

June 27, 1939.

W. FERRIS

2,163,672

SECTIONAL DRIVE

Filed Aug. 24, 1936

4 Sheets-Sheet 1

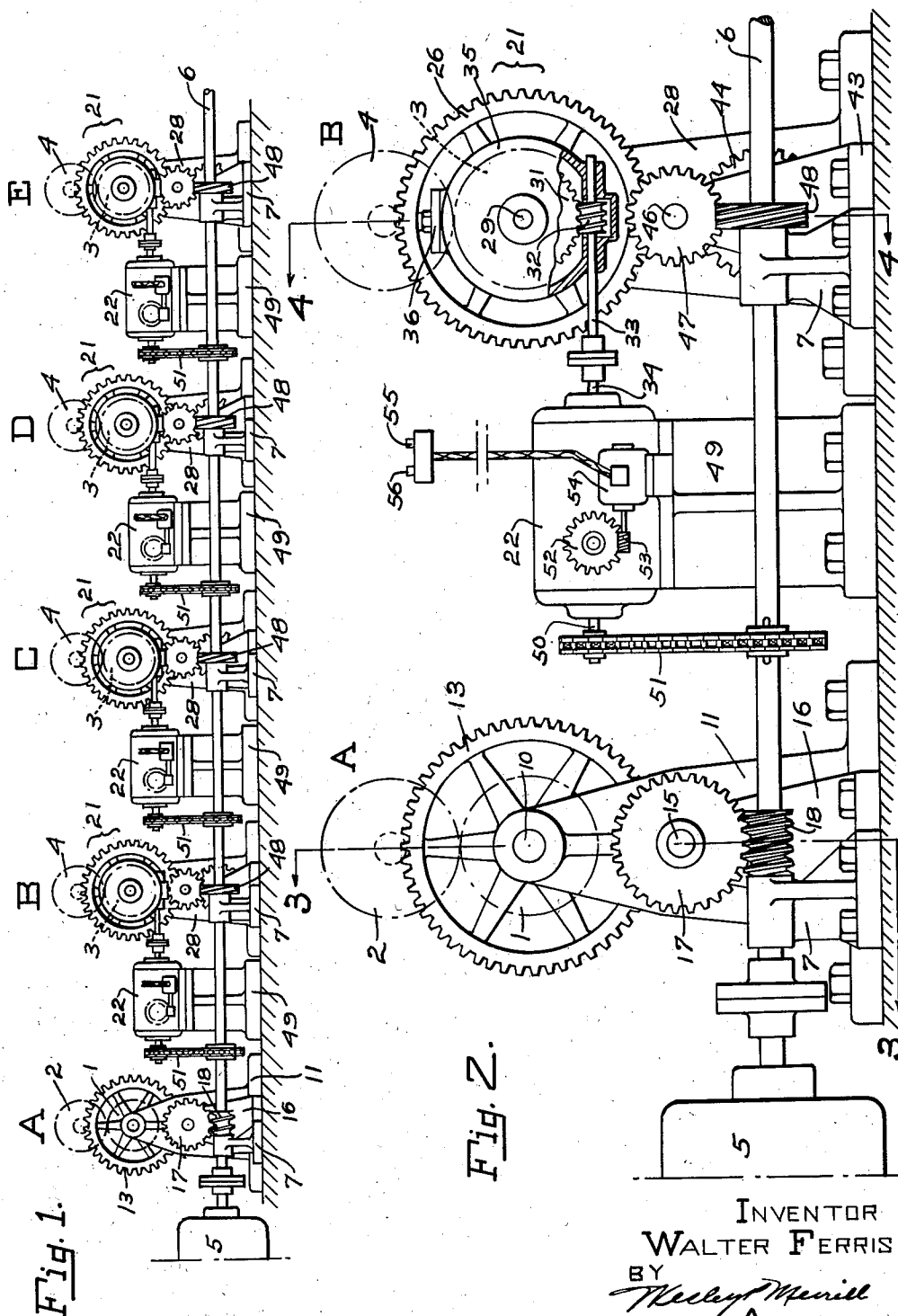


Fig. 2.

INVENTOR
WALTER FERRIS
BY *Kelley Merrill*
ATTORNEY.

June 27, 1939.

W. FERRIS
SECTIONAL DRIVE
Filed Aug. 24, 1936

2,163,672

4 Sheets-Sheet 2

Fig. 3.

