc rectifier tubes to build press drives which utilized direct current motors in press drives. These systems had disadvantages which have been overcome in the present system, as well. These disadvantages were concerned with the complex circuitry, the need for cooling systems for the tubes, need for large space in control rooms, high cost, etc.

The present invention teaches a system which, in addition to overcoming the disadvantages of the drives which use alternating current motors, also comprises a substantial improvement over the systems which were based upon the use of mercury-arc rectifiers to change the alternating current to direct current.

In the instant invention, the source of rotary power for the press comprise direct current motors, as previously stated. The speed of a D.C. motor can be controlled by varying the magnetic field which is to be cut by the conductors moving relative thereto, the ampere-turns of the conductors, or by varying both. As known, the magnetic field is varied by varying the voltage applied to the field winding, and the ampere-turns of the conductors is varied by varying the current applied to the armature. Hereinafter reference made to the field or armature of the D.C. motor will concern only the electrical nature thereof, it being immaterial which is the rotor and which is the stator.

The power requirements of the field and armature of a relatively large D.C. motor may be and usually are supplied by different sources, such as for example—a typical installation used 460 volts A.C. three phase power suitably rectified for the armature, and 240 volts A.C. suitably rectified for the field.

In the embodiment described herein, three phase power is applied through saturable core reactors, which operate into rectifying means connected to the armature. The saturable core reactors are controlled by D.C. signals applied to the windings of the reactors, and the signals are obtained in a novel manner as will be described.

The single phase power is also applied through a saturable core reactor whose control winding is energized by a variable signal obtained also in a novel manner as will be described, the output signal being rectified and applied as a voltage across the field winding.

One important object of the invention is the provision of a novel method for varying the speed of the drive motor between minimum and maximum values through the establishment of certain conditions of armature current and field potential and the provision of novel means for programming these conditions.

In connection with the means above referred to for programming the conditions for varying the speed of the drive motor, the invention contemplates the use of control means driven by a pilot motor. The use of a pilot motor per se in printing press drives and their controls is well-known, but heretofore such pilot motors have driven electrical contact means, such as plates having

contacts or terminals thereon moving relative to other contacts, terminals or wipers to establish, change or break an electrical circuit mechanically.

In the invention herein, and it is an important object to achieve such structure, the pilot motor changes the rotor-stator relationship of one or more rotary transformers the output of which may be modified by amplification or the like to form signals for controlling the saturable core reactors above mentioned. The degree of rotation of the pilot motor is converted to any desired other degree of relative rotor-stator rotation to provide for desired and predetermined programming, the provision of structure to enable this to be achieved being an additional object of the invention.

The pilot motor in addition, according to the invention, accomplishes other switching functions cooperatively related to the system and certain parts thereof, in order to enable the requirements outlined above to be met in an efficient and desirable manner.

The invention also contemplates the use of the static control devices referred to above as typified by the Ramey patented structures, which achieve conditions amounting to the making of logical decisions, which formerly were required to be made by unreliable relays or similar mechanically moving devices unsatisfactory and critical in operation. The inclusion of these static control devices in the system renders the system reliable, compact and foolproof, but it is also desired to point out that important features of the invention are of great advantage in systems which do not necessarily use static control devices, but which utilize conventional relays and the like in the control of the drives. This will be brought out hereinafter, and especially will be emphasized in the claims.

As the detailed description proceeds, many important other objects of the invention will become apparent to those skilled in this art. The invention is believed to be a complete and radical departure from all prior systems and methods of control, not only system-wise but also component-wise in that structures are used as components of the overall system which are novel and unobvious in and of themselves. Such components, as well as sub-combinations of the same with one another and with known structures and means, are considered to be included in the inventive concepts as delineated hereinafter and in the claims, and in certain instances, such inventions may be applicable in other fields which may be mentioned in passing. The basic purpose for the invention herein, however, and the application for which the same is specifically intended to give the maximum of advantages and benefits, is to control and energize the drives for printing presses, and hence, the description and illustrations concern only such applications.

So far as practicable, the drawings will illustrate the preferred embodiments of the invention and the parts thereof believed to be inventive collaterally, using known and conventional symbols, diagrams and schematic mechanical and electrical representations. Certain important structural features will be illustrated specifically in order to show a preferred manner of constructing the same. The diagrams representing functions are intended to cover typical conditions and substantially correct data, although it is to be understood that each installation will vary somewhat depending upon many factors which are known to artisans skilled in this field.

In the drawings:

FIG. 1 is a general block diagram of a press drive or system constructed in accordance with the invention.

FIG. 2 is a graph showing the acceleration and deceleration curves of the drive plotted against time and cam rotation.

FIG. 3 is a circuit diagram illustrating the armature and field control elements which are shown in block diagram in FIG. 1.

FIG. 4 is a chart showing the programming of auxiliary switches operated by rotation of the pilot motor.

FIG. 5 is a schematic diagram of the master control unit of the press drive showing the static control elements circuitry.

FIG. 6 is a side elevational view of the assembly of the pilot motor, rotary transformers and the drives for the various switches actuated thereby.

FIG. 7 is a front elevational view of the assemblage with the hand wheel removed.

FIG. 8 is a sectional view through the pilot motor drive taken along the line 8—8 of FIG. 6 and in the indicated direction.

FIG. 9 is an enlarged fragmentary sectional view of the left hand end of the pilot motor assemblage of FIG. 6.

FIG. 10 is a diagrammatic view of a basic printing press installation using a single drive motor and control.

FIG. 11 is a perspective view of a pair of cabinets mounting the supervisory controller of a folder and a unit controller for a single motor.

FIG. 12 is a diagrammatic view of a typical newspaper press having a unitized drive according to the invention, in which there is a single motor for each press unit and folder all driven in synchronism and controlled from an assemblage of controllers such as shown in FIG. 11.

Referring now to FIGS. 1, 2 and 3, the general arrangement of the press drive and control therefor will be explained. Perhaps the heart of the system comprises a pilot motor which is energized by two windings and which is shown schematically at 50 in the block diagram of FIG. 1. This pilot motor drives two rotary transformers, comprising the armature control transformer 52 and the field control transformer 54 to provide the necessary control for the press drive motor 55, the armature windings being designated 56 and the field winding or windings 57, 58 and 59. The rotation of the pilot motor 50 also operates certain switches on a program which is schematically shown in the graph FIG. 4. The series field winding is 58 and the commutating field winding is 59.

As previously mentioned, pilot motors per se have been used in other press drives and controls therefor. These prior pilot motors have been operated by push-buttons and other directly connected manual switching devices with extensive use of latching relays de-energized when the pilot motors achieved certain positions to accomplish certain functions. These pilot motors drove positioning plates operating in conjunction with contacts which were opened, closed, wiped, etc. in order properly to program the necessary operating relays. De-energization of the latching relays was usually accomplished through contacts provided in the plate driven by the pilot motor. Such latching as done was only where automatic switching was accomplished, since most of the functions desired were accomplished through the use of manual push-buttons operating relays and the like mechanically actuated switching gear.

So far as known, there has been no arrangement in which the pilot motor was driven through completely contactless circuitry for all phases of operation, and in turn drove rotary transformers which programmed the energization of the drive motor or motors in response to the predetermined programming built into the system.

The pilot motor 50 is caused to rotate by signals applied thereto by the static control elements system, which is generally designated 60. The system 60 is illustrated in some detail in FIG. 5 but for this general explanation, suffice it to say at this point that the signals which are produced by the system 60 are obtained by changing the 120 volts A.C. source energizing the system 60 to suitable pulses and currents. This is accomplished through the medium of various manual controls such as push button switches at one or more stations, such as for example a primary group of push buttons 62 on a supervisory control unit located at a folder, and a secondary group of push buttons 64 at a press unit. In addition, certain auto-

matic controls are arranged to affect the operation of the system, such as detector means **66** which may operate for example in connection with web-severing signal producing switches or other emergency signal producing devices.

Each of the rotary transformers **52** and **54** has a primary winding and a secondary winding, one of which is a stator and the other of which is the rotor. The primary windings are **78** and **80** respectively, and the secondary windings are **82** and **84** respectively. The rotors or both transformers **52** and **54** and several cams for operating certain limit switches are all driven by the pilot motor **50** in a manner which will be described in connection with FIGS. 5, 6, 7, 8 and 9.

The power for the drive system is obtained from a 460 volts, three phase, 60 cycle source **70**, and the various requirements of voltage are transformed from this source. The source has three lines **71**, **72** and **73** which are taken through three circuit breakers **74**, **75** and **76** to the lower voltage transformers, but are connected directly to the components of the system which use the full voltage. This is shown in FIG. 3.

One step-down transformer **88** has its primary winding **86** connected across the breakers **74** and **75** and provides 230 volts A.C. at its secondary **90** for energizing a saturable core reactor **92** in the control channel for the armature **56**. Another step-down transformer **94** has its primary winding **96** connected across the breakers **75** and **76** and provides 280 volts A.C. at its secondary **98** for energizing a saturable core reactor **100** which is in the control channel for the field **58**. Still another step-down transformer **102** is connected across breakers **74** and **76** to reduce the voltage to 120 volts A.C. for the magnetic amplifier **104** which is in the armature control channel, for the magnetic amplifier **106**, for the primary **78** of the armature control rotary transformer **52**, for the primary winding **80** of the field control rotary transformer **54** and for any other components not shown which require ordinary 120 volts A.C. The voltage input for the primary winding **78** of the rotary transformer **52** may be regulated in which case a constant potential transformer **103** whose primary winding **105** is connected across the secondary **101** of transformer **102**, and whose secondary **107** is in parallel with secondary **78**.

The main power line **70** is the source of power for the armature **56**, and its conductors **71**, **72** and **73** are connected directly through the circuit breakers **108**, **109** and **110** and line contactors **111**, **112** and **113** to the saturable core reactors **114**, **115** and **116** respectively which provide the necessary power.

