

April 30, 1963

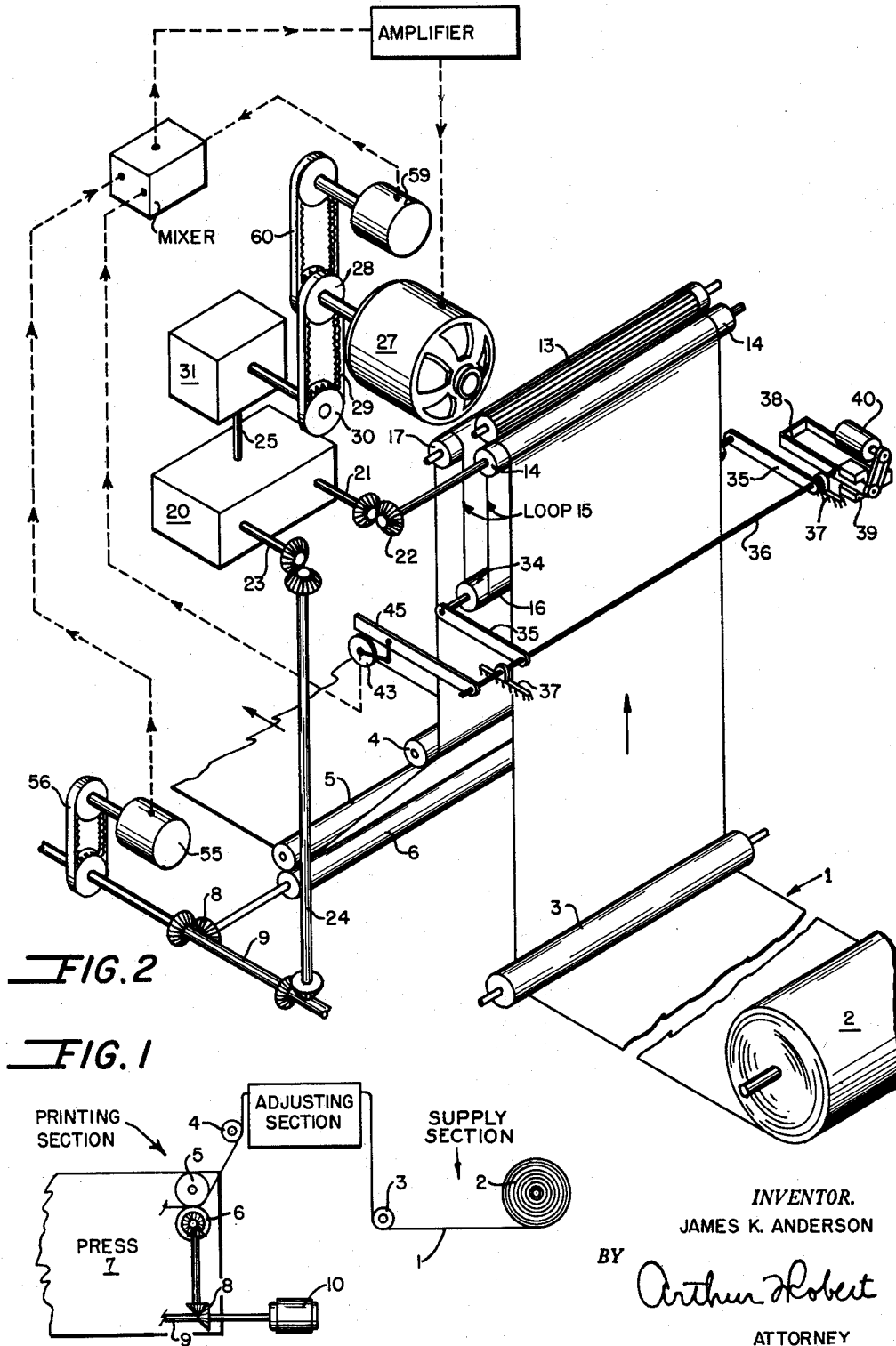
J. K. ANDERSON

3,087,663

APPARATUS FOR ADJUSTING PRINTING WEB TENSION

Filed April 13, 1961

4 Sheets-Sheet 1



April 30, 1963

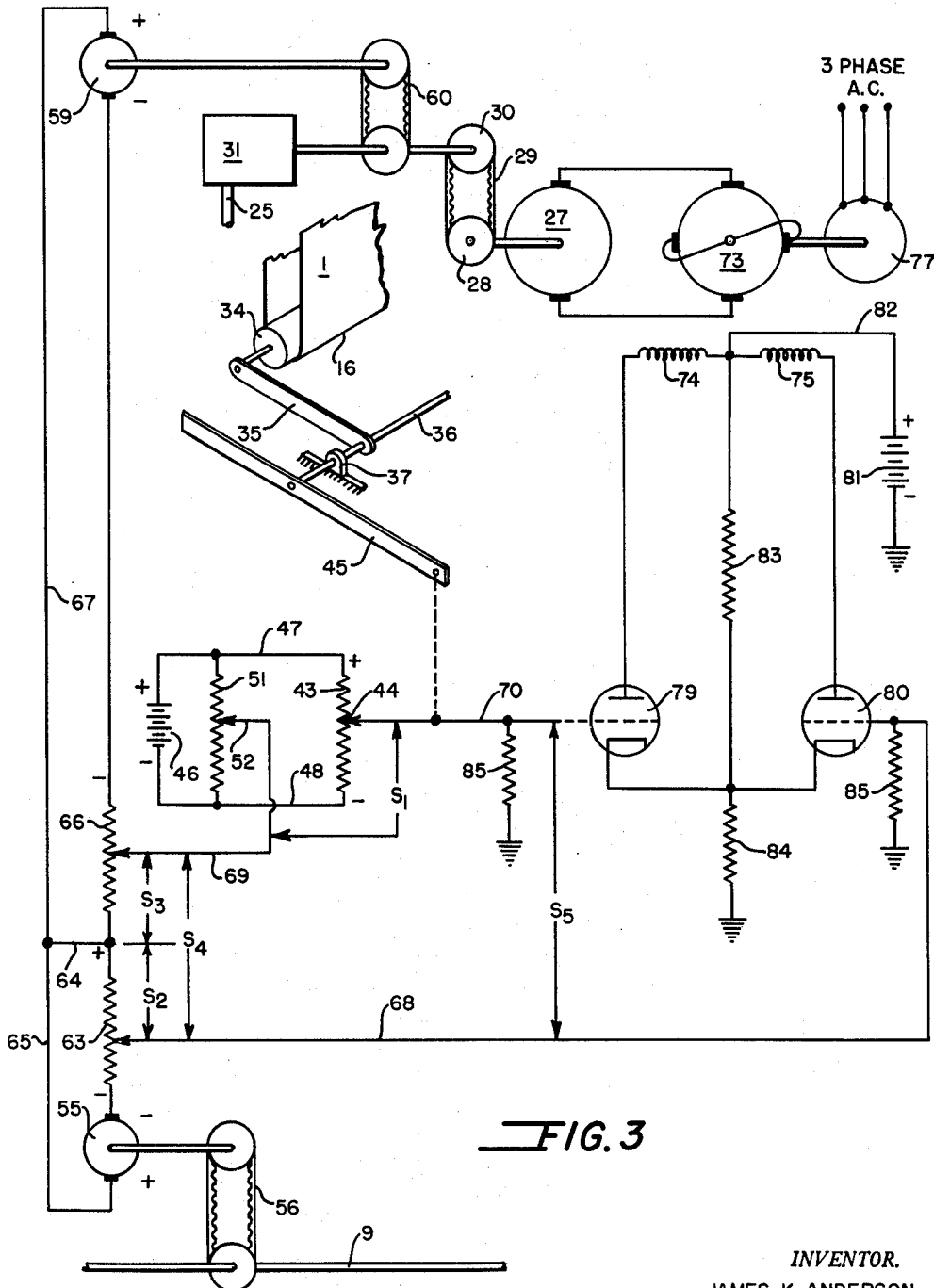
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APPARATUS FOR ADJUSTING PRINTING WEB TENSION