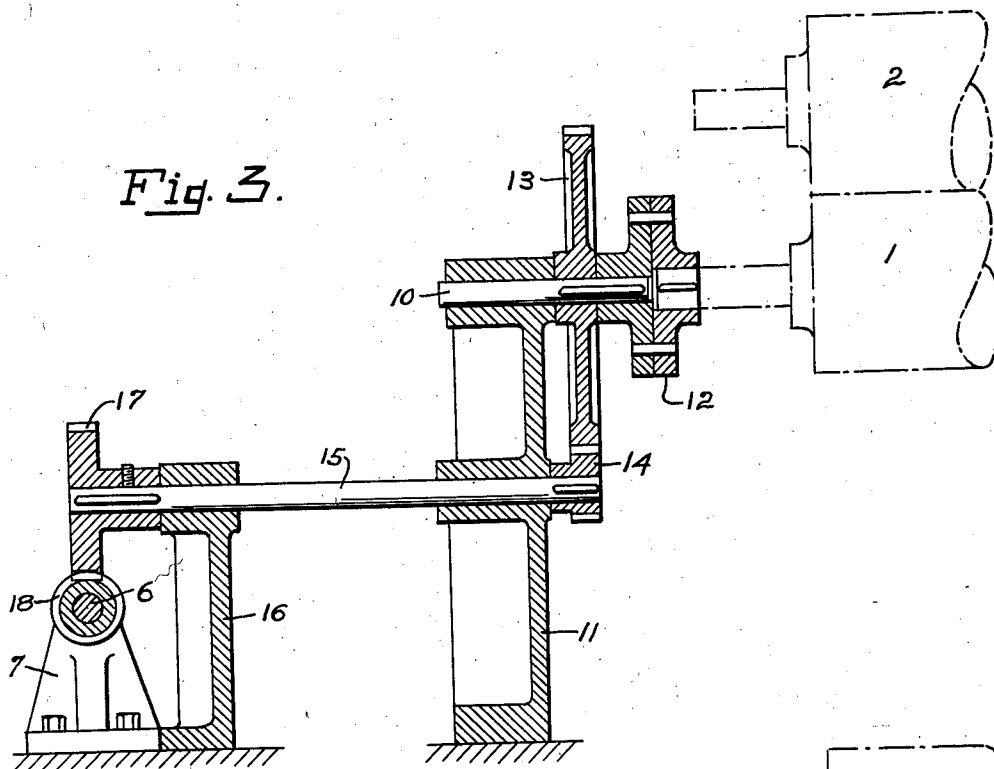
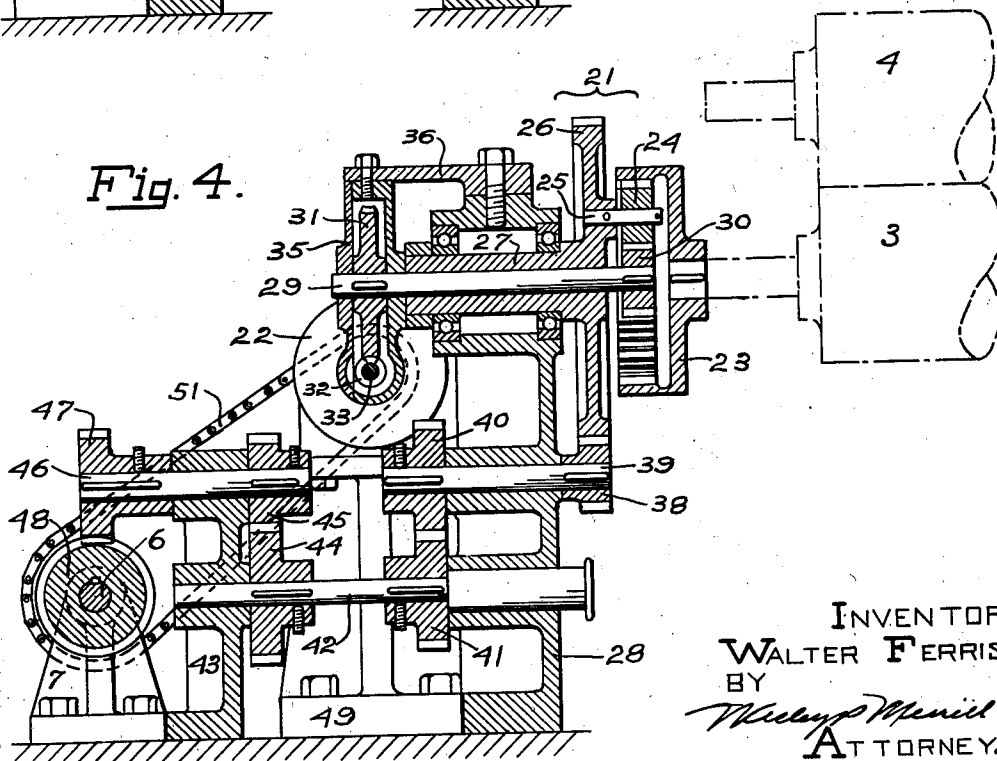


Fig. 4.



INVENTOR
WALTER FERRIS
BY
Walter Ferris
ATTORNEY.

June 27, 1939.