Considering only the general block diagram of FIG. 1 the overall operation of the press drive system may be discussed, without regard to the nature of the control signals.

The basic control channel, that is, the path of signal transmission, for the operation of the armature **56** follows to the right of the rotary transformer **52**, and is symbolically indicated by the lines between the block elements, which are designated for convenience AC–1 to AC–8 inclusive, signifying "armature control channel." Likewise, the basic control channel for the operation of the field is shown symbolically by means of the lines FC–1 to FC–4 inclusive, signifying "field control channel." These lines do not necessarily represent conductors or leads but are merely diagrammatic to clarify the paths of command or variation signals. They represent signal transmission by any of different means.

Examination of the block diagram will indicate at once that the power supplied to the respective parts of the drive motor **55** is obtained in different manners. The armature **56** requires large amounts of power, and hence the control channel provides a signal which serves in effect for "valving" the power provided directly from the high voltage three phase line **70**. In the case of the field **57**, however, the power requirements are substantially less, and hence the power source is the 280 volts A.C. transformer **94** which is controlled. Note that the control channel for the field extends only up to the saturable core reactor **100**.

The speed control achieved in the drive motor **55** is obtained, as will be explained in connection with FIG. 2, by varying the excitation of the armature and field respectively. The rotational aspect of the windings of the transformers **52** and **54** provides this variation.

Considering first the armature control transformer **52**, its output is an A.C. signal which is transmitted by the path AC–1 to the rectifier **118**, which converts the signal into a direct current applied to the control windings of the magnetic amplifier **104** along the path AC–2. The power applied directly to the magnetic amplifier **104** is varied according to the signal in path AC–2 and the output from the magnetic amplifier **104** is applied through the path AC–3 to the rectifier **120** to the high power saturable core reactor **92** by way of the path AC–4. This reactor **92** provides the necessary power to control the large reactors **114**, **115** and **116**. Its output at AC–5 is applied through the rectifier **122** and the path AC–6 to the control windings of the reactors **114**, **115** and **116** in series. These large reactors produce an A.C. output which is rectified in rectifier **124** and applied to the armature **56** as a D.C. voltage.

Considering next the field control transformer **54**, its output is applied along path FC–1 to rectifier **124** so that the magnetic amplifier **106** received a D.C. control signal along path FC–2. The output of the magnetic amplifier **106** is A.C. and hence requires rectifying to be used as a control voltage for the saturable core reactor **100**. The signal from amplifier **106** is applied by way of path FC–3, rectifier **126** and path FC–4 to the saturable core reactor **100**. The output from the saturable core reactor **100** is rectified at the rectifier **126** directly to the shunt field **58**.

Each of the armature and field has a feed-back path to its respective magnetic amplifier. The armature **56** has the feed-back path FBA which is shown in FIG. 1, and the feed-back path for the field **57** is shown at FBF.

The above described system is readily understood, the armature control transformer **52** serving to vary the ampere-turns of the armature windings **56**, and the field control transformer **54** serving to vary the magnetic field produced by the field windings **57**, the combination of these two resulting in various speeds of the motor **55**. The rate at which the speed changes, either to speed up or slow down, can be altered by changing the combinations of these two control conditions and the ease with which this is done provides the great flexibility of the system.

Much of the detail of the actual structure is not shown in FIG. 1, but a considerable portion is illustrated in FIG. 3. The components which are not shown in FIG.1 include the dynamic braking means, series field windings **58** and **59**, regulation means for adjusting the system to load changes, etc.

The detailed explanation of the armature and field control circuit follows:

Starting with the signals which comprise the outputs of the rotary transformers **52** and **54**, in each case the output is a variable A.C. voltage the amplitude of which depends upon the relative dispositions of the rotors and stators with respect to one another. While the electrical circuits of the respective transformers are independent, the rotors are both rotated by means of mechanical couplings connected with the same shaft driven by the pilot motor **50** (not shown on FIG. 3) but the couplings provide desired dispositions in accordance with predetermined characteristics desired of the press drive motor. The rotors are not ganged in the ordinary sense understood, but are driven together, and hence the symbolic arrows representing variable coupling are connected by a broken line.

The secondary windings **82** and **84** respectively provide

outputs that are connected across full-wave bridge rectifiers 118 and 124 respectively. Full wave rectified current appears at the output terminals of each bridge, the amplitude again being dependent upon the respective transformer coupling. The signals which are produced in the respective channels are the speed signals and they are referred to as pattern signals since the speed curve of the press drive motor is expected to follow a predetermined pattern which is dependent upon the amounts of respective armature and field signals and their relations to one another. The amount of pattern signal is adjusted in each case by means of a variable resistor 131 and 132 respectively, and some of the ripple is removed by filter chokes 133 and 134 so that the input to the magnetic amplifiers is fairly smooth D.C.

The magnetic amplifier 104 has four windings, which are designated 136, 138, 140 and 142. The winding 136 is the main control winding which is energized by the output of the rectifier 118. Winding 138 is a feed-back winding which adjusts the output of the magnetic amplifier 104 for changes in load to good regulation characteristics. The winding 140 is the bias winding, by means of which the operating point of the characteristic of the magnetic amplifier is determined. The A.C. voltage from the secondary winding 101 is dropped through voltage divider 144 which includes a variable resistor by means of which any desired A.C. voltage may be applied across the rectifier 146 and the D.C. output connected in series with said bias winding 140 and a current-limiting resistor 148. The winding 142 is the output winding of the magnetic amplifier and, as seen, a pair of self-saturating rectifiers 150 is connected in this winding, with the A.C. voltage supply having one side thereof connected to a terminal 151 between the rectifiers 150.

These self-saturating rectifiers provide a conducting path for the flow of current in the forward direction through the output windings and block the supply voltage in the reverse direction. The particular circuit is a so-called full-wave bridge circuit, the output of which is an A.C. signal, but since the load in this case is a saturated core reactor 92 which requires a D.C. control signal, the magnetic amplifier is followed by the full-wave bridge rectifier 120. The second side of the A.C. supply is connected to the terminal 152 of the rectifier 120, the other terminal 153 being connected to the both ends of the output winding 142.

The D.C. output of the rectifier bridge 120 is applied to control winding 154 of the saturable core reactor 92 through variable resistor 156. The output of the rectifier 120 is also shunted by a variable resistor 157, and both of the resistors 156 and 157 have a plurality of taps with a wiper arrangement that can connect opposite taps of the respective resistors. These taps are chosen so that there is a particular tap for the number of motors which will be controlled by the system.

Nothing has been said concerning the use of more than one motor in the drive, but it will be understood that the minimum number of motors that will require to be controlled and operated by the same master control is two, comprising a folder and a unit. The usual requirements of a press drive for a normal installation may run from one to as many as ten units. Certain portions of apparatus are duplicated in each motor, and all of the motors are mechanically coupled together with clutches which can be de-coupled to use only the number desired. The portions of the apparatus to the right of the path AC–6 are repeated for every drive motor, and hence the signal from the rectifier 122 will be applied to as many motors as used. The addition of parallel loads results in more current being drawn from the control channel, for every condition of operation, and hence there must be some compensation for such variations. This is furnished by the resistors 156 and 157 and their rotative wiper engaging the various taps. A similar arrangement is provided in the field control channel, and the wipers of the two channels are ganged together.

The output winding 158 is connected across the rectifier bridge 122 and the D.C. output of that bridge is connected in series with the three control windings 159, 160 and 161 of the three saturable core reactors 114, 115 and 116 respectively. The resistor 162' is a high ohmage bleeder to decrease transients. The contacts illustrated provide the following functions: 162 are the run relay contacts (see 324, FIG. 5) and must be closed for the motor to operate; 163 are motor transfer switches whose purpose is to enable manual disconnecting of the motor from the circuit; the contacts 164 shunting each of the output windings 165, 166 and 167 comprise switches which close when the base speed has been reached (as will be explained below) so that there is no reactance and no power loss because of the inclusion of the output windings in the circuit to the armature 56. A thyrite protective resistor shunts the circuit. Note that the output of the rectifier bridge 122 may be applied to other motor control circuits, as indicated at 169.

The three phase power from the source 70 is applied and controlled through the saturable core reactors 114, 115 and 116 to high current-carrying capacity rectifiers to the armature 56 and the field windings 58 and 59 which are in series with the armature. The three-phase full-wave rectifier designated 124 is formed of 24 rectifier elements of the dry type, providing the D.C. output at the output terminals 170 and 171. The dynamic brake resistor 172 is connected across the armature and series field windings to enable the motor 55 to be changed into a generator when the contacts 174 are closed and produce bucking flux to stop itself. 175 is an ammeter shunted in the lead 171. Various fuses and the like are not numbered.

Note that there is a series of resistors which shunt the windings 56, 58 and 59. The entire arrangement comprises a regulating bridge in which 170 and 171 are one pair of terminals, and 176 and 177 are the other terminals. Resistors 178, 179 and 180 balance the resistance of the windings on the other side of the bridge. Terminals 176 and 177 connect through a variable resistor 182', switch 184' and the filter choke 135' to the winding 138. The values of the bridge are chosen so that when the load on the motor varies causing current change in the series and commutating fields 58 and 59, or the speed varies causing changes in the current flow of the armature, there will be an unbalance in the bridge and a signal applied to the feed-back winding 138 to compensate for the change in load. The bridge values are adjusted for a condition of normal load resulting in no output from the bridge. Thus, the regulation of the motor 55 is automatic for any setting irrespective of change of load and speed.