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4 Sheets-Sheet 2



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APPARATUS FOR ADJUSTING PRINTING WEB TENSION

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4 Sheets-Sheet 3

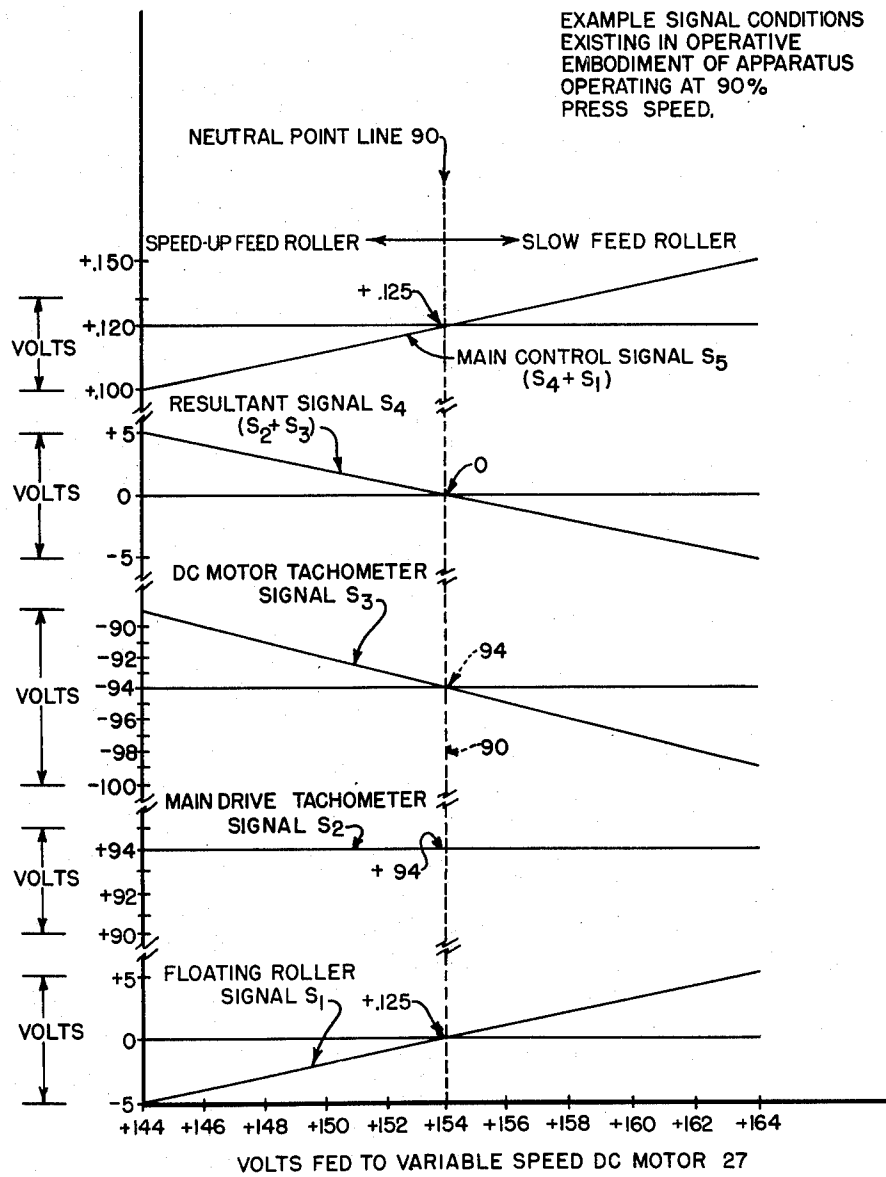


FIG. 4

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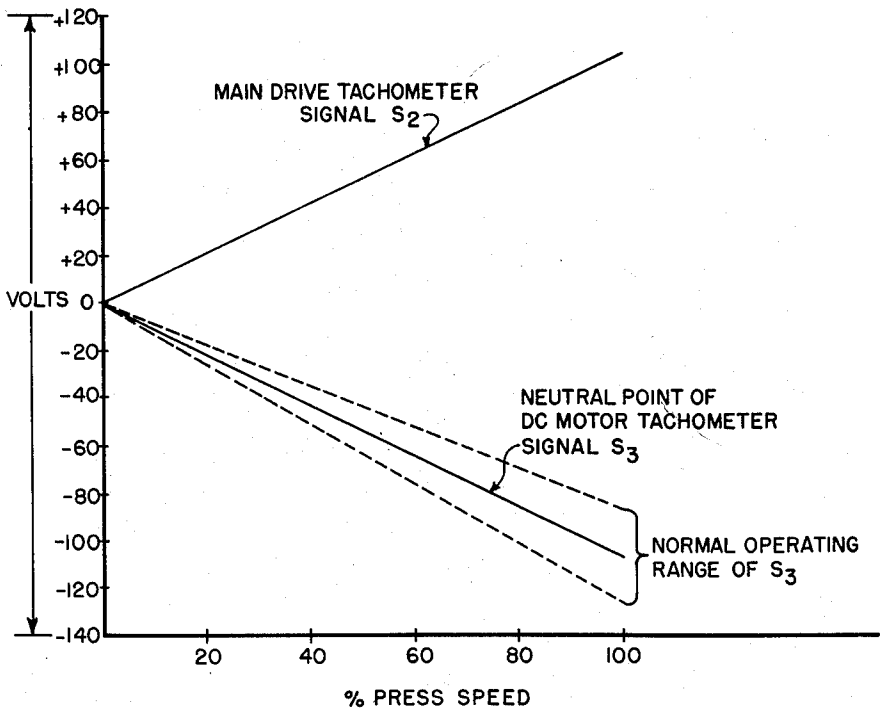
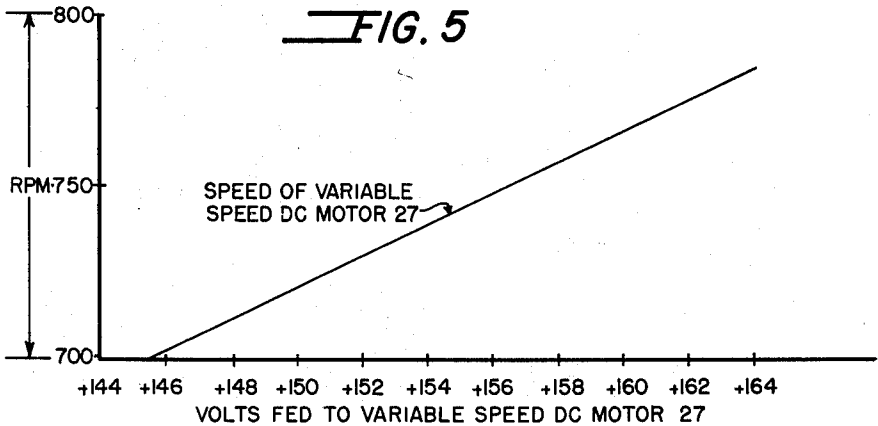
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APPARATUS FOR ADJUSTING PRINTING WEB TENSION

Filed April 13, 1961

4 Sheets-Sheet 4



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3,087,663 APPARATUS FOR ADJUSTING PRINTING WEB TENSION

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13 Claims. (Cl. 226-44)

This invention relates to apparatus for maintaining the web entering a printing press under a substantially constant predetermined value of tension.