W. FERRIS

2,163,672

SECTIONAL DRIVE

Filed Aug. 24, 1936

4 Sheets-Sheet 3

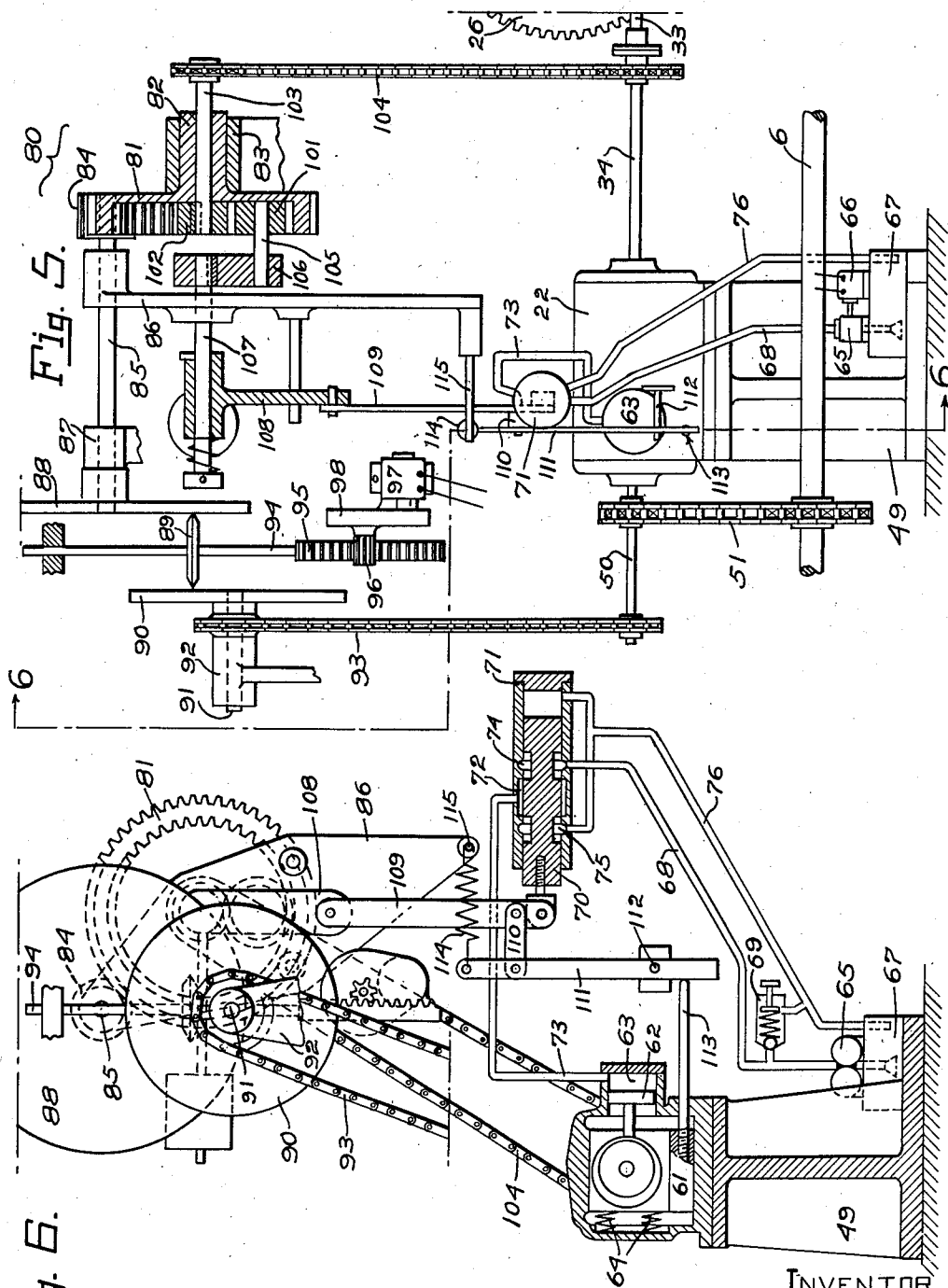


Fig. 6.

INVENTOR
WALTER FERRIS
BY
Wesley Merrill
ATTORNEY.

June 27, 1939.

W. FERRIS

2,163,672

SECTIONAL DRIVE

Filed Aug. 24, 1936

4 Sheets-Sheet 4

Fig. 7.

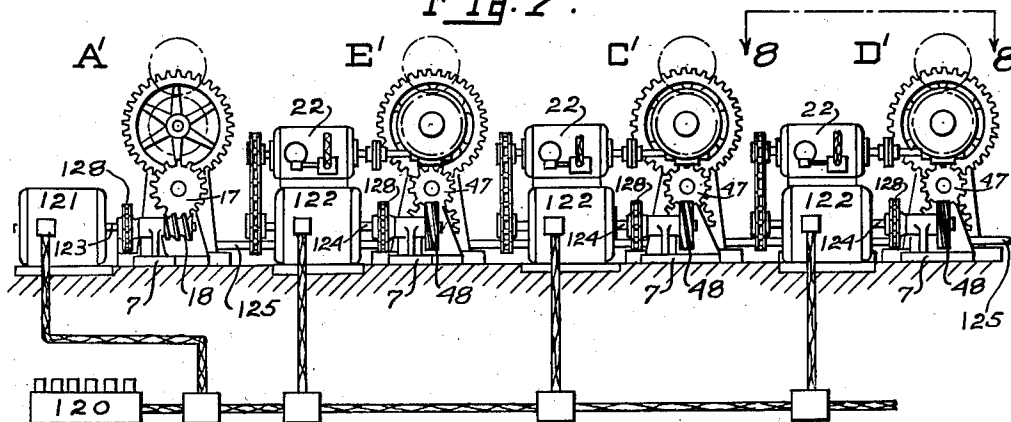
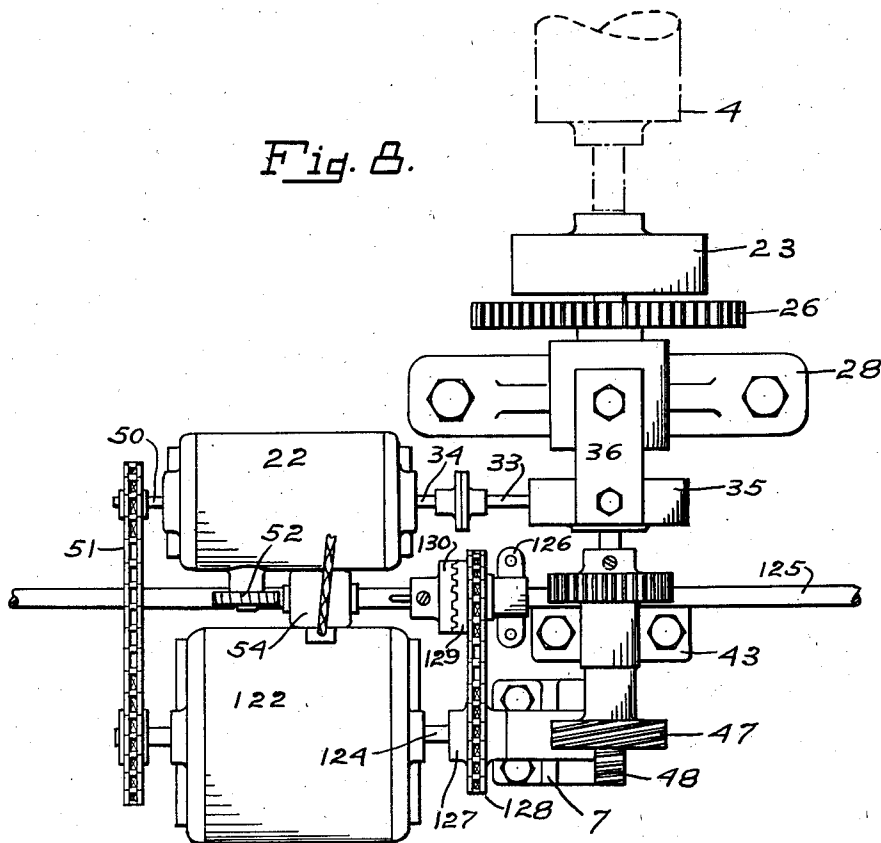


Fig. 8.