The field control channel is similar to the armature control channel except that less power is handled. The pattern winding of the magnetic amplifier 106 is designated 181, and the amount of signal to the said winding is controlled by the resisetor 132. There are two additional control windings 182 and 183, the bias winding 184 and the output winding 185. The manner of biasing the magnetic amplifier, applying the A.C. input and rectifying the output are substantially the same as in the case of the magnetic amplifier 104 and hence similar characters of reference are used for equivalent components, although primed. The method of adjusting the output for different loading because of the addition of motors is also the same, the double-ended wiper of the resistors 156' and 157' being ganged to that of the resistors 156 and 157.

The output of the rectifier 126 is applied to the input or control winding 154' of the saturable core reactor 100 which has a slightly greater capacity than the reactor 92 because the output of the saturable core reactor 100 is applied directly to the shunt winding 57 instead of being

used as a control signal. The output of the reactor 100 is rectified in the full wave rectifier bridge 128 whose output terminals 186 and 187 provide the D.C. source for the shunt field 57. A field loss relay 274 is connected across these terminals as are the leads 189 and 190 which have resistors 191 and 192 in series therein. This a feedback path to the magnetic amplifier 106 being connected in series with the control winding 183 and a filter choke 193. Motor transfer relays 194 are provided as well as connections 195 to other motors. A thyrite protective resistor shunts the field winding 57.

A novel arrangement provides constant braking irrespective of speed by field control of the shunt field. A variable resistor 196 shunts the dynamic braking resistor and a feedback channel is provided by way of the leads 197 and 198 through series resistors 199 and transfer switch 200 equivalent to switch 184 and ganged therewith, to the control winding 182. Variations in speed will result in signals to the control winding 182 providing more or less shunting field to give constant braking. When the counter E.M.F. due to braking in the armature windings 58 and 59 is high, there will be a control signal applied to winding 182 which reduces field flux to smoothen the braking effect. Lower counter E.M.F. has the opposite effect.

It will be recalled that the signals produced in the channels controlling the field and the armature cooperate to provide the pattern signals to produce the desired speed characteristics of the motor 55 for various conditions of operation. The acceleration and deceleration curves of FIG. 2 are not intended as limitations, but could be considered as typical for a given installation, varying from installation to installation depending upon the requirements, equipment, etc. These curves are plotted with coordinates that represent along the X-axis cam rotation in degrees, and two separate time axes, measured in seconds; along the Y-axis rotation of the drive motor 55 in r.p.m., which may be translated into newspapers per minute, feet per minute or the like.

By way of overall explanation, this diagram represents the speed that can be expected from the drive motor for any given rotational aspect of the cam shaft of the drive motor 50 during either acceleration or deceleration command signals. The control system 60 applies suitable signals to the motor 50 which moves to a particular position at a controlled speed. The detailed explanation of the curves of FIG. 2 will be more easily understood if one can picture in general terms what is happening mechanically in the apparatus shown in detail in FIGS. 6 to 9 inclusive. The detailed explanation will be undertaken later.

The motor 50 rotates a shaft 201 which has cams 203 and 205 affixed thereto so that rotational aspect of the shaft 201 represents as well rotational aspect of both cams 203 and 205. Each cam drives a follower 207 and 209 respectively which causes rotation of the shafts 211 and 213 of the rotary transformers 54 and 52 respectively. Thus, it can be deduced that the rotational aspects of the respective transformers 52 and 54 can be chosen independently and built into the apparatus through choice and design of the contours of cams 205 and 203, and the connecting linkages. A given position of the shaft 201 represents two conditions of coupling between the respective windings of the transformers 52 and 54 and hence also represents two conditions of energization of the armature 56 and field winding 57 of the motor 55.

Alluding once more to the explanation of the curves of FIG. 2, the base or X-axis scales are designated 214, 215 and 216. The scale 214 represents the rotation of the shaft 201 in degrees and it will be seen that it is desired and intended that the drive motor 55 will be able to vary its speed from a stand-still to maximum for a half revolution of the shaft 201. The speed in r.p.m. is scaled at 217 on the Y-axis, on the right hand side of the graph. The scale 215 is the time scale in seconds, when the motor speed is increasing from minimum to maximum; the scale 216 is the time scale in seconds when the motor speed is decreasing from maximum to minimum; the curves 218 and 219 represent the acceleration-deceleration curve and the stop curve respectively.

The speed of the particular motor whose characteristics are graphed varies from zero to 2000 r.p.m. and this latter speed is reached when the shaft 201 has rotated 180° during acceleration or manual increase of speed. The degree of rotation could of course be any amount chosen and designed into the apparatus. The time elapsed during this rotation is 60 seconds. Deceleration occurs along the same line 218 but in a matter of 40 seconds, since it is usually easier to decelerate than accelerate, and more desirable to do so faster. The stopping of the motor quickly, as for an emergency occurs along the line 219 with reference to the scale 216 and hence in a time of ten seconds.

The speed characteristics could be graphed against the rotational positions of the rotary transformers, but timewise this would be complex and the interpretation would be confusing because of the variations throughout rotation of the shaft 201 by the pilot motor 50.

The curves shown are typical as stated, and must be computed for each installation. They will not necessarily be straight lines, but could curve in various manners, depending upon the motors, the loads, etc. Also the motor circuits may vary from installation to installation. In this instance, as seen from an examination of FIG. 3, the motors are connected series-shunt, in a manner known as stabilized shunt wound.

The motor 55 of the installation chosen as typical has a base speed which is marked along the line 218 as the point 220, representing a speed of 1150 r.p.m. This base speed is the condition which exists when the field and armature are at maximum excitation, represented by maximum signal output from the secondaries of both of the rotary transformers 52 and 54 with maximum pattern signals in the armature and field control channels. The cam shaft 201 of the pilot motor 50 at this point has rotated through about 105° from its zero position. Speed is increased from the base speed 220 by decreasing the excitation of the field 57 so that at the maximum speed of 2000 r.p.m., field excitation is at a minimum and armature excitation is at a maximum. From the base speed to the maximum speed, that is, in moving along the line 218 from the point 220 to the point 221 the armature excitation remained at maximum while the field excitation was decreased. During this period of increase of speed the cam shaft 201 rotates through 75° and the rotary transformer 54 will have its coupling changed, but the coupling of transformer 52 will remain constant. In terms of mechanical linkages, the follower 209 would be on a dwell portion of the cam 205 of substantially constant radius.

The other range of speed of the motor 55 is also controlled by the variation of the coupling of the transformers 52 and 54. This may be discussed as though the motor were starting from zero. Neglecting for the moment the small plateau 222 which represents inching speed, the initial energization of the motor 55 from a start occurs by applying full field excitation with minimum armature current. Thereafter, to increase the speed, the armature current is increased along the line 218 from the plateau to the point 220 which is, of course, the base speed. The field remains fully excited during this portion of the characteristic, and hence its rotary transformer 54 will maintain constant coupling, while the coupling of the transformer 52 varies.

It should be understood from the above, that the contours of the cams 203 and 205 are worked out on the basis of the characteristics of the motor which is being controlled, for applying the proper pattern signals to the respective control channels. Compound wound motors which have more than two different zones of control for

the characteristics of excitation versus speed can as readily be controlled by suitable choice of cam contours through the rotation of only a single shaft of the pilot motor.

The deceleration of the motor along the line **218** is identical to acceleration except that it occurs at a greater speed. This function is also known as "reset." The change of speed of the cam shaft **210** which is required for this can be accomplished by de-clutching the pilot motor **50** and coupling another motor of different speed to the cam shaft **201**; or could be accomplished through the shifting of gears of a gear train; but preferably is achieved through the use of a separate winding built into the pilot motor and used for driving the same at a different speed in the reverse direction.

The curve **219** is the emergency stop characteristic related to the scale **216**. It has no relation whatsoever to the scale **214** because it functions independently of the rotary transformers. When suitable apparatus is actuated for an emergency stop, the excitation of the armature is removed and the dynamic brake is permitted to slow the motor down to a full stop. Various considerations of the apparatus control the rate of stop, including, the efficacy of the brake, the inertia and friction of the apparatus, etc.

The inching speed **222** represents a condition of excitation which is permitted to remain over a few degrees of rotation of the cam shaft **201**, such as for example 10°, for the purposes explained above.

The pilot motor **50** performs other functions besides the programming of the excitation of the main drive motor or motors of the press. The fact that each position of rotation of the cam shaft represents a condition of excitation giving rise to a particular speed of the motor **55** (as well as any other motors being controlled by the master control), or a particular time in the cycle of control, enables the rotation of the shaft **201** to be used to open and close certain control switches in synchronism with the control cycles. For example, nine cams are shown mounted on the shaft generally at **235**, and rotating therewith. Each cam operates a switch, there being nine switches as indicated at **224** to **232**, each having a follower as indicated at **236**. The various switches operate various circuits which are explained in the chart of FIG. 4 over the range of rotations of the cams indicated. The solid bars represent switches closed, the open spaces represent switches opened, and the dotted lines represent ranges over which the switches can be adjusted to open. For normally closed switches the opposite is true. Thus, for example, the tension regulating device is operated from the position of 12° of rotation of the shaft **210** throughout the entire rotation thereof; the normally closed faster limit switch is opened only at the end of rotation of the shaft; the normally closed slower limit switch is opened during the first few degrees of rotation; the web severers can be adjusted to close at any time from about 106° of rotation to about 135° of rotation; etc.

The various functions controlled by the switches **224** to **232** driven by cams **235** are generally as follows:

The detector switches are energized after the press is moving at a good speed, say with the web travelling at a speed of about 100 feet per minute so that if the web tears or breaks, the detector circuits will automatically stop the press. Breaks occurring at lower speeds are not as serious since they usually occur during testing or the like.

The web severers operate in conjunction with the folder for cutting the web during the assembly thereof into the final product and the equipment need not be operated until a higher speed is reached, the exact speed being adjustable.

Automatic web tensioning regulating equipment is placed into operation after the press gets moving and is operative during the entire range of speeds.

The faster limit switch determines the maximum speed at which the drive motor is permitted to operate and hence will not open until the upper speed limit is reached.