Under normal operating conditions, the tension of a high speed web entering a high speed printing press, equipped with conventional web-tension controls, usually varies as much as 10%. These variations of web tension in a multi-color printing operation cause portions of the web to be printed out of register. Poor or inaccurate register is objectionable because it lowers the quality of the printing. Furthermore, this error in register usually becomes extreme when making a "flying splice" of the starting end of a new web to the tail end of an exhausted web. As a result, substantial amounts of the printed web have to be discarded.

The principal objects of this invention are: to minimize the above objections to a substantial degree; to improve the quality of multi-color printed webs; and to reduce, to a substantial degree, the amount of waste of printed webs normally resulting from making a "flying splice."

Other important objects of this invention are: to provide a web tensioning apparatus that can be simply and easily installed adjacent the web inlet of a conventional printing press without appreciably modifying either the printing press or its web supply means; to provide one which will maintain a printing press web under a constant value of tension within a range of much less than 10%; to provide one which is so effective that it will often allow a "flying splice" to be made without causing any discernible error in multi-color register (the splice itself will usually be printed in register); and to provide an economical web tension apparatus, which will operate in a reliable and relatively trouble-free manner.

Briefly, these objects are attained in an apparatus constructed in accordance with my invention wherein the web is fed from a supply section through a web tension adjusting section to a printing section, by: means constraining the web, as it moves through the web adjusting section, to form a vertically depending U-shaped loop; a web feed roller for pushing the web to the adjusting section; variable speed drive means for the web feed roller; a floating roller gravitationally resting on the bight of the U-shaped loop to maintain the tension of the moving web in the adjusting section at a predetermined constant value corresponding to the weight of the floating roller; and speed control means operative, in response to a drop or rise of the floating roller from its normal elevation, to control the variable speed drive means and cause it to decrease or increase the speed of the web feed roller sufficiently to restore the equilibrium of the system and, more particularly, tend to maintain the floating roller substantially at its normal elevation within a narrow range of vertical movement.

When the tension of the web entering the adjusting section is below the predetermined tension value, the weight of the floating roller stretches the U-shaped web loop to increase the web tension to the correct value and, in doing so, progressively moves itself and the loop bight downwardly from its normal elevation and correspondingly increases the length of the web in the U-shaped loop. On the other hand, when the tension of the web entering the adjusting section is above said predetermined value, the length of the U-shaped web loop shrinks sufficiently to reduce its tension to the predetermined value

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and, in doing so, progressively moves the loop bight and the floating roller upwardly from its normal elevation and correspondingly decreases the length of the web in the U-shaped loop. My apparatus responds to the rising and falling movements of the floating roller to vary the speed of the web entering the adjusting section sufficiently to compensate for the tension changes which cause the floating roller to rise or fall.

The invention is illustrated in the accompanying drawings wherein:

FIG. 1 schematically illustrates a press installation of the type to which the present invention may be applied;

FIG. 2 is a fragmentary perspective view schematically illustrating an apparatus made in accordance with the present invention to maintain the tension of the web leaving the adjusting section and entering the printing section at a constant predetermined value;

FIG. 3 is a schematic view of the control means used, in accordance with the present invention, to sense variations in the tension of the web entering the adjusting section and, in response thereto, effect corrective or compensating variations in the speed of the web entering the adjusting section, this means including various electrical circuits producing various electrical control signals;

FIG. 4 is a graph which is obtained when the press is operating at 90% of its normal operating speed and the apparatus, as a whole, is in operational equilibrium whereby the web tension in all sections is at the correct value and which shows the prevailing equilibrium relationship of the various FIG. 3 electrical circuit signals to each other and to the operating voltage (or speed) of the variable speed motor, which functions to adjust the speed of the web entering the adjusting section in response to changes in the tension of the web entering that section;

FIG. 5 is a graph showing the relationship between the variable operating voltage and the variable operating speed of the motor which, in response to variations in the tension of the web entering the adjusting section, operates to make corrective variations in the speed at which the web is fed into the adjusting section; and

FIG. 6 is a graph showing how one voltage signal, which corresponds to the press speed, varies in direct proportion to the press speed, how another voltage signal, which corresponds to the neutral point value of the variable motor speed, varies with the press speed and how the variable speed range of the variable speed motor changes as its neutral point changes.

CONVENTIONAL APPARATUS

In newspaper, magazine and other conventional printing press installations, the web to be printed flows serially through web supply, adjusting and printing sections. Thus, in the press installation schematically illustrated in FIG. 1, the web 1 flows through the supply section from a supply roll 2 around an idler roll 3 up to the adjusting section. Upon leaving the adjusting section, it flows through the printing section passing around idler roll 4 and between impression roll 5 and printing cylinder 6, which constitute the entrance to the press 7. The printing cylinder 6 is connected through a bevel gear 8 to the main power shaft 9 of the press. The main shaft 9 is driven by the press motor 10, the speed of which determines the speed of the press and of the web flowing through it.

Under ideal conditions, the web supply, adjusting and printing sections of the apparatus are intended to function as follows: (a) the supply section functions to feed the web from a suitable source of supply into the adjusting section under tension, which always varies somewhat; (b) the adjusting section functions to adjust the varying

tension of the web to a desired constant value and feed it at that value into the printing section; and (c) the printing section functions to print the web in exact register, which is possible when the web tension in the printing section is not varied.

Heretofore the web tension in the printing section has varied as much as 10% because of the failure of the controls in the adjusting section either to sense adequately all variations in the tension of the web entering the adjusting section or to respond properly to such variations. The present invention, therefore, proposes an improved apparatus for sensing variations and effecting the proper corrections. Under the general run of operating conditions, it normally reduces the variations in the tension below 2% and often reduces them to a point where register is maintained in making a flying splice.

IMPROVED APPARATUS

Stated generally, my improved apparatus comprises: (1) means constraining the web moving through the adjusting section to form a vertically depending U-shaped loop; (2) a feed roller push-feeding the web into the adjusting section; (3) variable speed drive means for said feed roller; (4) a floating roller bodily resting on the bight of the adjusting section loop to move down and up with it as the tension of the web entering that section decreases and increases; and (5) speed control means operative, in response to the down and up motion of said floating roller, to adjust said variable speed drive means to slow down and speed up said feed roller as required to bring the system back into equilibrium.

U-SHAPED WEB CONSTRAINING MEANS

As seen in FIG. 2, the web enters the adjusting section of the apparatus between a pair of inlet pinch rollers 13, 14, forms a depending U-shaped loop 15 having a bight 16 and flows over exit roller 17 as it leaves the adjusting section to enter the printing section. In this arrangement, the U-shaped loop 15 is supported at its opposite ends by inlet roller 14 and exit roller 17.

To promote the securement of the best end results, it is highly desirable that the legs of the U-shaped loop 15 extend not only parallel to each other but also in truly vertical planes. Accordingly, the inlet and exit rollers and the floating roller are all coordinated in size and position to compel the legs of the U-shaped web in the adjusting section to extend in truly vertical parallel planes.

WEB FEED ROLLER

The lower inlet pinch roller 14 also functions as a variable speed feed roller. The upper inlet pinch roller 13 presses the web 1 downwardly against feed roller 14 to prevent relative slippage of the web. In the absence of slippage, the peripheral speed, at which the feed roller 14 is driven, determines and controls the lineal speed at which the web is fed into the adjusting section.