INVENTOR
WALTER FERRIS
BY
Walter P. Merritt
ATTORNEY.

UNITED STATES PATENT OFFICE

2,163,672

SECTIONAL DRIVE

Walter Ferris, Milwaukee, Wis.

Application August 24, 1936, Serial No. 97,609

15 Claims. (Cl. 74—389)

This invention relates to sectional drives of a type employed to drive a group of related machines or the several sections of a single machine which require to be driven at closely regulated proportional speeds, and it is particularly applicable to machines which are employed to manufacture or process materials in substantially continuous webs or strips such as paper machines, rolling mills, printing presses, film processing machines and the like.

The manufacture or processing of such materials often requires that the speeds of the several machines or machine sections be independently adjustable and that the overall speed of the sectional machine or a group of related machines be variable through a wide range while maintaining the speeds of the individual machines or machine sections proportional to each other.

Certain materials which are manufactured or processed in substantially continuous strips or webs, such as paper and the like, require that the web be kept under tension during its passage through the machine and that the tension be maintained within close limits. However the action of certain machine units upon the web causes the web to vary in length during its passage through the unit so that it is necessary to compensate for such variations in length by driving each of certain units at a speed slightly different from the speed of the preceding unit to provide a draw between adjacent units and thereby maintain the proper tension upon the web.

In certain processes, the web may be varied but little in length during its passage through one machine unit so that, with the proper tension maintained thereon, its linear speed at one unit may vary but slightly, for instance one-tenth of one percent, from its linear speed at the adjacent unit. Consequently, provision should be made for the close and accurate adjustment of the speed of the several units.

The present invention has as an object to provide a sectional drive which will permit the speed of the several machine units driven thereby to be very accurately adjusted relative to each other and the overall speed to be varied through a wide range without altering the ratio between the speeds of the individual units.

Another object is to provide a sectional drive of the above character which is positive and precise in operation.

Other objects and advantages will appear from the description hereinafter given of the sectional

drives shown schematically in the accompanying drawings in which the views are as follows:

Fig. 1 is an elevation of a drive for a paper machine of which only the ends of certain rolls have been shown.

Fig. 2 is a view on a larger scale of a part of the drive shown in Fig. 1.

Fig. 3 is a section on the line 3—3 of Fig. 2.

Fig. 4 is a section on the line 4—4 of Fig. 2.

Fig. 5 is a view showing a control for one of the variable speed transmissions shown in Fig. 1.

Fig. 6 is a view taken approximately on irregular line 6—6 of Fig. 5.

Fig. 7 is a view similar to Fig. 1 but showing a modified form of drive.

Fig. 8 is a plan view taken on the line 8—8 of Fig. 7.

The invention has been shown applied to a paper machine but it is to be understood that it is applicable to other uses.

Figs. 1 to 4

The drive is provided with a plurality of sections, five being shown and indicated by the reference letters A, B, C, D and E. Each drive section is shown connected to a section of a paper machine which, since it forms no part of the present invention, has each section thereof represented solely by a pair of rolls, the rolls in the section driven by drive section A being indicated by the reference numerals 1 and 2 and the rolls in each of the sections B, C, D and E being indicated by reference numerals 3 and 4.

Power is transmitted to the several drive sections from a variable speed power source 5 through a line shaft 6 journaled in a plurality of stationary bearings 7 one of which is arranged at each of drive sections A, B, C, D and E. Power source 5 may be of any suitable type, such as a steam engine, a variable speed electric motor, or a constant speed prime mover connected to shaft 6 through a variable speed transmission such as a hydraulic transmission consisting primarily of a pump and a motor.

In order to provide the draw between the several sections of a paper machine, it is necessary to have all but one of the drive sections adjustable to vary the speed of the machine sections connected thereto relative to the speed of line shaft 6. To this end, section A has been shown as being non-adjustable and sections B, C, D and E have been shown as being adjustable and identical to each other.

Section A is provided with a drive shaft 10 (Fig. 3) which is journaled in the upper end of

a stationary double bearing 11 and connected by a coupling 12 to the axle or shaft of roll 1. Shaft 10 has a gear 13 fixed thereon and in mesh with a pinion 14 which is fixed upon one end of a shaft 15 journaled in bearing 11 and in a stationary bearing 16. The other end of shaft 15 has a worm wheel 17 fixed thereon and in mesh with a worm 18 which is fixed upon line shaft 6. The arrangement is such that roll 1 is caused to be driven from line shaft 6 at a speed exactly proportional to the speed of prime mover 5.

Each of drive sections B, C, D and E is provided with a three legged differential 21 which has one leg connected to a section of the machine to drive the same, a second leg driven from line shaft 6 and a third leg driven by the output shaft of a separate variable speed transmission 22 the input shaft of which is driven in synchronism with line shaft 6 by being either driven directly therefrom or from a separate power source synchronized therewith.

Differential 21 is so constructed and proportioned that a very large portion of the power required to drive the machine section is transmitted thereto through the second leg of the differential and only a small portion thereof is transmitted thereto through the third leg so that a relatively small transmission may be employed and the speed of the machine section varied micrometrically.