The slower limit switch speed controls the rest position of the pilot motor **50**.

The automatic acceleration limit switch stops the pilot motor rotation when the press has reached a predetermined speed. This may or may not be the same as the faster limit speed.

The automatic deceleration limit switch is adjustable, and it enables the press to be decelerated automatically only if the press speed has exceeded a certain predetermined value.

The register control go-down relates the operation of the registration control equipment with respect to press speed. Obviously the registration control equipment should not be set into operation until the press is ready to be driven at a fairly fast speed, after all preliminary adjustments have been made.

The shunting contactor switch is normally open and is closed after base speed has been reached. The contactors involved are **164** in FIG. 3. They cut out the saturable core reactors **114**, **115** and **116**, permitting the power to be applied to the rectifier **124** without passing through the reactor windings. Since the speed characteristic from point **220** to point **221** calls for maximum armature excitation, there is no need for control during this period, and in fact coupling of the transformer **52** is of little or no consequences during this range of speed. This arrangement eliminates hunting, uses less power, reduces losses in the reactors, and of course keeps the heat of the apparatus down.

The shunting contactors **164** need not be used, in which case the excitation control signal from armature control channel will be such as to permit the reactors **114**, **115** and **116** to pass maximum current.

Other switches and cams giving rise to additional switching operations can be provided.

Attention is now invited to the details of the assemblage shown in FIGS. 6 to 9 inclusive. These illustrate the pilot motor **50** and the rotary transformers **52** and **54** with their associated mechanical connections.

The pilot assemblage which comprises the pilot motor **50** and all of the structure coupling the same with the rotary transformers **52** and **54**, as well as the switches **235** and the like are mounted on a suitable base, such as illustrated at **202**. This base may be a part of the cabinets or panels housing the control gear or may be secured thereto. As previously mentioned, it is preferred that the pilot motor **50** have two independent windings operating the same in its forward or reverse direction, and obviously these cannot be illustrated in the drawings except by showing two symbolic inputs to the pilot motor in FIG. 1. Any suitable reduction gearing can be used, which may include a suitable gear box furnished with the motor by the manufacturer in the same housing as shown at **204** driving a pinion **206** which in turn drives a larger gear **208** secured to the shaft **201**. Actually the shaft **201** is journalled at **210** and **212** in suitable supports secured to the base **202**, and makes its connection with the drive gear through a clutch **233** so that shaft **201** is rotated through suitable control circuitry associated with the system **60**.

The side elevational view of the assemblage in FIG. 6 best illustrates the arrangement of the elements. The top of the assemblage is provided with several terminal strips such as **234** and **237**, but the wire leads are not shown for purposes of clarity. The terminal strips **234** may be mounted at the left hand end of the assemblage and be used in connection with the rotary transformers, and the strips **237** may be used in connection with the switches **235** and perhaps other electrical connections.

The rotary transformers **52** and **54** are also secured to the base **202** and each has a rectangular plate **238** and **240** secured respectively to the outwardly facing end thereof. The strips **234** and **237** as well as the switches

235 may be secured to elongate support brackets or structural elements 241 and 242 held in place on the plates 238 and 240 by suitable machine screws such as at 243 and on the support means 244 by screws 245. Each plate 238 and 240 is horizontally slotted, with the slot 246 provided in plate 238 and the slot 247 provided in plate 240. The follower 207 is actually a small roller mounted on the end of a rack 248 which is slidably mounted on the slot 246 and prevented from dropping out by a retaining cover plate 250 held on the plate 238 by suitable fasteners 251. The follower 209 is a similar roller mounted on the end of a rack 252 confined by the cover plate 253 held in place by screws 254. In each case the rack teeth are directed downward, and in each case the teeth mesh with a pinion gear mounted on shafts of the respective rotary transformers. The rack 248 meshes with pinion 255 mounted on shaft 211. The rack 252 meshes with pinion gear 256 which is secured to the shaft 213. In both cases, the shafts have spiral springs urging the shafts to rotate in directions which tend to force the pinions to push the racks in directions urging the followers against their respective cams. Thus, in FIG. 9, the spiral spring 256 is shown making a mechanical connection between the plate 240 and the shaft 213 to urge the shaft 213 in a counter clockwise direction as viewed in FIG. 7, which in turn urges the rack 252 to the left and the follower 209 against the cam 205.

Obviously the racks 248 and 252 and their respective pinion gears 255 and 256 are in different planes to align with the respective cams 203 and 205.

Any other suitable means can be used to bias the followers against their cams and still permit the rotary transformers to be rotated. As a symbolic example, in FIG. 7, on the left hand side there is a bracket 258 secured to plate 238 and confining a helical compression spring 259 which urges the rack 248 to the right.

The exact construction of the pilot motor-cam-rotary transformer assemblage is capable of wide variation. Primarily it forms means driven and controlled by the static control elements system to position both of the rotors of the rotary transformers at locations relative their respective stators such that the control channels will respectively receive pattern signal information directing the desired excitation of the armature and field of the drive motor 55 and any additional motors connected therewith.

A detailed explanation of the static control elements system follows: In the description, it should be appreciated that the elements which are discussed are for the most part static control elements or components, made up of small circuits which perform all of the cybernetic functions heretofore performed by means of relays and similar moving part components.

For this purpose, attention is invited to FIG. 5. Here the static control elements are laid out in a circuit which could be typical of a press drive control embodying the invention herein, providing all of the elements of control described above, and used in connection with the structure thus far described.

The static control elements which are preferred are those utilizing the circuits of Ramey Patents 2,717,965, 2,770,737 and 2,783,315 which have no moving parts and which are based upon circuits which use semi-conductor diodes and magnetic structures having substantially square hysteresis loop flux characteristics enabling them to occupy two completely different states of magnetization depending upon the direction in which polarized. The details of these circuits are known, and in recent years commercial versions have appeared on the market, including structures manufactured and sold by Westinghouse Electric Corporation of Pittsburgh, Pennsylavina, under the trademark "Cypak."

In order to describe the circuit of FIG. 5, the cybernetic symbols which have become conventional should be explained. The symbol for an "AND" function is most often a rectangle having one or more inputs, usually two, and a single output. There will be an output only if there is a signal applied to all inputs. The symbol for an "OR" function is a circle with a pair of inputs and a single output. A signal applied to either input will result in an output signal. The basic symbol for a "NOT" function is a rectangle with a small circle at its front end. There will be an output signal only if there is no input signal, and if there is an input signal there will be no output signal. The symbol for a "MEMORY" function is a pair of rectangles with two inputs on the left and one output. The small circles also are present on the input sides. The "MEMORY" elements provide an output when there is an input, instantaneous or otherwise, and discontinue the output when there is a second input. The symbol for a "TIME DELAY" is a semi-circle, and there will be an output a certain time after an input signal has been applied.

In the circuit, the symbols are designated in accordance with their functions. The "AND" symbols are designated A–1, A–2, etc.; the "OR" symbols are designated O–1, O–2, etc.; the "NOT" symbols are designated N–1, N–2, etc.; the "MEMORY" symbols are designated M–1, M–2, etc.; the "TIME DELAY" symbols are D–1 and D–2. There are amplifiers illustrated symbolically as triangles and designated AM–1, AM–2, etc.

The static control elements are supplied with various voltages from the sources, such as through a transformer 260 the primary 261 of which is connected across the line, and the secondary 262 of which is connected to the static control element power supply 264 which provides the voltages needed such as 8, 15 and 23 volts direct current with a common return. The static control elements use polarized signals, related to the phase of the line voltage, notwithstanding that the power supply to the elements is D.C. This is provided by reason of the relationship of the pulsing D.C. to the phase of line voltage. Accordingly, the power supply will provide these voltages of different polarities, and the polarities will be displaced by 180°. Note therefore, that the inputs and outputs of the static control elements of FIG. 5 are also polarized, the polarization being symbolized either by a ϕ or a θ. A signal cannot be received of opposite polarity, and this may be the basis for transfer of control to a second station, as described in my co-pending application Serial No. 729,200, filed April 17, 1958, and entitled "Static Control Switching Apparatus."

The phase sensitive characteristic of the static control elements is also useful as a gating means in logic circuits. For example, single input AND elements can be used to reject other than certain phase signals from multiple signal outputs. AND elements have opposite input and output phases as will be seen in the diagram. There are several triangles which are designated AN–1, AN–2, etc. These are actually combination elements made of AND and amplifier elements to give an increased amplitude signal output. They are equivalent, in the logic sense, to AND elements. The phase symbol illustrated on each of these is its input phase. Its output phase is the reverse.

The secondary winding 262 is also connected across the two bus conductors 265 and 266. A plurality of input transformer-rectifier combinations designated X–1 to X–12 are adapted to be connected across the bus conductors through switches or contact making devices which presently will be described. Various emergency and test apparatus interrupting the connections is not shown. The transformer-rectifier combination X–1 is in series with faster limit switch 224, whose cycle of operation is described in connection with the chart of FIG. 4. This is one of the cam-operated switches mounted on the pilot motor assemblage adapted to be opened and closed through movement of the shaft 201. The output from the closing of the switch 224 appears at the conductor 265'. The switch 225 is the slower limit switch, also cam-operated as switch 224. It is normally closed on the

contact 266' and is open only for the short period before the press is started up, at which time the contact 267 is engaged to ignite the lamj 268 to show that the slower limit switch is open. Output appears at the conductor 270.

The switch 226 is the automatic acceleration limit switch which is cam-operated and the function of which has been explained. Its output appears at conductor 272. Switch 227 is another cam-operated switch controlling the automatic deceleration limit, and its function has also been explained in connection with FIG. 4. The output of this switch appears at conductor 271. There are a series of switches and relays which are shown at 273, 274, 275, 276 and 277, and these are respectively the fail safe relay, the field loss relay, the feedback control relay, a test switch, and an emergency switch. The closing of any of these will provide a signal through the transformer-rectifier combination X–5 at the conductor 278, the purpose of which it is to stop the press.