VARIABLE SPEED DRIVE MEANS

The variable speed drive means for the web feed roller 14, includes: a differential drive unit having a pair of power input shafts and an output shaft; means for driving one input shaft at a relatively constant speed approximately the desired output shaft speed; and means for adjusting the output speed relative to said constant speed by driving the other input shaft at a controlled varying speed.

Differential Drive Unit

Any suitable form of differential drive may be employed. The unit, indicated by the numeral 20, is the epicyclic gear type having an output shaft 21, which drives the feed roller 14 through a miter gear 22, a constant speed input shaft 23 which is driven by the main shaft 9 through an interconnecting shaft 24, and a variable speed input shaft 25.

The operation of epicyclic gear types of drive units is conventional and well understood by those skilled in the art; hence, it will be readily understood that the output speed, at which the unit 20 drives the feed roller, is determined by the relative speeds and directions of the two input shafts 23 and 25. Depending on the particular gear ratio provided by the differential unit 20, the input shaft 23 may be driven by the main shaft 9 at a constant speed which normally approximates the desired output shaft speed or is at some relatively constant value extending above or below the output shaft speed.

When one input shaft is driven at a relatively constant speed, the speed of the output shaft may be varied by varying the speed of the other input shaft. In the present case, I prefer to have the one constant input shaft 23 contribute a major percentage of the output shaft speed and to limit the variable speed input shaft 25 to contributing and controlling only a minor percentage of the output shaft speed. All other things being equal when the web tension varies, the present apparatus operates in response to tension variations, to vary the speed of the variable speed input shaft 25 in the corrective direction.

Drive Means For Constant Speed Input Shaft

The constant speed input shaft 23 of differential unit 20 is driven by the main drive shaft 9 through an interconnecting shaft 24. So long as the main drive shaft 9 drives the printing press at a relatively constant speed, as it normally does, the input shaft 23 will be driven at a corresponding speed. Any change in the speed of the main drive shaft 9 correspondingly changes the speeds of the press and of the input shaft 23.

Drive Means for Variable Speed Input Shaft

The variable speed input shaft 25 is driven by a variable speed direct current electric motor 27 through a drive train which is schematically shown in FIG. 2. Proceeding from the D.C. motor 27 to the input shaft 25, this drive train comprises: a sprocket 28 fixed on the shaft of motor 27; a chain belt 29 driven by the sprocket 28; a second sprocket 30 driven by the chain belt 29; and a geared speed reducer 31 driven by the sprocket 30 and connected to drive the input shaft 25.

In one operative embodiment of the apparatus wherein the web 1 travels through the printing press at a normal substantially constant speed of 1000 ft. per minute, various other parts of the embodiment will rotate as follows: (a) the main drive shaft 9 rotates at 763.94 r.p.m.; (b) the constant speed input shaft 23 (being driven by the main drive shaft 9 through a speed reducer having a reduction ratio of 51 to 30 or 1.7 to 1) rotates at 449.35 r.p.m.; (c) the variable speed D.C. motor 27 rotates in the speed range of 400 to 1200 r.p.m., always in the same rotary direction; (d) the input shaft 25 (being driven by variable speed motor 27 through a speed reducer 31 having a reduction ratio of approximately 11.46, rotates in the speed range of 35 to 104 r.p.m.; and (e) the output shaft 21 rotates in the speed range of 446 to 455 r.p.m.

These conditions, plus certain gear ratio changes in the differential drive unit 20, result (a) in the constant speed input shaft 23 tending to drive the differential 20 in a direction causing the web to move forwardly toward the press at the desired constant speed plus 1 to 2% in excess of the desired constant speed and (b) in the variable speed input shaft 25 tending to drive the differential 20 in a direction causing the web to move backwardly away from the press at a speed of 1 to 2% of the desired constant speed. In other words, in the preferred arrangement, the constant speed input shaft 23 contributes say "plus" 102% of the speed desired while the variable speed input shaft 25 contributes "minus" 2% of such speed in order that the differential 20 may deliver 100% to the output shaft 21. Thus the variable speed motor

27 operates to subtract speed; hence, as it increases in

speed, it increases the magnitude of its minus contribution or subtraction. Under these conditions, if the speed of the motor 27 is increased over its range of 400 to 1200 r.p.m., the speed of the web feed roller 14 will cause the web to be decreased correspondingly from about 1010 ft. per minute to about 990 ft. per minute. This range is wide enough to counteract substantially all of the variations in the tension of the web entering the tension adjusting section (the maximum stretch or elongation of the usual paper web used in printing presses is about ½ ft. to 1 ft. per 1000 ft. length).

It should be noted that the variable speed D.C. motor 27 always rotates (400–1200 r.p.m.) in the same direction. While it might be arranged to reverse its direction of rotation during the speed change adjustment of the feed roller 14, I prefer to avoid such reversal since better control is obtainable that way. If the D.C. motor 27 always rotates in the same direction, its speed need only be increased or decreased (and never stopped) to slow down or speed up the feed roller 14 and the web.

Before passing, it may be noted that my invention contemplates an arrangement wherein both constant speed and the variable speed input shafts make positive contributions to the forward speed of the web. In such case, the constant speed input will approximate 98 to 99% of the desired constant speed and the variable speed input, the remainder.

FLOATING ROLLER

The floating roller 34 rests in the bight 16 of the U-shaped loop 15. Its weight applies a predetermined constant gravitational load to that portion of the whole web, which forms the U-shaped loop. This constant load tends to maintain the U-shaped web under a constant degree of tension.

As noted previously, the elevation of the floating roller 34 tends to fall and rise as the tension of the web entering the adjusting section falls and rises. Again to promote the securing of the best end results, it is highly desirable to have the floating roller rise and fall along a vertical path which is truly vertical or a very close approximation thereof. To this end, the opposite ends of the floating roller 34 are guided along a vertical path by means of a pair of horizontally extending vertically swinging guide arms 35 which pivot about the fixed horizontal axis of a shaft 36. This axis is located at a horizontal level or elevation corresponding to that of the axis of the floating roller 34 which is in a neutral position lying about midway between the extreme upper and lower limits of the vertical movement of the floating roller. The shaft 36 is pivoted adjacent its opposite ends in bearings 37 which are fixed on a suitable stationary support means (not shown). The shaft 36 rocks in bearings 37 as the floating roller 34 moves up and down.

The swinging guide arms 35 may be provided with a means for applying an adjustable torque to the shaft 36 so as to adjust the effective weight of the floating roller 34. This variable torque adjusting means includes a horizontal radius bar 38 fixed, intermediate its ends, to one end of the shaft 36 to lie generally in the same plane as the guide arms 35 and to extend diametrically across the axis 36. A weight 39 is slidably mounted on the radius bar 38 for back and forth adjustment along the length of the bar to apply variable amounts of torque to the shaft 36, depending on the location of the weight 39 relative to the axis of the shaft 36.

This torque changing means is also provided with an electrically controlled motorized means for driving the weight 39 back and forth along the radius bar 38. Although, this motorized means is not shown completely in FIG. 2, it includes: a reversible electric motor 40 suitably mounted or supported on an assembly of which the radius bar 38 is a part; and a suitable drive means joining the motor 40 to the weight 39 for driving the weight back and forth along the bar 38, such as, for example, a

worm or screw (not shown) threaded through the weight 39, journaled on the bar 38 and rotatively driven through a suitable drive by the motor 40.

SPEED CONTROL MEANS

The speed control means directs and controls the variable speed D.C. motor 27 to operate at a speed which will maintain the floating roller 34 at or near its normal operating elevation. When the floating roller 34 moves up or down from its normal elevation, as a result of a change of tension in the web entering the adjusting section, the speed control means quickly directs the D.C. motor 27 to change its speed in a compensating direction which will hold the floating roller 34 at an elevation near its normal elevation.