The use of such a small transmission limits the range through which the speed of the machine section may be varied by adjusting the transmission. For example, if 90% of the power is transmitted through the second leg of the differential and only 10% is transmitted through the third leg of the differential, a speed range of only 10% may be obtained by adjustment of transmission. Therefore, in order to provide a wider speed range and to avoid using the entire range of the transmission, each adjustable section is also provided with change speed gears as will hereinafter appear.

Since drive sections B, C, D and E are identical, only one will be described and the corresponding parts of the other sections will be indicated by corresponding reference numerals.

As best shown in Fig. 4, differential 21 is provided with an internal gear 23 which is fixed upon the axle of roll 3 and meshes with a planet pinion 24 journaled upon a stub shaft 25 fixed in a gear 26 intermediate the axis and periphery thereof. Only one planet pinion has been shown but additional ones may be similarly connected to gear 26 according to the usual practice.

Gear 26 is provided with an elongated hollow hub 27 which is journaled in suitable bearings arranged in the upper end of a bearing bracket 28. A shaft 29 extends through and is journaled in hub 27 and has a sun pinion 30 fixed upon its rear end and in mesh with planet pinion 24.

Shaft 29 has a worm wheel 31 fixed upon its front end and in mesh with a worm 32 fixed upon a shaft 33 (Fig. 2) which is connected by a suitable coupling to the output shaft 34 of transmission 22. Worm wheel 31 and worm 32 are arranged inside a gear case 35 in which the ends of shaft 33 are journaled and which is supported from bracket 28 as by means of an arm 36.

Gear 26 (Fig. 4) meshes with a gear 38 which is fixed upon one end of a shaft 39 journaled in bracket 28. Shaft 39 has a gear 40 arranged upon the other end thereof and in mesh with a gear 41 which is arranged upon a shaft 42 journaled in bracket 28 and in a bearing bracket 43.

Shaft 42 has a gear 44 arranged thereon and in mesh with a gear 45 arranged upon one end of a shaft 46 which is journaled in bracket 43 and has a spiral gear 47 fixed upon its outer end and in mesh with a spiral gear 48 fixed upon line shaft 6 so that gear 26 may be driven from line shaft 6 through shafts 39, 42 and 46 and the gears carried thereby.

Gears 40, 41, 44 and 45 are removably fixed upon their respective shafts, as by being keyed thereto and restrained from axial movement by suitable set screws, so that they may be removed and replaced by gears of a different ratio to thereby vary the speed of gear 26 relative to the speed of line shaft 6. To this end, that part of shaft 42 which is journaled in bracket 28 is enlarged so that its bearing in bracket 28 is large enough to permit the keys in shaft 42 to pass therethrough.

In order that transmission 22 may be so small that it is capable of transmitting only a small fraction of the power required to drive a section of the machine, and in order that it may be adjusted to vary the speed of the section micrometrically, it should be of a type capable of having its output speed varied steplessly from approximately zero to maximum, such as a hydraulic transmission consisting of a variable displacement pump and a constant displacement motor arranged in a single casing. Since such transmissions are well known and in extensive commercial use, a detailed description thereof will not be given, it being deemed sufficient to state that transmission 22 is supported upon a pedestal 49 and has its input shaft 50 driven from line shaft 6 through a chain and sprocket drive 51 and that the ratio between the speed of its output shaft 34 and its input shaft 50 may be varied by varying pump displacement.

As shown, transmission 22 has the stroke changing mechanism of its pump provided with a worm wheel 52 rotation of which in one direction or the other will increase or decrease pump displacement. Worm wheel 52 meshes with a worm 53 connected to and driven by a reversible electric motor 54 operation of which is controlled by two normally open push button switches 55 and 56. Closing one or the other of switches 55 and 56 will cause motor 54 to rotate worm wheel 52 through worm 53 to vary pump displacement and thereby vary the ratio between the input and output speeds of transmission 22.

The arrangement is such that the speed of roll 3 relative to the speed of line shaft 6 may be varied in steps through a relatively wide range by changing the ratio of change speed gearing 40-41-44-45, and it may be varied gradually and uniformly through a limited range by closing switch 55 or 56 to thereby vary the ratio between the output and input speeds of transmission 22.

As previously explained, differential 21 is so proportioned that the greater part of the power required to drive roll 3 is transmitted thereto through the second leg of the differential and only a very small part of the power is transmitted thereto through the third leg of the differential. To this end, the gear ratios are such that gear 26 is rotated at a relatively high speed and sun pinion 30 at a very slow speed.

If transmission 22 should be so adjusted that the speed of its output shaft 34 would be reduced to zero, roll 3 would be driven at a given speed which would be proportional to the speed of gear 26. Then, if transmission 22 should be adjusted

to cause sun pinion 30 to rotate in a positive direction, roll 3 would be rotated at a speed equal to the given speed plus the speed imparted thereto by rotation of sun pinion 30. Also if a reversible transmission should be employed and it should be adjusted to rotate sun pinion 30 in a negative direction, roll 3 would be rotated at a speed equal to the given speed minus the negative speed imparted thereto by rotation of sun pinion 30.

- 10 From the foregoing it is obvious that, when line shaft 6 is rotated, roll 1 will be driven by section A and rolls 3 by sections B, C, D and E at speeds proportional to the speed of shaft 6 so that all of the machine sections will be driven at speeds proportional to each other, that the speed of any or all of sections B, C, D and E may be varied relative to the speed of any other section, and that by varying the speed of shaft 6 the overall speed of the entire machine may be varied without varying the relative speed of the several machine sections.

Figs. 5 and 6

- In case the drive is provided with a hydraulic transmission for driving the third leg of a differential 21 and if the load on that transmission is variable and great enough at times to cause an appreciable amount of internal leakage or slip in the transmission so that there would be a variation in the ratio between the speeds of the input and output shafts of the transmission, a control may be provided for maintaining the speed of the output shaft exactly proportional to the speed of the input shaft under all operating conditions. A control which may be employed for this purpose is fully illustrated and described in my co-pending application Serial No. 47,008 filed October 28, 1935.