The other controls operating into the circuit are not automatically operated but comprise the manual buttons located on the push button station 62, normally the master control panel. Note that each switch is shunted by a conductor leading to another station for parallel or alternate control, depending upon circumstances which we need not discuss. This is shown at 280.

Switch 281 is the SAFE-READY switch which provides an output at the conductor 282. The switch 283 is the INCHING switch which provides an output through the transformer-rectifier combination at the conductor 284. The switch 285 is the SLOWER switch operating through the transformer combination X–8 to place a signal at the conductor 286. The switch 287 is the FASTER switch which provides an output signal through the transformer-rectifier combination X–9 at the conductor 288. The switch 289 is the STOP switch which provides an output signal at 290 through the transformer-rectifier combination X–10. Switch 291 is the AUTOMATIC DECELERATION switch and its output is at 292. Switch 293 is the AUTOMATIC ACCELERATION switch and its output signal appears at 294.

The operation of the various parts of the circuit will now be explained.

The SAFE-READY switch 281 has two buttons, one of which is referred to as "SAFE" and the other as "READY." Both operate on the same switch—the one to close the switch which will automatically latch itself in this position and the other to open it, that is, release the latch. When the SAFE button is depressed, the primary winding of the transformer-rectifier combination X–6 is energized by 115 volts A.C. and the output of the combination is a full wave rectified signal which appears at the conductor 282. This lead 282 is connected through the conductor 296 to the amplifier AM–10 to a relay 297 which closes a contact to green lights at suitable locations (not shown) on the press to inform the operators that the SAFE button has been depressed providing the safe condition represented thereby. The amplifier AM–10, as well as the other amplifiers AM–4 to AM–11 inclusive, all obtain their power from a full wave rectifier 298 supplying direct current over the buses 299 and 300 and energizing the relays which will be described, the relays being connected between the amplifier outputs respectively, and the bus 300. Rectifier 298 is powered through transformer 269.

The signal from the depressing of the SAFE button is also applied to three other static control elements, namely—the OR element O–3, the OR element O–7 and the NOT element N–3.

The OR element O–7 has the signal applied thereto through the conductor 301 and applies an output to the lead 302. Conductor 302 in turn applies a signal to another OR element O–2. It will be recalled that the conductor 272 was provided with an output signal from the switch 226, the AUTOMATIC ACCELERATION LIMIT switch, and hence there will be an output from the OR element O–2 if either the switch 226 is closed or the SAFE button is depressed. This output appears at the conductor 303 and applies the signal to still another OR element O–8, providing an output at the conductor 304. Since the original signal was a full wave rectified D.C., the signal at 304 is still full-wave, and the signal applied to the lower section of the MEMORY element M–2 will be accepted by the ϕ input of that section. This will hold the MEMORY element M–2 in an "off" state, and prevent an output from appearing at the conductor 305. This output would comprise a θ signal. (Hereinafter the upper and lower sections of the memory units will be designated by the suffix U or L following their character references, such as for example, M–2–U is the upper section of MEMORY element M–2, M–2–L is the lower section of MEMORY element M–2, etc. These designations are only to be used in considering the circuit, and have no significance physically upon the actual structures.)

The signal on conductor 305 is adapted to be applied through the OR element O–11 to the conductor 306 to the middle θ input of the AND element A–8. The ϕ output of the AND element A–8 is connected by the conductor 307 through the amplifier AM–4 to the relay 308. This relay 308 is the faster pilot relay, and when it is energized, it connects the forward driving winding of the pilot motor 50 to a source of power such as to rotate the shaft 201 in a direction to increase the speed of the drive motor 55. Obviously, when the SAFE button 281 is depressed and held down by the mechanical latch thereof, there can be no θ signal output from the MEMORY element M–2 and the relay 308 cannot be energized.

In addition to the above removal of an input to the center θ input of the three channel AND element A–8, there is an additional safety factor to prevent the energizing of the relay 308. As noted above, the signal on depressing the SAFE button 281 is also applied through conductors 282, 301 to the NOT element N–3 by way of the conductor 309. This signal being full-wave, it is accepted by the θ input of the NOT element N–3 and removes the ϕ output signal from the conductor 310. Referring to the OR element O–11, it will be seen that the lower input was also capable of producing a signal at the conductor 306. This signal to O–11 is obtained as the output of the three channel AND element A–3 on the conductor 311. Since the three inputs to the AND element A–3 include as the top input a connection 312 with the conductor 310, if there is no signal output from the NOT element N–3, there will be no θ signal at 311 and again no output at 305 so that relay 308 cannot be energized.

In passing it will be noted that all transformer-rectifiers produce full wave outputs having both ϕ and θ pulses.

The third application of the signal output from the transformer-rectifier combination X–6 through depression of the SAFE button 281 is to the OR element O–3. From the element O–3, the signal is applied by way of the conductor 313 to the OR element O–1. The other signal which is applied to the OR element O–1 is by way of lead 270 to the upper input from the transformer-rectifier combination X–2 which occurs when the slower limit switch is closed to its bottom contact 266. The OR element O–1 output is applied to the input of the NOT element N–1 which removes the θ output signal from the conductor 315. This conductor 315 applies one of the inputs to the two channel AND element A–2 which supplies a signal to the upper input of MEMORY element M–4 by way of the conductor 316. The upper section M–4–U has a ϕ input which can be provided by the output of A–2, and it in turn can provide a ϕ output at 317 which passes through the single channel AND element A–4, which serves as a phase gate to the conductor 318. This conductor is adapted to apply a signal to amplifier AM–7 which

energizes the relay 319, the line contactor relay by means of which the press drive is energized. With the output signal at 315 gone, there is no output signal at 316, and there must be a signal at the ϕ input of M–4–U to turn on the MEMORY element M–4. If the MEMORY element had been in its "on" state, the removal of the signal to its upper input would not have changed it to "off." Without a signal output from the MEMORY element M–4, the line contactor relay 319 cannot be energized. This results again from depressing and holding the SAFE button. The significance of the system is that if the motor 55 were not already running, the depressing of the SAFE button 281 would thereafter prevent it from being started because the line contactors could not be closed.

Another function is performed by the depression of the SAFE button 281. The output of the AND element A–2 which was removed when the SAFE button was pressed is also applied to a conductor 320 that comprises one of the inputs to a two channel AND element A–7. This AND element applies a θ output by the conductor 321 to one of the inputs of the OR element O–14, the output of which is at 322 and is applied to amplifier AN–3, conductor 323 and amplifier AM–8 to energize relays 324 and 325. These are the run relay and the run light relay, the latter providing a signal to show that the run relay has been energized. The run relay is connected to energize the pilot motor to provide inching speed, and hence, with the SAFE button depressed, there can be no output at 321 and no inching of the press. The INCH switch 283 provides an output from the transformer-rectifier combination X–7 at the conductor 284 which goes directly to the lower input of the AND element A–7.

Attention may be given at this time to the FASTER button 287, the depressing of which will apply a signal through the transformer-rectifier combination X–9 to the conductor 288, which in turn places the signal at the upper input of the OR element O–5 through conductor 326 and to the central ϕ input of the AND element A–3 by way of the conductor 327. It is desired that the depressing of the FASTER button does not start the press or increase its speed if already running when the SAFE button 281 is depressed. Since the upper input of the AND element A–3 is already removed, adding a signal in the center channel will have no effect on the faster pilot relay 308. The depression of the FASTER button 287 also provides a signal in a manner which will be described hereinafter, by way of the conductor 326 through OR element O–5, conductor 327, OR element O–6, conductor 328, MEMORY element M–5, conductor 329, gating AND element A–5, conductor 330, time delay element D–1, conductor 331, MEMORY element M–8, and conductor 332 to the lower input of the AND element A–2. As explained, when the SAFE button 281 is depressed, there is no input to the upper channel of the AND element A–2, and hence the signal received from MEMORY element M–8 is without effect.

It becomes apparent from the above description, that the use of the SAFE button is quite versatile since it renders the press completely safe to work on by preventing its starting if it has not been started and by locking the speed of the press to the speed it has if the press is running when the button is depressed. The logic functions are all performed by means of the static control elements described, the final connections being achieved through simple relays energized in response to the logic commands of the system.

The other command button affecting speed of the press is the AUTOMATIC ACCELERATION button 293, and this button cannot change the speed of the press when the SAFE button has once been depressed. The closing of the switch 293 applies a signal to the conductor 294 through the transformer-rectifier combination X-12 which in turn applies the signal through conductor 333 to the bottom input of the OR element O–6. We have already seen that the FASTER button 287 was unsuccessful in increasing the speed of the press by means of a signal applied to the OR element O–6, and hence the ANTOMATIC ACCELERATION signal cannot do so either. The signal of conductor 294 is also applied by way of the conductor 334 to the upper input of the AND element A–1 which, even were there a ϕ input on lead 335 such as to combine with input of lead 334 to provide a θ output at conductor 336, would be of no avail so long as there is a signal at M–2–L. It is noted that the presence of both inputs on a MEMORY element will provide no output. Thus, with the SAFE button 281 depressed, it is impossible for the faster pilot relay 308 to be energized.

The functions performed by the SLOWER button 285, AUTOMATIC DECELERATION button 291 and the STOP button 289 can be carried out notwithstanding the depression of the STOP button. This, of course, is consistent with the concept of rendering the press safe to operate and work on, since each of these buttons tends to bring the press to a stop.