The speed control means includes: a floating roller sensor means operative, in response to the vertical travel of the floating roller 34, to generate a signal S_1 which varies between plus and minus extremes as the floating roller 34 moves along its vertical path; a main drive tachometer means operative, in response to the speed of the main drive shaft 9, to provide a plus signal S_2 which varies as the normally constant speed of the main drive shaft varies; a variable tachometer means operative, in response to the speed of the variable speed D.C. motor 27, to provide a minus signal S_3 which varies as the speed of that motor varies; a signal mixer circuit for receiving all three signals, S_1 , S_2 and S_3 , using plus and minus signals S_2 and S_3 to produce a resultant signal S_4 which varies between plus and minus extremes, and using signals S_1 and S_4 to produce and generate a main control signal S_5 ; and amplifier means for receiving the main control signal, amplifying that signal as a direct current and feeding that direct current to the variable speed D.C. motor 27 for controlling its speed.

Floating Roller Sensor Means

This means is shown in FIG. 3 and comprises a rheostat 43 having its movable slider arm 44 mechanically connected to the floating roller 34 for operation thereby. To this end, arm 44 is mechanically connected to lever 45 which is fixed to one end of the rocker shaft 36, which is rocked by the guide arms 35 for the floating roller 34. As the floating roller 34 moves up and down, it swings the guide arms 35 and the lever 45 moves the slider arm 44 along the rheostat 43 in response to the vertical movement of the floating roller 34.

The rheostat 43 is connected across (in series with), a constant direct current source 46 by respective upper and lower connecting wires 47 and 48, the upper wire 47 connecting the positive side of the source 46 to the upper end of rheostat 43 (as is shown in FIG. 3) and the lower wire 48 connecting the negative side of the source 46 to the lower end of the rheostat 43. It should now be clear that the movable slider 44 of the rheostat encounters a variable voltage as it moves along the rheostat.

The above circuit is also provided with a base or contact voltage point for cooperating with the slider 44 to produce a variable voltage floating roller signal S_1 which varies as the slider 44 moves along the rheostat 43. In FIG. 3, this base voltage point is provided by connecting a tapped resistor 51 between the upper and lower wires 47 and 48 and using the adjustable tap 52 of the resistor 51 as the base voltage point. The floating roller signal S_1 indicating the movements of the floating roller 34 is produced between the adjustable tap 52 and the rheostat slider 44. Due to the tap 52 being located about in the middle of the resistor 51, the variable signal S_1 produced by the slider 44 will pass through zero voltage, as the slider 44 moves, and the polarity of the signal S_1 will change.

Main Drive Tachometer Means

This means is simply a tachometer 55 which is driven from the main drive shaft 9 through a gear-toothed belt

56 running over gear-toothed pulleys or sprockets. The tachometer 55 is similar to a direct current generator in that it generates a direct current main drive tachometer signal S_2 which varies in voltage substantially in proportion with the speed of the main drive shaft 9. Hence, the electrical signal S_2 produced by the tachometer increases and decreases in voltage as its driven speed increases and decreases. The polarity of the main drive tachometer signal S_2 produced by the tachometer 55 always remains the same, since its direction of rotation remains the same.

Variable Speed D.C. Motor Tachometer Means

This means is another tachometer 59 which is similar to the main drive tachometer 55 and is driven by the variable speed D.C. motor 27 through a cooperating gear-toothed belt 60 running over gear-toothed pulleys. Like the main drive tachometer 55, the variable speed D.C. motor tachometer 59 generates a D.C. motor tachometer signal S_3 which varies substantially in proportion with the speed of the tachometer 59. Also like the tachometer 55, the polarity of the D.C. motor tachometer signal S_3 produced by the tachometer 59 remains the same since the direction of rotation of the tachometer 59 does not change.

Signal Mixer Circuit

This circuit connects the two tachometers 55 and 59 so that their respective signals S_2 and S_3 oppose each other to produce a resultant signal S_4 which may have either a plus or minus polarity, depending on the direction in which the signal difference extends. This circuit is also connected in series with the floating roller sensor means to add S_4 to S_1 and thereby produce a main control signal S_5 . This main control signal S_5 could have either a plus or minus polarity, depending on the polarities of the added signals and their relative values. However, in this case, since it is desired to have motor 27 rotate in the same direction at all times, the system is designed so that the main control signal S_5 normally remains the same polarity.

The signal mixer circuit comprises: a first series circuit including the main drive tachometer 55, a resistor 63 having one end connected to the negative pole of the tachometer 55, a common wire 64 having one end connected to the other end of the resistor 63 and a connecting wire 65 connected between the other end of the common wire 64 and the positive pole of the tachometer 55; a second series circuit, similar to the first series circuit, including the variable speed D.C. motor tachometer 59, a resistor 66 having one end connected to the negative pole of the tachometer 59 and its other end connected to the common wire 64, and a connecting wire 67 running between the other end of the common wire 64 and the positive pole of the tachometer 59; a first main control signal wire 68 connected to a tap movable along the first series circuit resistor 63; a wire 69 connected at one end to a tap movable along the second series circuit resistor 66 and at the other end to the adjustable tap 52 of the floating sensor means; and a second main control signal wire 70 connected to the slider 44 of the rheostat 43. The main control signal S_5 is produced between the two main control signal wires 68 and 70.

Amplifier Means

This means receives the main control signal S_5 from the signal mixer circuit, converts or amplifies that signal to a greatly increased current and supplies that current to the variable speed D.C. motor 27, to operate that motor at a speed determined by the amount of current being fed or supplied to it.

The amplifier means is shown in FIG. 3 as comprising: an Amplidyne generator electrically connected to the variable speed motor 27 for supplying its operating direct current; an alternating current motor driving the Ampli-

dyne generator at a constant speed; and a control amplifier circuit which receives the main control signal S_5 , amplifies that signal and controls the current flowing in the control field coils of the Amplidyne generator in response to that amplified signal.

Amplidyne Generator

This generator is a special type of direct current generator 73 having two sets of brushes with each set being located at right angles, around the generator commutator, relative to the other set of brushes and with one set of brushes being short-circuited. This generator also includes a set of control field coils 74 and 75 for controlling the current output of the generator, that is, the currents flowing in the field coils 74 and 75 control the current produced by the generator. The generator 73 is known by the trade name Amplidyne, is a commercially manufactured item, General Electric being at least one company manufacturing this item, and is well known for use in servo systems as a current amplifier.

A.C. Motor

The alternating current motor 77 is shown as a three-phase motor in FIG. 3, and is mechanically connected through a suitable direct drive to the generator armature. Obviously, other types of constant speed sources of power could be used to drive the generator 73.

Control Amplifier Circuit

The electronic amplifier circuit shown in FIG. 3 is greatly simplified in order for its operation to be easily understood. This simplified circuit may be termed a balanced D.C. amplifier and includes: a pair of amplifier tubes 79 and 80, each having its plate anode connected to an end of a respective control field coil 74 and 75 of the generator 73, the tube 79 being connected to the coil 74 and the tube 80 being connected to the coil 75, and the other ends of the coils, remote from the tubes 79 and 80, being connected together; a direct current source 81 having its positive pole connected by a wire 82 to the common connection between the field coils 74 and 75 and having its negative pole grounded; a voltage divider formed by a pair of resistors 83 and 84 connected in series between the positive pole of the D.C. source 81 and ground and being connected at a point between the two resistors 83 and 84 to the cathodes of both tubes 79 and 80 for providing the cathode with a positive voltage relative to ground; and a pair of suitable resistors 85 of equal resistance value connecting the grids of both tubes to ground for cooperating with the cathode voltage to bias the tubes 79 and 80 at equal appropriate voltages.