- When such a control is employed, transmission 22 is provided with a hydraulically operated stroke changing mechanism instead of the electrically operated stroke changing mechanism previously described. As shown, the pump of transmission 22 is adapted to have its stroke changing member or slide block 61 shifted in one direction or the other by operation of a hydraulic servomotor the piston 62 of which is connected to slide block 61 and fitted in a cylinder 63 carried by the transmission casing. Slide block 61 is continuously urged in one direction by springs 64 and is adapted to be moved in the opposite direction by motive liquid supplied to cylinder 63.

- Liquid for operating servo-motor 62-63 is ordinarily supplied thereto from a gear pump arranged in a transmission casing and driven in unison with the pump. For the purpose of illustration however, the control is shown provided with an external gear pump 65 which is driven continuously by an electric motor 66. Gear pump 65 draws liquid from a reservoir 67 and discharges it into a supply channel 68. All liquid discharged by gear pump 65 in excess of control requirements is exhausted into reservoir 67 through a low pressure relief valve 69 which is connected to channel 68 intermediate the ends thereof and enables pump 65 to maintain a low pressure therein.

- The delivery of liquid from gear pump 65 to cylinder 63 is controlled by a valve 70 which is closely fitted in a valve casing 71 and shown as extending through the front end thereof. Valve casing 71 is provided with a port 72 which is connected by channel 73 to cylinder 63, a port 74 which is arranged at one side of port 72 and has channel 68 connected thereto, and a port 75 which is arranged at the other side of port 72 and

has connected thereto a drain channel 76 which discharges into reservoir 67 and is also connected to the rear end of valve casing 71.

When valve 70 is shifted toward the left from a central or neutral position, liquid from pump 65 may flow through channel 68, valve casing 71 by way of ports 74 and 72 and then through channel 73 to cylinder 63 and move piston 62 and slide block 61 toward the left to increase pump displacement and, when valve 70 is shifted toward the right from its central or neutral position, springs 64 may move slide block 61 toward the right and cause piston 62 to expel liquid from cylinder 63 through channel 73, valve casing 71 by way of ports 72 and 75 and through channel 76 into reservoir 67.

Valve 70 is shifted in one direction or the other in response to any variation in the speed of the output shaft 34 of transmission 22 relative to the speed of the input shaft 50 thereof as reflected by any movement of the output leg of a three legged differential 80 which has one of its input legs driven at a speed proportional to the speed of shaft 34 and its other input leg driven at a speed proportional to the speed of shaft 50.

As shown, differential 80 is provided with an external-internal gear 81 having a hollow hub 82 which is journaled in a bearing 83. The external teeth on gear 81 mesh with a pinion 84 fixed upon one end of a shaft 85 which is journaled in stationary bearing brackets 86 and 87 and has a disk 88 fixed upon its other end. Rotation is imparted to disk 88 through an idler disk 89 from a disk 90 which is fixed upon a shaft 91 journaled in a bearing 92. Disk 90 is rotated by means of a chain and sprocket drive 93 which connects shaft 91 to the input shaft 50 of transmission 22.

Disks 88, 89 and 90 and the shafts thereof constitute a variable speed transmission for transmitting motion from shaft 50 to one input leg of differential 80. The speed of shaft 85 relative to the speed of shaft 91 may be varied by moving disk 89 toward and from the axes of disks 88 and 90. This may be accomplished in any suitable manner but, solely for the purpose of illustration, disk 89 is shown journaled upon a stem 94 which has a rack 95 fastened thereto. Rack 95 meshes with a pinion 96 which is adapted to be rotated at a slow speed in one direction or the other by a reversible electric motor 97 through a reduction gear 98. Electric motor 97 may be controlled in the same manner that motor 54 is controlled as shown in Fig. 2.

The internal teeth on gear 81 mesh with a planet pinion 101 which also meshes with a sun pinion 102 fixed on one end of a shaft 103 which extends through hub 82 and is driven through a chain and sprocket drive 104 from the output shaft 34 of transmission 22.

Planet pinion 101 is arranged upon one end of a shaft 105 which is carried by an arm 106, either the shaft being rotatable in the arm or the pinion being rotatable on the shaft. Arm 106 is fixed upon one end of a shaft 107 which is journaled in bracket 86 and has an operating arm 108 arranged thereon and yieldingly held against rotation relative thereto.

Arm 108 is pivoted at its lower end to the upper end of a lever 109 which is connected at its lower end to valve 70 and pivoted intermediate its ends by a link 110 to a lever 111 intermediate the ends thereof. Lever 111 is pivoted intermediate its ends upon a stationary pin 112 and its lower end engages a follow up rod 113 fastened

to slide block 61. The lower end of lever 111 is held in contact with rod 113 by a spring 114 which has one end thereof connected to the upper end of lever 111 and its other end connected to a pin 115 carried by bracket 86.

The arrangement is such that, when transmission 22 is so adjusted that its output shaft 34 is rotated at the desired speed relative to the speed of input shaft 50, gear 81 and sun pinion 102 will be rotated at such speeds that planet pinion 101 will rotate upon a stationary axis. Consequently, no motion will be imparted to arm 106 and valve 70 will remain in its central or neutral position and thereby retain slide block 61 in its adjusted position.

However, if the load on transmission 22 should vary enough to cause a variation in the speed of shaft 34, sun pinion 102 would be rotated at a faster or slower rate and thereby cause planet pinion 102 to move a short distance in one direction or the other around gear 81. Pinion 101 in moving around gear 81 would swing arm 106, and consequently arm 108, through a small arc. Arm 108 would swing the upper end of lever 109 in one direction or the other, and lever 109 would pivot upon the pin in the end of link 110 and shift valve 70 in one direction or the other.