The SAFE-READY button has a mechanical latching arrangement which keeps the button in SAFE position, once depressed. The latch can be released by the operator, such as by pressing a button or lever (not shown) which is usually marked READY. This removes all of the signals at conductors 282, 296, 301, and 309, and along therewith removes all of the conditions provided by the SAFE button, described above. The removal of the signal from the input to the NOT element N–3 restores signal at 310 which now appears at conductor 337 and is applied through OR element O–15, conductor 338 and amplifier AM–9 to energize relay 339 which lights red warning lights to inform the operators that the press is in readiness to operate. Removal of the signal from the conductor 296 extinguishes the green safe lights 297.

The line contactor relay 319 may originally be operated, as will be seen, by either the INCH, FASTER or AUTOMATIC ACCELERATION push buttons 283, 287 or 293 respectively. The energization of this relay (or relays) will light suitable indicating lights on the master control panel, at the station where 62 is located and elsewhere if desired, and also provides 220 volts A.C. to the line contactors 111–113. The INCH button will not de-energize the line contactors when used to start or stop the motor, but the STOP button 289 will do so.

When the pilot motor is in reset, that is its initial position, the switch 225 is open (see chart of FIG. 4, SLOWER LIMIT). There is at this time no signal at conductor 270, and if the SAFE button 281 has not been depressed, there is no signal on conductor 313. With no output from OR element O–1 on conductor 314, there will be an output from the NOT element N–1 at the conductor 315, and this is applied to the upper channel of the AND element A–2. The lower channel of the AND element A–2 has an input from the conductor 332 and hence the two inputs to A–2 will provide an output at 316, when a signal is provided on conductor 332 from the signal and delay circuit designated generally 340. If this delay and signal circuit is not in the system, the signal comes from the OR element O–6 directly.

The signal at the lower channel of AND element A–2 is produced whenever any one of the buttons 283, 287 or 293 is depressed. The latter of these, the AUTOMATIC ACCELERATION button provides a signal at 333 to the OR element O–6 which passes through the signal and delay system 340 to the AND element A–2. The INCH button 283 provides signal on conductor 341 to the OR element O–5 which in turn provides signal at 327 to OR element O–6. The FASTER button 287 also applies its signal by way of the conductor 326 to O–5.

The AND element A–2 has an output at 316 when both channels have inputs and this is applied to M–4–U, being a ϕ signal. This signal will turn MEMORY unit M–4 to "on" condition, providing a ϕ output state in conductor

317. This passes through the ϕ gate A–4 which passes through the amplifier AM–7 to energize the line contactor relay 319.

From the above it will be seen that any push button which calls for press movement can close the line contactor relay 319, but this is true only when the pilot motor 50 is in reset condition. It will be recalled that if the pilot motor and its shaft 201 are not in reset position, the switch 225 will be closed, there will be a signal at 270, a signal at 314, and the NOT element N–1 will remove the signal from the conductor 315 and there will be no output from the AND element A–2.

The functions of the INCH button 283 and the FASTER button 287 will now be discussed. As understood from above, either of these can energize the line contactor relay 319 from reset position of the pilot assemblage. In addition, the INCH button 283 provides a signal at conductor 284 which is an input to the AND element A–7. Since there is a signal at 320 when the pilot assemblage is in reset condition, there will be an output from the AND element A–7 at 321. This will energize the run relay 324 through the OR element O–14, the conductor 322, the AND element AN–3, conductor 323, and the amplifier AM–8. When the line contactors are closed and the run relay 324 is closed, sufficient power will be supplied to the armature 56 to start the motor 55. Release of the INCH button 283 will stop the motor. The movement of the pilot motor 50 is such as to bring the operating point of the drive motor 55 onto the small plateau 222 (see FIG. 4) to a slow speed, the character of which can be built into the system in a manner which is believed understandable from the description thus far.

When the INCH button 283 is released, the signal on the conductor 284 is removed and hence the relay 324 is de-energized. This will not affect the line contact relay 319, since this relay is energized and continued to be energized by the output of the MEMORY element M–4. 344 is an optional inching brake relay.

If the INCH button 283 had not been pressed from reset position of the pilot assemblage, the line contactor relay 319 would not have been energized, but the pressing of the FASTER button 287 would have do so, as previously explained. Furthermore, the line contactor relay would remain energized thereafter, just as in the case of the pressing of the INCH button first.

Pressing the FASTER button 287 applies a signal to the center input of the AND element A–3 by way of conductors 288 and 327. Since the upper input has a signal because the READY button is pressed, and the lower input has a signal through the signal and delay system 340 from the AND element A–2, permitted because of the signal from NOT element N–1 due to the SLOWER LIMIT switch being open, there will be an output at conductor 311 which will place a signal to the center input of the three channel AND element A–8. This signal is also applied by way of the conductor 342 to the MEMORY element M–7–U which places this memory element in "on" state, providing a θ output at conductor 343 which passes through the OR element O–14 in a manner previously described to energize the run relay 324 and its warning light relay 325. Another relay, namely the run tensioning relay 344 may simultaneously be energized through the conductor 345, one input AND element AN–4, conductor 346 and amplifier AM–3. This circuit is in broken lines to show that it is optional at this point.

The momentary closure of the FASTER button 287, it will be recalled, energized the line contactor relay 319 and turned on the MEMORY element M–7 to maintain the run relay 324. The energization of these two relays provides a continuous or threading speed of the press, in any event, if the FASTER button had momentarily been depressed and released.

If it is desired to run the press at a faster speed, increasing it continuously, but at a controlled rate without the increase following any predetermined automatic pattern, the FASTER button may be held depressed as long as desired. As soon as the button is released, the speed attained will be constant until further control is exerted. When the FASTER button 287 is depressed, there will be a continuous signal output at the conductor 327, and presuming an input at the upper and lower inputs of AND element A–3, there will also be a continuous signal at conductor 306. The FASTER LIMIT switch 224 is normally closed and hence provides a signal on the conductor 265 through the transformer-rectifier combination X–1 which provides an input at the upper channel of the AND element A–8. Assume for the moment, that there is no signal from the SLOWER button 285. This causes the NOT element N–4 to provide an output at conductor 347 which is θ and the AND element A–8 having all three inputs now energizes the faster pilot relay 308. This energizes the faster winding of the pilot motor 50 to rotate the shaft 201 in a direction to cause the drive motor 55 to increase speed. Suitable warning lights can simultaneously be energized. If the FASTER button 287 is released, the signal from AND element A–3 drops out and stops the pilot motor. Note that when the maximum speed is approached, the FASTER LIMIT switch 224 will be opened by its cam 235 and de-energize the relay 308 to stop rotation of the pilot motor 50.

Another control function which will de-energize the relay 308 is the pressing of the SLOWER button 285 which applies a signal to the NOT element N–4 and removes the lower input to the AND element A–8.

The next control function which will be described in detail is the manual decrease of speed of the press by pressing the SLOWER button 285. The SLOWER LIMIT switch 225 must be closed for the SLOWER button 285 to accomplish any function, and hence the press must be running at some speed which results from the cams 203 and 205 (FIG. 7) being in a position in which the shaft 201 and a cam 235 have closed said switch 225.

When depressed, the SLOWER button 285 applies a signal through the transformer-rectifier combination X–8 to the conductor 286 which provides an input to the OR element O–9, an output on conductor 348 to the OR element O–12 and a signal on conductor 349. This provides an input signal to the upper channel of the two channel θ AND element AN–1. The lower channel of AN–1 receives its signal on conductor 350 which connects with conductors 351 and 270 to the SLOWER LIMIT switch 225. If above the lower limit, this switch will be closed and a signal will be provided at 350. Since AN–1 has both of its input signals there will be a ϕ output on conductor 352 through amplifier AM–5 to energize the slower pilot relay 353 which in turn supplies an A.C. drive voltage to the slower winding of the pilot motor 50 to drive the shaft 201 in a direction to decrease speed of the drive motor 55. Suitable indicating lights can simultaneously be energized.

If the SLOWER button 285 is kept depressed, the press will run slower and slower. Any speed attained will be maintained if the SLOWER button is released. When the lower limit has been reached and the SLOWER LIMIT switch opened, the lower input to the AND element AN–1 will be removed and further control is removed from the SLOWER button 285.

The SLOWER button does not affect the line contactor relay 319 or the run relay 324, but it takes control from the FASTER button 287 by supplying an output from AND element AN–1 on conductor 355 to the NOT element N–4 which cuts off the lower input on 347 to the AND element A–8 to prevent energization of the faster pilot relay 308.

The STOP push button 289 is a control by means of which the press can be brought to a complete stop in as short a time as possible. Pressing this button provides a signal on conductor 290 to inputs of the OR elements O–3 and O–4. Output of O–4 on conductor 355 and 356

turns off the MEMORY element M–7. The "off" state of this element is a ϕ output which when passed through OR element O–14 will not be accepted by θ AND element AN–3 and hence will remove input to amplifier AM–8 and de-energize the run relay 325. A signal is also applied to MEMORY M–4–L to provide an "off" state θ output which is not acceptable to the ϕ phase input of AND element A–4 so that the line contactor relay 319 is de-energized.

The line contactor relay is a time delay opening type of relay and hence the line contactors will remain closed for the time of the delay. Since the run relay 324 is closed, however, there will be no direct current on the control windings of the reactors 114, 115 and 116 and the A.C. will return these reactors to desaturated state.

If the STOP button is pressed while the press is operating at higher than threading speed, there are other functions required to be performed to bring the press to a complete stop. The signal on the conductor 355 is also a signal on conductor 357 which provides an input to MEMORY element M–3–U which turns the element in "on" state with a θ output at conductor 358. This passes through the OR element O–12 as a θ signal and, applied to AND element AN–1 along with the signal from the switch 225, operates the relay 353 to energize the slower pilot motor winding until the pilot assemblage is reset, which opens switch 225. Since signal output from MEMORY element M–3 continues, even after the STOP button 289 has been released, it follows that every time the STOP button is pressed, the pilot assemblage will be driven to reset condition and stop there. Furthermore, when reset condition is reached and the switch 225 opened, signal on conductor 351 will be removed, NOT element N–2 will have an output on conductor 359 which connects with M–3–L placing the MEMORY element M–3 into "off" condition with a ϕ output unacceptable to AND element AN–1. This therefore resets the MEMORY element M–3 to a state which does not interfere with operation of the press, but is available to reset the pilot motor 50 when the STOP button is once more presssed.