The arrangement of the two tubes 79 and 80 and the field coils 74 and 75 form a balanced bridge. As is well understood, the grids of the tubes 79 and 80 control the amount of current flowing in each amplifying tube circuit and in its interconnected field coil (74 or 75). With zero signal input to the grids, the grids are always biased by equal voltages so that the plate currents of the tubes are balanced, causing equal and opposing currents to flow through the control field coils 74 and 75 (field coil 74 conducts a D.C. current flowing in one direction and field coil 75 conducts an equal D.C. current flowing in the opposite direction) and the bridge to be balanced. The field coils 74 and 75 are arranged in the generator 73 so that when they are balanced (conducting equal and opposing currents) they produce equal and opposing fields in the generator which cancel each other and result in zero electrical output of the generator. Hence, in order for the generator 73 to produce an electrical output, the opposing currents in the respective field coils must be unbalanced.

The main control signal S_5 provided by the signal mixer circuit is applied across the grids of the tubes 79 and 80. In particular, the main control signal wire 68 is connected to the grid of the tube 80 and the main control signal wire 70 is connected to the grid of tube 79.

It should now be obvious that the application of the direction current main control signal S_5 across the control grids of the two tubes 79 and 80 will upset the plate current balance of these tubes and cause one tube to draw more current and the other to draw less, the direction of the current unbalance depending on the polarity of the main control signal S_5 . Unbalancing the plate currents of the amplifier tubes will also unbalance the opposing currents flowing in the field coils 74 and 75 and this will cause the Amplidyne generator 73 to produce a current output flowing to the variable speed D.C. motor 27 with the polarity of the direct current output of the generator 73 being determined by the direction of the current unbalance in the field coils.

For example, we may assume: that the bias voltage on the grid of each tube is -4 volts relative to the cathode at zero signal input, when the plate currents are balanced; and that S_5 equals $+5$ volt, with the positive side of S_5 extending in the direction of tube 79. Due to the grid resistors 85 being equal in resistance value and connected to ground, the signal voltage S_5 will be divided equally between the tubes with the grid of tube 79 receiving $+2.5$ volt and the grid tube 80 receiving -2.5 volt. This will shift the grid voltage of tube 79 to -3.75 volts and that on tube 80 to -4.25 volts. Since the bias on tube 79 drops, its plate current increase. Conversely, the bias on the tube 80 increase and its plate current decreases. As a result, the field coil 74 conducts more current than the field coil 75 and the generator 73 produces a current having a polarity determined by the direction of current unbalance in the field coils.

OPERATION

In explaining the operation of the apparatus, we initially assume: that the main drive shaft 9 is driving a printing press at a constant 90% of its maximum operating speed; that the web 1 is being fed by the printing cylinder 6 at a speed of, say, 900 ft. per minute; that the main drive shaft 9 and the variable speed D.C. motor 27 are cooperatively driving the web feed roller 14, with the shaft 9 contributing 101% of the load needed to drive the roller 14; that the floating roller 34 is located at its neutral point, about midway in its normal vertical movement range; that the tension on the web 1 in the supply and adjusting sections is at a constant value of, say, 100 units; and that the main control signal S_5 is such as to cause the Amplidyne to generate the current required to operate the variable speed D.C. motor 27 in the middle of its speed range at, say 740 r.p.m. The neutral point of the floating roller 34 is assumed to be midway between its upper and lower extremes and in the horizontal plane of the horizontal axis of its vertical guide means.

FIG. 4 shows representative curves of the various signals existing in an operative embodiment of the apparatus operating at 90% maximum press speed. The voltage of the various signals are plotted on the vertical coordinate with the horizontal coordinate representing the D.C. voltage supplied by the Amplidyne to the variable speed D.C. motor 27. It should be noted that when the floating roller 34 is at its neutral point, indicated by the vertical dotted line 90, for 90% press speed, the floating roller signal is $+1.25$ volt which corresponds to $+154$ volts fed to D.C. motor 27. Running up the graph in FIG. 4 along the vertical dotted line 90 representing the neutral point, we find that the main drive tachometer signal S_2 is $+94$ volts (this signal remains the same while the press speed remains constant), the D.C. motor tachometer signals S_3 is -94 volts, the resultant signal $S_4(S_2+S_3)$ is zero volts and the main control signal $S_5(S_1+S_4)$ is $+1.25$ volt. It will be understood that so long as the tension on the web 1 in the supply and adjusting sections remains at the same 100 units, these signals will remain at their neutral points lying along the dotted line 90.

It should be understood that the voltage fed to the D.C. motor 27 substantially determines its speed and

that the ratio between the voltage fed to it and its speed varies substantially along a straight line over its normal operating speed range. FIG. 5 illustrates this relation for the portion of its speed range covering the voltage range plotted along the horizontal coordinate in FIG. 4.

We next assume that the tension on the web entering the adjusting section drops from 100 to 90 units. As this lower tensioned or relaxed web flows into the adjusting section, it will be instantly stretched by the weight of the floating roller 34 so as to maintain the tension in the adjusting section at 100 units. In instantly stretching this web, the floating roller 34 moves instantly downward a very small degree. To keep it stretched, it must continue to move downward and thereby progressively lengthen the U-shaped loop. This continued downward movement of the floating roller is slow. For example, when using paper webs, it will seldom, if ever, exceed about 3 inches per minute (which corresponds to a stretch of 1 ft. per 1000 ft. of web length and a web feed speed of 1000 ft. per minute). As the floating roller 34 moves downwardly, it operates lever 45 to raise the rheostat slider 44 and thereby change the floating roller signal S_1 in the positive direction.

We assume that the floating roller signal S_1 rises in the positive direction. Now looking at the graph of FIG. 4, we find that increasing the positive voltage of S_1 also increases the positive voltage of the main control signal S_5 which results in the Amplidyne generator 73 increasing its current output to the D.C. motor 27. In response to the increase in its voltage, the motor 27 increases its speed and causes the web feed roller 14 to reduce its speed a fraction sufficient to feed the web to the adjusting section at a reduced rate sufficient to stop the downward movement of the floating roller 34 (it will be remembered that the D.C. motor 27 and differential drive unit 20 are arranged so that increasing the speed of motor 27 reduces the speed of the web feed roller 14). The arrow pointing to the right of the neutral point line 90 on FIG. 4 indicates this slowing of the feed roller 14.

In the meantime, the increase in speed of the D.C. motor 27 increases the negative voltage of the D.C. motor tachometer signal S_3 which, consequently, subtracts from and reduces the main control signal S_5 and aids the system in reaching a new equilibrium point which we assume corresponds to the point on FIG. 4 where $+158$ volts are fed to the D.C. motor 27. At this new point, S_1 is $+2.135$ volts, S_2 is $+94$ volts, S_3 is -96 volts, S_4 is -2 volts and S_5 is $+1.135$ volt. The system will remain at this point until the tension on the web entering the adjusting section again changes.

Next, we again assume the original conditions and that the tension on the web 1 entering the web feed roller 14 rises from 100 to 110 units. As this web of increased tension flows past the feed roller 14, the web in the adjusting section shrinks, since the tension in the adjusting section is only 100 units, this shrinkage progressively shortens the U-shaped loop and raises the floating roller 34. This progressive rise in the floating roller moves the rheostat slider 44 downward, causing the floating roller sensor means to decrease its positive signal. Looking at FIG. 4, we find that decreasing the positive signal S_1 also decreases the positive main control signal S_5 . Reducing the main control signal S_5 results in reducing the current output of the Amplidyne 73 and slowing the speed of the motor 27 which, in turn, increases the web feeding speed of the feed roller 14 and stops the rise of the floating roller 34 (a reduction in the speed of the D.C. motor 27 raises the speed of the feed roller 14 as indicated on FIG. 4 by the arrow pointing to the left of the neutral line 90).