If the speed of shaft 34 should decrease due to an increase in the load on transmission 22, valve 70 would be shifted toward the left to permit liquid to flow to cylinder 63 and move slide block 61 toward the left to increase pump displacement and thereby increase the speed of shaft 34. As slide block 61 moved toward the left, it would move rod 113 with it and permit spring 114 to swing lever 111 upon pin 112 and thereby tend to move valve 70 toward the right to its neutral position as fast as lever 109 moved it toward the left so that, as soon as shaft 34 had been accelerated to its initial speed, valve 70 would be closed and further adjustment of pump displacement would cease.

If the speed of shaft 34 should increase due to a decrease in the load on transmission 22, valve 70 would be shifted toward the right to permit liquid to escape from cylinder 63 and springs 64 would move slide block 61 toward the right to decrease pump displacement and thereby decrease the speed of shaft 34. As slide block 61 moved toward the right, it would move rod 113 with it. Rod 113 would swing lever 111 upon pin 112 and thereby tend to move valve 70 toward the left to its neutral position as fast as lever 109 moved it toward the right so that, as soon as shaft 34 has been decelerated to its initial speed, valve 70 would be closed and further adjustment of pump displacement would cease.

The speed of shaft 34 is thus maintained exactly proportional to the speed of shaft 50 regardless of the variation in load upon transmission 22. If it is desired to vary the speed of shaft 34 relative to the speed of shaft 50 to thereby provide draw or to change the draw between two sections of the paper machine, disk 89 may be shifted to vary the ratio between shafts 85 and 91.

Figs. 7 and 8

The drive shown in these figures differs from the drive shown in Figs. 1 to 4 only in that each section is driven by a separate variable speed prime mover and the speeds of the prime movers are synchronized by an equalizing shaft. Consequently, corresponding parts of the two drives have been indicated by corresponding reference

numerals and further detailed description thereof will not be given.

For the purpose of illustration, the drive is shown provided with variable speed electric motors which are controlled from a single station by means of push button switches arranged upon a panel 120 but it is to be understood that other types of prime movers, such as steam engines, may be employed and that the prime movers may also be controlled from individual stations.

Fig. 7 shows four drive sections A¹, B¹, C¹ and D¹ which are the same, respectively, as the previously described sections A, B, C and D except that section A¹ is driven by a variable speed electric motor 121 and each of sections B¹, C¹ and D¹ is driven by a variable speed electric motor 122 instead of all of the sections being driven from line shaft 6. In section A¹ the worm 18 which meshes with worm wheel 17 is fixed upon the shaft 123 of motor 121 and, in each of sections B¹, C¹ and D¹, the spiral gear 48 which meshes with spiral gear 47 is fixed upon the shaft 124 of a motor 122, the motor shafts 123 and 124 being journaled in bearings 7 which are substantially the same as the bearings 7 shown in Figs. 1 to 4.

Motors 121 and 122 are adapted to operate at proportional speeds when each is carrying its normal load. In order to keep the speed of all of the motors absolutely synchronized, the drive is provided with an equalizing shaft 125 which is journaled in bearings 126 and to which all of the motors are mechanically connected as by means of a chain and sprocket drive.

As shown, each of motor shafts 123 and 124 has a sprocket 127 fixed thereon and connected by a chain 128 to a sprocket 129 which is arranged upon shaft 125 and ordinarily fixed for rotation therewith. In order that one or more of the drive sections may remain idle when the other sections are operating, each sprocket 129 may be journaled upon shaft 125 and connected thereto by a clutch 130 which is keyed thereon and restrained from axial movement by a suitable set screw. Then, if it is desired that any section shall remain idle during operation of any other sections, it is simply necessary to cut the motor connected to that section out of the circuit by means of a switch on panel 120 and to disengage the clutch 130 which connects that motor to shaft 125.

The speeds of the active motors will be positively synchronized by equalizing shaft 125 so that the drive will function in exactly the same manner as the drive shown in Figs. 1 to 4 and previously described. Also, if desired, the control mechanism disclosed in Figs. 5 and 6 may be applied to each or any of the transmissions 22 in the manner previously explained.

The invention herein set forth in susceptible of various modifications and adaptations without departing from the scope thereof as hereafter claimed.

The invention is hereby claimed as follows:

1. The combination, with two machine units which require to be driven at proportional speeds, of a drive, means for driving the first of said units from said drive at a speed proportional to the speed thereof, a three legged differential having a first or output leg connected to the second of said units to drive the same and a second or input leg driven from said drive, a variable speed transmission having an input shaft driven from said drive at a speed proportional to the speed thereof and an output shaft connected to the

third or other input leg of said differential to drive the same and thereby enable said first leg to drive said second unit, means for initially adjusting said transmission to vary the speed of its output shaft relative to the speed of its input shaft and thereby vary the speed of said second unit relative to the speed of said first unit, and means responsive to a variation in the ratio between the input and output speeds of said transmission for automatically adjusting said transmission to correct said variation.

2. The combination, with two machine units which require to be driven at proportional speeds, of a drive, means for driving the first of said units from said drive at a speed proportional to the speed thereof, a three legged differential having a first or output leg connected to the second of said units to drive the same and a second or input leg driven from said drive, a hydraulic transmission including a pump driven from said drive at a speed proportional to the speed thereof and a hydraulic motor driven by liquid supplied thereto by said pump and having an output shaft connected to the third or other input leg of said differential to drive the same and thereby enable said first leg to drive said second unit, said differential being so constructed and proportioned that only a small fraction of the power required to drive the unit connected thereto need be transmitted through said third leg whereby a relatively small transmission is enabled to drive said third leg, and means for varying the displacement of said pump between zero and maximum to effect a variation in the speed of said output shaft and thereby vary the speed of said second unit relative to the speed of said first unit.