The removal of the signal output from AND element A–4 provides an output from the NOT element N–5 to the ϕ phased two channel AND element AN–2. The second input to the AND element AN–2 comes by way of the conductor 360 as a ϕ signal from the output of AND element AN–1 which had been providing the signal energizing the slower pilot relay 353. The output from the AND element AN–2 appears at conductor 361, passes through amplifier AM–6 and energizes the dynamic brake relay 362 and the field drop relay 363 both of which function to bring the motor 55 to a stop as rapidly as possible. The dynamic brake relay is energized until the pilot motor 50 is driven to reset.

In the event that the pilot motor 50 is being driven in a faster direction under the control of the automatic acceleration circuit, which will be explained, the STOP button 289 must provide a signal to remove this control. This is done by the signal output from the STOP button being applied by way of conductor 290, OR element O–4, conductor 364, OR element O–7, conductor 302, OR element O–2, conductor 303, OR element O–8 and conductor 304 to MEMORY M–2–L. This turns MEMORY M–2 to "off" state, with a ϕ output not acceptable to the AND element A–8, which will de-energize the relay 308. As seen below, the AUTOMATIC ACCELERATION button 293 can turn the MEMORY element M–2 to "on" condition for automatic "increase speed" operation of the pilot motor 50.

The STOP button, as stated, closed the dynamic brake relay 362 which closed the dynamic brake contactors. There is also a normally closed interlock on the line contactor which is operated when the line contactors open after their delay as explained above. The desaturation period of the power reactor absorbs the initial shock of the transfer from the press being driven to its being braked to a stop. The relay 362 is also a time delay opening relay to maintain the dynamic brake contactors after the pilot assemblage has been reset until the press has come to a complete stop.

The effects of pressing the AUTOMATIC ACCELERATION button 293 to some extent has been mentioned above. The purpose of this button is to bring the press up to its maximum speed along the characteristic 218 (see FIG. 2) as rapidly as possible and without the need for holding the button 293 depressed, either from a condition of reset or from some speed at which the press may have been running. It has previously been explained that the signal output at the conductor 294 can energize the line contactor relay 319 under certain conditions which would usually obtain when the AUTOMATIC ACCELERATION button 293 is depressed. The signal output from X–12 on 294 is also applied by lead 334 to the upper input of AND element A–1. The second input to the AND element A–1 is applied by way of lead 335 from the MEMORY element M–4, which, it will be recalled, is required to be in "on" state in order to provide an output to energize the line contactor relay 319. The θ output at 336 turns on MEMORY element M–2 which applies a signal on 305 through OR element O–11 to provide the center input to the AND element A–8. The other two inputs to A–8 being present, there will be a signal output on 307 to energize the relay 308 through the amplifier AM–4.

Turning the MEMORY element M–2 to "on" state maintains the energization on the faster pilot relay 308 until this memory element is turned off or one of the other inputs to AND A–8 is removed. If the slower pilot relay 353 is energized during automatic acceleration, as by pressing the SLOWER button 285, there will be an output from the AND element AN–1 applied by way of the conductors 360 and 365 back to the OR element O–8 applying an input at 304 to M–2–L which turns off the MEMORY element M–2. Since this state is retained by the MEMORY element M–2, discontinuing the application of signal to the slower pilot relay 353 will have no effect on the state of MEMORY element M–2 so that automatic acceleration will not be resumed. This is an obviously safe procedure since it prevents the press from moving at a rate faster than that which obtains when a slow down signal is discontinued.

The automatic acceleration limit switch 226 operating through the transformer-rectifier combination X–3 is normally open. When a preselected speed is reached, represented by a certain rotational disposition of the shaft 201, the cam 235 closes the switch 226 and a signal is applied at 272 to OR element O–2. The output from the OR element O–2 at 303 is applied through OR element O–8 to conductor 304 which places MEMORY element M–2 in an "off" state and hence de-energizes the faster pilot relay 308.

The pressing of the AUTOMATIC DECELERATION button 291 serves to slow the press down at an automatic rate along characteristic 218 not requiring the button to be kept depressed, and under normal non-emergency conditions. The speed will decrease to some value which is determined by the automatic deceleration limit switch 227. This switch is normally open, but is closed when the lower limit of speed is reached, due to the rotational disposition of the shaft 201 operating a cam 235. At all points above the minimum setting, there is no output on the conductor 271, and no input to MEMORY element M–1–L. The pressing of the AUTOMATIC DECELERATION button 291 applies a signal through the transformer-rectifier combination X–11 to lead 292 to MEMORY element M–1–U to place this element in "on" condition, providing a θ output on the conductor 367 to OR element O–9, the output of which provides an input to the AND element AN–1 through the conductors 348 and 349 and OR element O–12. Since for speeds faster than the lower limit, the switch 225 is closed, there will also

be a signal on conductor 350 and the slower pilot relay 353 will become energized and remain so as long as the MEMORY element M–1 is on and the lower automatic deceleration limit has not been reached. The lower automatic deceleration limit is a speed which is either greater than or the same as the slower limit. When the lower automatic deceleration speed is reached, the switch 227 is closed and the MEMORY element M–1 is turned off, thereby stopping the rotation of the pilot motor. The speed at this time will be maintained.

If the press is moving at a speed which is above the slower limit but below the automatic deceleration limit, pressing the AUTOMATIC DECELERATION button 291 will supply both inputs to MEMORY element M–1, and as previously explained, with both inputs applied to a memory element there will be no change in its output, hence no command signal will pass.

The various signal lights that are usually associated with a press can be installed and operated in parallel with the several relays, with contactors and the like to signal the condition of the press. The SAFE and READY conditions have been explained. The usual convention is that the SAFE condition is represented by a green light, and the READY condition by a red light. Usually there are SAFE buttons at several stations, and the significance of the green light would be that the control pilot assemblage is in reset condition, and at least one of the SAFE buttons at some station is depressed. The red light would means that there is no SAFE button depressed at any station, but the control pilot assemblage may be in reset position or the press may be running. In order to give better information, a combination of red and green lights can be used to notify the operators that the press is running, but has been locked to some speed by depression of a SAFE button somewhere. This is done by applying the signal from the AND element AN–3 by way of the conductor 368 through the OR element O–15 to the amplifier AM–9 to energize the ready relay 339 while the run relay is energized, even though the other signal to the OR element O–15 is removed by depressing the SAFE button.

It will be noted that there is a fail-safe circuit which returns the pilot to reset condition in emergencies operating through transformer-rectifier combination X–5 by way of conductor 278 to OR element O–4 to function as though the STOP button 289 were depressed. Other relays and switches perform similar emergency functions in parallel with the fail-safe relay 273.

Mention has been made of the delay and signal circuit 340 which is another safety measure that is automatic and can be embodied in a system. This is an arrangement which works in conjunction with the controls that start up the press to provide a warning and also to require some action to be taken in a given time in order to achieve the movement. Simply stated, when the operator decides to start the press and presses one of the three buttons INCH, FASTER or AUTOMATIC ACCELERATE, there will be an alarm sounded, and this will continue for a short time, say three seconds. As soon as the alarm has stopped, the press will be operative, that is, capable of being started for another short time by the FASTER or AUTOMATIC ACCELERATION buttons. The operator must again press the starting button within this short time, or the entire process must be gone through. The operator is thus required to press the button twice for the press to run; there will be an alarm for the first period; and if he has changed his mind or learned of adverse conditions to operation in the meantime, he need not press the button after the alarm, and the press will remain in its quiescent condition.

The manner in which this is accomplished by means of the static control elements is described hereinafter.

Pressing the buttons 283, 287 or 293 will, besides any other function performed, apply a signal on the conductor 328 and place the MEMORY element M–5 in "on" state. The "on" state is a ϕ signal which appears at 329, passes the gating AND element A–5 and appears at 330. It energizes the alarm relay 369 through the conductor 370 and the amplifier AM–11. So long as the MEMORY element M–5 is on, the alarm relay 369 will be energized. The same signal at 330 turns on the TIME DELAY elements D–1 which may be set for three seconds. After the three seconds have passed, the signal from the TIME DELAY element appears at 331 and places MEMORY element M–8 in "on" condition. This provides the θ output signal on conductor 332 which has been mentioned previously. The delayed output signal also is applied by the conductor 371 to the OR element O–10 and the output of this element appearing at conductor 372 resets the MEMORY element M–5 to "off" and hence the signal output to the alarm relay 369. The press has in the meantime been rendered operative through the AND element A–2.

This same signal on 371 applies a signal by way of conductor 373 to the MEMORY element M–6 to place same in "on" condition providing a θ output to the gating AND element A–6 and starting the TIME DELAY element D–2. At the end of a given time, say three seconds, there will be a signal output from the TIME DELAY element D–2 which passes through the OR element O–13 and this signal at the conductor 374 will place MEMORY element M–8 in "off" condition, removing the signal from the conductor 332 If the press has not in some manner been started in the meantime, it cannot now be started without the lower input to AND element A–2. Since the run relay must be energized to run the press, the signal which operates it out of the AND element AN–3 is used to reset the MEMORY element M–6 by way of conductors 368 and 375. Since the FASTER button 287 and the AUTOMATIC ACCELERATION button 293 start the press through the AND elements A–3 and A–1 respectively, and these elements require an input controlled by the delay and alarm system, it will be seen that the buttons must be pressed during the second three second period to start the presses. Once moving, the delay and signal circuit does not affect the press.