The slowing of the motor 27 reduces the negative voltage of the D.C. motor tachometer signal S_3 which cooperates with the other signals to bring the system back to equilibrium. We assume that the system reaches equilibrium at a point when the D.C. voltage fed to the D.C.

motor 27 is +150 volts. FIG. 4 shows that at this equilibrium point, the signals are as follows: S_1 is -1.885 volts; S_2 is +94 volts; S_3 is -92; S_4 is +2 volts; and S_5 is +.115 volt.

So far we have limited the description of the apparatus operation to a single speed which was arbitrarily chosen as 90% press speed. It will be realized that an entirely new set of signal conditions are present for each different press speed. It will also be realized that the specific voltage signals used as examples may be varied in many different ways to accomplish the same result, since the relationship between the signal voltages is the important feature, rather than simply the magnitudes of any particular signal.

FIG. 6 shows how the example voltages of the main drive tachometer signal S_2 and the D.C. motor tachometer signal S_3 vary over the speed range of the apparatus between zero and 100% press speed. It will be noted that the main drive tachometer signal S_2 varies along a substantially straight line. This is also true of the D.C. motor tachometer signal S_3 if the tension on the web 1 entering the tension adjusting apparatus always equals the tension of the web inside the adjusting section; this is shown in FIG. 6 by the solid line indicated as the neutral point of the D.C. motor tachometer signal S_3 .

However, normally the D.C. motor tachometer signal S_3 will vary on each side of the neutral point solid line and the diverging dotted lines indicate the limits of the normal range over which the signal S_3 may vary. Note that this signal variance range increases as the press speed rises. This is caused by the fact that, as the press speed rises, the speed of the D.C. motor 27 must vary over a greater speed range to compensate for the usual tension changes in the web 1.

Under the equilibrium conditions of operation illustrated in FIG. 4 along the neutral point line 99, it will be observed: that the floating roller signal S_1 is electro-positive; that the constant-speed signal S_2 is electro-positive; that the variable-speed signal S_3 is electro-negative; and that the electro-positive constant-speed signal S_2 and the electro-negative variable-speed signal S_3 are of equal value, hence produce a resultant speed signal S_4 of zero value. Since the electro-positive control signal S_5 constitutes the sum of the electro-positive floating roller signal S_1 and the zero resultant signal S_4 , it follows that the position of the floating roller alone determines the direction and magnitude of the electro-positive control signal S_5 . However, it is not essential that this be so.

For example, my system can be operated in a manner such that, when it is in equilibrium, the speed signals S_2 and S_3 remain at different values so that they do not cancel each other out but, on the contrary, produce a resultant signal S_4 either of electro-positive or electro-negative character. In such event, the magnitude of the electro-positive control signal S_5 is a function of the sum of signal S_1 , the FIG. 4 curve of which varies in one direction from electro-negative to electro-positive and the resultant signal S_4 , the FIG. 4 curve of which varies in the same direction from electro-positive to electro-negative, these variations taking place in a manner such that the main control signal S_5 normally remains electro-positive.

While the polarity of the main control signal S_5 normally does not change, there are occasions when it may change from electro-positive to electro-negative for an extremely short period of time. For example, if the press control is actuated to decrease the speed of the press, the variable speed D.C. motor 27 will not instantly follow this change in operating speed. As a consequence, if a positive S_5 were being generated immediately prior to this change in operating speed, then, when the change is instituted, a negative signal S_5 will be generated for a fraction of a second. This causes the motor 27 to be dynamically braked and in this way made quickly to respond to the changing condition.

When my apparatus is completely shut down, the web 1

will become slack and the floating roller 34 will fall to its lowest position. With my apparatus, it is possible to restore the tension of the web to its proper value and simultaneously raise the floating roller to its null point elevation simply by energizing the controls without starting up the press motor. The particular manner in which the controls accomplish this result depends upon whether or not the press motor contributes more than 100% or less than 100%.

For example, where the press motor contributes 102%, it tends to rotate the push-feed roller 14 in the correct or forward-feed direction but at a speed of 102% instead of 100%. At the same time, the variable speed motor 27 must contribute a negative 2%; hence, it must try to rotate the push-feed roller 14 in the wrong or backward-feed direction at a speed equal to 2% of normal. Consequently, when the controls are energized before the press motor starts to roll, the variable speed motor 27 will drive the push-feed roller 14 in the wrong direction until the floating roller 34 is raised to its null point level. At this point, the variable speed motor 27 stops rotating but remains energized and continues to apply to push-feed roller 14 whatever torque is required to hold the floating roller 34 at its null point level.

Where the press motor contributes less than 100%, say 98%, the variable speed motor 27 must make a positive contribution of 2%; hence, it must normally tend to rotate the push-feed roller 14 in the same direction as it is rotated by the press motor. Consequently, when the controls only are energized, they will reverse the variable speed motor 27 so that it now makes a negative contribution of 2% and thus tends to feed web from the loop 15 toward the supply roller 2 until the floating roller 34 reaches the null point level. As before, the motor 27 will stop rotating but remain energized sufficiently to apply the torque required to hold floating roller 34 at its null point elevation. However, when motor 10 is energized, it will move the web in the right direction while the energization of motor 27 will be reversed so that it operates to move the web in the same direction.

The arrangement in which the press motor contributes more than 100% is preferred over the arrangement which contributes less than 100% because it avoids a reversal of both the variable speed motor 27 and the tachometer 59. This is desirable because the commutator brush contact of the tachometer changes with changes in direction of rotation and this may undesirably affect the production of the proper electrical signal by the tachometer 59. Furthermore, a constant reversing of the variable speed motor 27 would soon burn and damage its brushes.

SUMMARY

The U-shaped loop 15 of web in the adjusting section has incoming and outgoing legs. The means constraining this web to form loop 15 may be viewed as including the floating roller 34. When the speeds of the incoming and outgoing legs of the looped web are the same, the floating roller position is stationary. It changes only as the amount of web in said U lengths and shortens. This occurs (a) when the web speed of the incoming leg increases or decreases above or below the speed of the web in the outgoing leg. The (a) changes occur with decreases and increases in the tension of the supply web.

The press drive means may be viewed as a means for driving three things, namely: the press; the web leaving the adjusting section; and the web entering the adjusting section. The press drive means for the web leaving the adjusting section includes pinch rollers 5 and 6 which will pull the web from the outgoing leg of the loop 15 and push-feed the web into the printing section at a controlled or desired web printing speed. (In this connection, it may be noted that, when the speed of the press drive shaft 9 increases or decreases, the speed of the web in both legs of loop 15 will increase or decrease in like manner.) The press drive means for the web entering the adjusting section includes a pair of pinch rollers 13-14 which include

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web feed roller 14. The press drive means for the web feed roller 14 operates through differential 20 and tends to drive the web feed roller at a speed such that the speed of the web in the incoming leg of loop 15 normally approximates but does not equal the web printing speed of the outgoing leg of said U, this approximate speed preferably being about 2% in excess of the web printing speed.

The variable speed auxiliary drive for the web feed roller 14 also operates through differential 20 and it tends to drive web feed roller 14 at a speed such that the speed of the web in the incoming leg of loop 15 normally equals the difference between said approximate speed and the web printing speed. Where the same web tension exists before and after the web feed roller 14 and with the press operating to drive the incoming leg web forwardly at a rate equal to 102% of the desired web printing speed, the variable speed motor 27 normally drives the same incoming leg web rearwardly at a rate equal to 2% of the web printing speed.

The speed control system may be said to include: (a) a first means operating, in response to the vertical movement of said floating-roller relative to a stable operating position, to produce an electrical floating-roller signal S_1 of corresponding magnitude and of corresponding electrical sign, which is minus for movement in one direction and plus for movement in the other; (b) a second means operating, in response to a given press-speed of said press drive means, to produce an electrical press-speed signal S_2 of corresponding magnitude and of one electrical sign; (c) a third means operating, in response to the speed of said auxiliary drive means, to produce an electrical auxiliary-speed signal S_3 of corresponding magnitude and of electrical sign opposite to said one sign of said press-speed signal; (d) a fourth means balancing the press-speed signal of said one electrical sign against the auxiliary-speed signal of said opposite sign to produce a resultant-speed signal S_4 of corresponding magnitude and of corresponding electrical sign, which, in relation to said floating-roller signal, is plus for movement in said one direction and minus for movement in said other direction; and (e) a fifth means balancing said resultant-speed signal against said floating-roller signal to produce a main control signal S_5 of corresponding magnitude and of one electrical sign.

As indicated in FIG. 4, for equilibrium operation at a given press speed, each of said five signals has an individual neutral point.

Broadly speaking, the control system operates, in response to a change in said floating-roller signal, to initiate a corrective change in the speed of the variable speed motor, and, in response to a corrective change in the speed of said variable speed motor, to initiate counter-balancing changes tending to bring the system back into equilibrium operation. More specifically, there are two phases of operation.

In the first phase, upon an increase in the speed of the web in the incoming leg of said U and a consequent lowering of the floating-roller, said control system operates, through changes in the floating-roller signal of the first means and in the main control signal of the fifth means, to increase the speed of the auxiliary speed motor and thereby effect a corrective reduction in the speed of the web feed roller. The same sequence occurs with a decrease in the speed of the web in the outgoing leg of said U.

In the second phase, upon said increase in the speed of said auxiliary speed motor and the resultant decrease in the speed of said web feed roller, said apparatus operates to raise said floating-roller to a stable operating position, and said control system operates through said first means to restore said floating-roller signal S_1 , through said third and fourth means to change the resultant-speed signal S_4 , and through said fifth means to balance the changed resultant-speed signal S_4 against the restored floating-roller signal S_1 so as to produce a changed main control signal

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S_5 tending to hold the system in equilibrium operation at the new web feed roller speed.

Having described my invention, I claim:

1. In the art of feeding a printing web from a supply section through an adjusting section into a printing section, an improved apparatus for maintaining the web entering the printing section at a desired speed and under a constant value of tension, comprising:

A. means constraining the web traveling through said adjusting section to form a downwardly depending U-shaped loop having incoming and outgoing web legs,

(1) said means including a floating-roller gravitationally resting on the bight of said loop to maintain the web throughout said loop under a constant value of tension,

(a) said floating-roller rising and falling vertically with said bight as the amount of web in said U lengthens and shortens with changes in the relative speeds of the web constituting the legs of said U;

B. a web feed roller between the supply and adjusting sections;

C. press drive means for continuously

(1) driving the press,

(2) driving the web between the adjusting and printing sections by pulling web from the outgoing leg of the adjusting section and push-feeding the web into the printing section at speeds corresponding to said desired web printing speed, and

(3) driving the web feed roller to pull web from said supply section and to push-feed it into the incoming leg of said adjusting section U at a speed normally approximating but not normally equaling the web printing speed of the outgoing leg of said U;

D. variable speed auxiliary drive means to drive said web feed roller at a speed normally equaling the difference between said approximate speed and said web printing speed and in the corrective direction required normally to cause the web in said incoming leg to travel at the said web printing speed of said outgoing leg, and thereby hold said floating-roller in a stable position; and

E. a control system operative, in response to the vertical motion of said floating-roller out of a stable floating position, to actuate said auxiliary drive means in the direction required to restore said floating-roller to a stable floating position.

2. The apparatus of claim 1 wherein:

A. said press drive and auxiliary drive means for said web feed roller cooperatively include a differential gear unit having an output shaft driving said web feed roller and a pair of power input shafts;

B. said press drive means for the web feed roller normally drives one input shaft of said unit at a relatively constant speed; and

C. said variable auxiliary drive means for the web feed roller comprises a variable speed electric motor driving the other input shaft.

3. The improved apparatus of claim 2 wherein:

A. said web feed roller drive means is arranged so that (1) said press drive means normally tends to drive said differential unit forwardly at a speed in excess of the forward speed required by the differential output shaft to drive the web at the desired web printing speed, and

(2) said variable speed motor normally tends to drive said differential unit backwardly at a speed equal to said excess.

4. The improved apparatus of claim 3 wherein:

A. said variable speed motor is operative to vary the web feed speed of said web feed roller over a range which extends up to about 2% of said web printing speed.

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5. The apparatus of claim 3 wherein said control system includes:

A. a first means operating, in response to the vertical movement of said floating-roller relative to a stable operating position, to produce an electrical floating-roller signal of corresponding magnitude and of corresponding electrical sign, which is minus for movement in one direction and plus for movement in the other.

6. The apparatus of claim 5 wherein said control system includes:

A. a current amplifying means operative, in response to said floating-roller signal, to change the speed of said variable speed motor correspondingly in the corrective direction.

7. The apparatus of claim 5 wherein said control system includes:

A. a second means operating, in response to a given press-speed of said press drive means, to produce an electrical press-speed signal of corresponding magnitude and of one electrical sign.

8. The apparatus of claim 7 wherein said control system includes:

A. a third means operating, in response to the speed of said auxiliary drive means, to produce an electrical auxiliary-speed signal of corresponding magnitude and of electrical sign opposite to said one sign of said press-speed signal.

9. The apparatus of claim 8 wherein:

A. said control system operates, in response to a change in said floating-roller signal, to initiate a corrective change in the speed of the variable speed motor, and, in response to a corrective change in the speed of said variable speed motor, to initiate counter-balancing changes tending to bring the system back into equilibrium operation.

10. The apparatus of claim 8 wherein said control system includes:

A. a fourth means balancing the press-speed signal of said one electrical sign against the auxiliary-speed signal of said opposite sign to produce a resultant-speed signal of corresponding magnitude and of corresponding electrical sign, which, in relation to said

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floating-roller signal, is plus for movement in said one direction and minus for movement in said other direction.

11. The apparatus of claim 10 wherein said control system includes:

A. a fifth means balancing said resultant-speed signal against said floating-roller signal to produce a main control signal of corresponding magnitude and of one electrical sign.

12. The apparatus of claim 11 wherein:

A. each of said signals has an individual neutral point under a given condition of equilibrium operation; and

B. upon an increase in the speed of the web in the incoming leg of said U and a consequent lowering of the floating-roller, said control system operates, through changes in the floating-roller signal of the first means and in the main control signal of the fifth means, to increase the speed of the auxiliary speed motor and thereby effect a corrective reduction in the speed of the web feed roller.

13. The apparatus of claim 12 wherein:

A. upon said increase in the speed of said auxiliary speed motor and the resultant decrease in the speed of said web feed roller,

(1) said apparatus operates to raise said floating-roller to a stable operating position, and

(2) said control system operates

(a) through said first means to restore said floating-roller signal,

(b) through said third and fourth means to change the resultant-speed signal, and

(c) through said fifth means to balance the changed resultant-speed signal against the restored floating-roller signal so as to produce a changed main control signal tending to hold the system in equilibrium operation at the new web feed roller speed.

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