Only the alarm portion of the circuit 340 is used with the INCH button 283. Keeping the INCH button depressed delays the time that a signal will appear at 332 while sounding the alarm. Since the lower signal input to AND element A–7 is being provided directly from the INCH button 283, as soon as there is an output from MEMORY element M–8 to AND element A–2, the run relay 324 will be energized as well as the line contact relay, and the press will start. Signal from conductor 375 keeps MEMORY element M–6 in "off" condition, preventing M–8 from being turned off.

The STOP signal or reset of the pilot assemblage will turn off MEMORY elements M–5 and M–8 at any time by way of conductor 376.

Not a great deal has been said about the manner in which the invention can be applied to typical installations, primarily because the nature of the invention is such that practically any kind of rotary press can advantageously use the drive hereof. The discussion which follows is in the nature of a conclusion, describing generally the manner in which the invention may be used in different installations.

The described apparatus could be considered that required for a basic installation. This is shown in FIG. 10 diagrammatically. None of the power sources is shown. The block 380 at the right represents the control unit of a minimum installation, and as noted, it is formed of several sections shown symbolically as rectangles. The entire structure of the block diagram of FIG. 1 is contained in the block, with the exception of the motor 55 and some other apparatus such as the detectors 66 and some of the safety apparatus associated with the press itself and the motor. The block thus includes the push buttons 62, the

static control system 60, the pilot motor 50 and assemblage, the control channels and saturable core reactors of FIG. 3. These latter are designated AC and FC, signifying armature control and field control.

From the master control unit 380, the excitation and control are provided to the drive motor 55 by suitable electrical connections designated generally 381. The motor 55 is coupled to a printing press P_1 by suitable power transfer elements 382 and 383 transmitting power through the shafts 384 and 385 to press P_1. Such an installation as shown in FIG. 10 using one motor is typical for many magazine, rotogravure and newspaper presses, and is quite common for rotary presses which do not have large power requirements.

The master control unit 380 of FIG. 10 is practically formed as shown in FIG. 11 of two modular cabinets 386 and 387, which are termed press supervisory controller and unit controller, respectively. The press supervisory controller 386 has the master push button control panel 60, the static control system 62, the pilot motor 50 and its assemblage, and the control channels AC and FC excepting for the saturable core reactors 114, 115 and 116, the rectifiers 124 and associated circuitry, and dynamic braking resistor 172. These latter elements, comprising the armature power source for a single motor, along with breakers, contactors, switches and the usual paraphernalia associated with such apparatus, are housed in the second cabinet, the unit controller 387. The advantage in breaking up the basic master control unit 380 into two modular parts is that for the addition of motors, all that need be added is one unit controller for each added motor, the entire grouping being controlled from the supervisory controller 386.

In FIG. 12 there is diagrammed a typical large press for a newspaper or the like, designated P_2. The press is formed of groupings of units and folders. Each unit is an independent functional structure having printing, inking, drying, and the like means, and each folder has structure for severing the web and folding the same into newspapers or the like and delivering the completed item. Obviously several printing units will feed a single folder—as many as ten. The units are grouped front and rear of the folder they normally feed, such as shown in the diagram, where units numbers 1, 2 and 3 are on one side of the folder A, while units 4, 5 and 6 are on the other side. Often, where the newspaper or other printed article is larger than usual, units grouped near a remote folder may be threaded into a single folder, by-passing the remote folder which is permitted to run idle.

Each unit and folder is driven by a motor, and for the unitized installation as it is known, all motors are identical, all are coupled together for synchronized rotation. In FIG. 12, the motors are each the equivalent of the drive motor 55, and for convenience, are designated 55–1, 55–2, etc. to identify the associated unit. The motor driving the folder A is designated $55\text{–}F_A$. The shafts of all of the motors are coupled together to rotate at the same speed, these shafts being collectively designated 388, there being suitable clutches between motors, as shown at C–1, C–2, C–3, etc. Suitable power take-offs such as gear trains transfer power from the shaft 388 to the units and to the folder, as shown at TO–1, TO–2, TO–3, etc. Note that the press continues both right and left of the portion shown, and this means there will be additional shafting, motors, clutches, take-offs and the like.

For each folder there will be a press supervisory controller 386 and one unit controller 387, and for each unit there will be one unit controller 387. Thus, for the installation shown in FIG. 12 there will be the press supervisory controller F_A for the folder A with a unit controller U_A for the motor $55\text{–}F_A$ of the folder, the unit controllers U_1, U_2 and U_3 on the left for the first three units, and the unit controllers U_5, U_4 and U_6 on the right for the three other units. The assembly of cabinets housing the controllers shown as a series of rectangles includes rectangles marked U_a, U_b, U_x, U_y, U_z representing unit controllers for other press units not shown, and rectangles marked F_B and U_B for another folder B which is not shown. Control of a group of units can be switched between folders or between a folder and another station. Groups of units can be connected to be controlled by one folder, such grouping being one or more units. The entire arrangement of control is so flexible that almost any desired arrangement can readily be made. Each motor provides its own inching function, its own braking, its own threading, and takes its share of the load.

The general channel of command to the motors is shown as connections CC–1, CC–2, CC–3, etc. from each unit controller to the motor it controls, but it should be appreciated that the supervisory controller which provides the command and control provides the field excitation of all motors under its control and hence the illustrated connections include channels from the supervisory controller F_A as well. The interconnections between controllers are symbolized by the conductors 390.

A large amount of detail has been omitted as unnecessary for a complete understanding of the invention, but would normally be required for any press installation. This includes testing equipment and terminals and lights, sockets, but apparatus, cooling and blowing apparatus and controls, circuit breakers and fuses, power connections and switches and safety devices, and many more items which need not be mentioned. Furthermore, the exact arrangement of components while convenient, is not to be considered a limitation. The physical and electrical details are capable of wide variation without departing from the spirit or scope of the invention as described in the appended claims.

Although described hereinabove as embodied in a drive for printing presses, it should be apparent that the basic control system is applicable to the operation of electric motors regardless of the equipment driven thereby. Where the requirements of a machine are similar to those of press drives, the advantages and features of the invention will obtain where control is achieved with the invention herein.

What it is desired to obtain by Letters Patent of the United States is:

1. A press drive which comprises, a direct current motor coupled to the press and having separately excitable armature and field of windings, separate magnetic reactive means for exciting the respective windings, control signal producing means for varying the outputs of the respective reactive means in accordance with predetermined programs, a first and a second independent and separate control channel respectively connecting each of said reactive means with said control signal producing means, each control channel having magnetic signal regulating means therein, a plurality of manual controls for choosing said programs, and said control signal producing means including a static control element circuit energized by said manual controls.

2. A press drive which comprises, a direct current motor coupled to the press and having separately excitable armature and field windings, separate magnetic reactive means for exciting the respective windings, control signal producing means for varying the outputs of the respective reactive means in accordance with predetermined programs, a first and a second independent and separate control channel respectively connecting each of said reactive means with said control signal producing means, each control channel having magnetic signal regulating means therein, a plurality of manual controls for choosing said programs, said control signal producing means including a static control element circuit energized by said manual controls, pilot means energized by said static control element circuit, and connected to said first and second separate control channels for respectively varying the control signals regulated thereby.

3. In a press drive in which there is a drive motor hav-

ing a field and an armature and the motor is coupled to the press, and in which there are two independent excitation control channels respectively serving the armature and field, pattern signal producing means for producing pattern signals for controlling excitation of said field and said armature, respectively, said last named including a programming motor and a circuit for energizing said programming motor according to a certain program, the drive motor adapted to be energized for different characteristics under accelerate and decelerate speed conditions, and the programming motor having different windings energized by said circuit selectively in accordance with the desired speed condition of said drive motor.

4. A drive for a press which comprises, a direct current motor coupled with said press, said motor comprising an armature winding and a fielding winding, first and second independent control channels comprising first and second pattern producing means for respectively exciting said armature winding and said field winding, means for simultaneously actuating said first and second pattern producing means, static control means arranged in controlling relation with said first and second pattern producing means, and manually operated means for applying a selected one from a plurality of programs to energize said static control means, whereby said armature winding and said field winding are independently excited according to programs selectively applied to said pattern producing means by said static means under control of said manually operated means.

5. In a press drive having an electric drive motor and control circuits for actuating pilot means operable to regulate excitation of said motor, a first plurality of manual control members, a second plurality of electric signal devices adapted to be selectively energized by the operation of the control members of said first plurality, a third

plurality of static control elements operable in mutually dependent, logical relation, the elements of said third plurality being connected in circuit with said signal devices for selectively providing output control signals to actuate said pilot means in accordance with one program of a plurality of preassigned programs selected in response to the operation of said first plurality of manual control members.

6. An electric drive comprising a direct current motor adapted for coupling to machinery to be driven, said motor comprising an armature winding and a field winding, first and second independent channels comprising first and second means for producing pattern signals for respectively exciting said armature and field windings, control means arranged in controlling relation with said first and second pattern signal producing means, and a plurality of manually operated means for applying a selected one from a plurality of programs to energize said control means, whereby said motor and field windings are independently excited according to programs selectively applied to said pattern producing means by said control means under manual direction by said plurality of manually operated means.

References Cited in the file of this patent

UNITED STATES PATENTS

1,550,186	Tuppen	Aug. 18, 1925
1,847,943	Elder et al.	Mar. 1, 1932
2,760,134	Johnson	Aug. 21, 1956
2,773,231	Adriansen et al.	Dec. 4, 1956
2,783,427	Bracutt	Feb. 26, 1957
2,813,236	De Westfelt	Nov. 12, 1957
2,833,941	Rosenberg et al.	May 6, 1958

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,132,295 May 5, 1964

John E. Black

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 29, line 6, after "named" insert -- means --.

Signed and sealed this 8th day of September 1964.

(SEAL)
Attest:

ERNEST W. SWIDER
Attesting Officer

EDWARD J. BRENNER
Commissioner of Patents

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