3. The combination, with two machine units which require to be driven at proportional speeds, of a drive, means for driving the first of said units from said drive at a speed proportional to the speed thereof, a three legged differential having a first or output leg connected to the second of said units to drive the same and a second or input leg driven from said drive, a hydraulic transmission including a pump driven from said drive at a speed proportional to the speed thereof and a hydraulic motor driven by liquid supplied thereto by said pump and having an output shaft connected to the third or other input leg of said differential to drive the same and thereby enable said first leg to drive said second unit, said differential being so constructed and proportioned that only a small fraction of the power required to drive the unit connected thereto need be transmitted through said third leg whereby a relatively small transmission is enabled to drive said third leg, means for varying the displacement of said pump between zero and maximum to effect a variation in the speed of said output shaft and thereby vary the speed of said second unit relative to the speed of said first unit, means responsive to a variation in the ratio between the input and output speeds of said transmission for automatically operating said displacement varying means to effect a correction of said variation, and means cooperating with the last named means for effecting operation of said displacement varying means to obtain an initial adjustment of pump displacement.

4. The combination, with two machine units which require to be driven at proportional speeds, of a drive, means for driving the first of said units from said drive at a speed proportional to the speed thereof, a three legged differential having a first or output leg connected to the second

of said units to drive the same and a second or input leg driven from said drive, a hydraulic transmission including a pump driven from said drive at a speed proportional to the speed thereof and a hydraulic motor driven by liquid supplied thereto by said pump and having an output shaft connected to the third or other input leg of said differential to drive the same and thereby enable said first leg to drive said second unit, said differential being so constructed and proportioned that only a small fraction of the power required to drive the unit connected thereto need be transmitted through said third leg whereby a relatively small transmission is enabled to drive said third leg, change speed gears connected between said drive and said second leg of said differential for varying in definite steps the speed of said second unit relative to the speed of said first unit, and means for varying the displacement of said pump between zero and maximum to effect a variation in the speed of said output shaft and thereby vary the speed of said second unit through a limited stepless range relative to the speed of said first unit.

5. The combination, with a plurality of machine units which require to be driven at proportional speeds, of a three legged differential associated with each of certain of said units and having the first leg thereof connected to that unit to drive the same, means for driving a second leg of each differential at a speed proportional to the speed at which the corresponding legs of the other differentials are driven, a stepless variable speed transmission associated with each differential and having an input shaft driven at a speed proportional to the speed of said driving means and an output shaft connected to the third leg of that differential to drive the same and thereby enable the first leg thereof to drive the unit connected to that differential, means for initially adjusting each transmission to vary the speed of its output shaft relative to the speed of its input shaft and thereby vary the speed of the unit associated with that transmission relative to the speed of another unit, and means responsive to a variation in the ratio between the input and output speeds of said transmission for automatically adjusting said transmission to correct said variation.

6. The combination, with a plurality of machine units which require to be driven at proportional speeds, of a three legged differential associated with each of certain of said units and having the first leg thereof connected to that unit to drive the same, means for driving a second leg of each differential at a speed proportional to the speed at which the corresponding legs of the other differentials are driven, a stepless variable speed transmission associated with each differential and having an input shaft driven at a speed proportional to the speed of said driving means and an output shaft connected to the third leg of that differential to drive the same and thereby enable the first leg thereof to drive the unit connected to that differential, said differential being so constructed and proportioned that more than three-fourths of the power required to drive the unit connected thereto is transmitted through said second leg whereby a relatively small transmission is enabled to drive said third leg, means for initially adjusting each transmission to vary the speed of its output shaft relative to the speed of its input shaft and thereby vary the speed of the unit associated with that transmission relative to the speed of another

unit, and means responsive to a variation in the ratio between the input and output speeds of said transmission for automatically adjusting said transmission to correct said variation.

- 5 7. The combination, with a plurality of machine units which require to be driven at proportional speeds, of a line shaft for driving all of said units, a variable speed prime mover connected to said shaft to drive the same, a three
10 legged differential associated with each of certain of said units and having a first or output leg connected to the unit associated therewith to drive the same and a second or input leg
15 driven from said line shaft, a variable speed transmission associated with each differential and having an input shaft driven from said line shaft and an output shaft connected to the third or
20 other input leg of that differential to drive the same and thereby enable said first leg to drive said unit, means for initially adjusting said transmission to vary the speed of its output shaft relative
25 to the speed of its input shaft and thereby vary the speed of the third leg of said differential whereby varying the speed of said prime mover will vary the speed of all of said units and adjusting one transmission will vary the speed of
30 one unit relative to the speed of the other units, and means responsive to a variation in the ratio between the speeds of the input and output shafts of at least one of said transmissions for automatically correcting said variation.

8. The combination, with a plurality of machine units which require to be driven at proportional speeds, of a line shaft for driving all of
35 said units, a variable speed prime mover connected to said shaft to drive the same, a three legged differential associated with each of certain of said units and having a first or output leg connected to the unit associated therewith to
40 drive the same and a second or input leg driven from said line shaft, a variable speed transmission associated with each differential and having an input shaft driven from said line shaft and an output shaft connected to the third or other
45 input leg of that differential to drive the same and thereby enable said first leg to drive said unit, said differential being so constructed and proportioned that more than three-fourths of the power required to drive the unit connected
50 thereto is transmitted through said second leg to thereby enable a relatively small transmission to drive said third leg, means for initially adjusting said transmission to vary the speed of its output shaft relative to the speed of its input shaft
55 and thereby vary the speed of the third leg of said differential whereby varying the speed of said prime mover will vary the speed of all of said units and adjusting one transmission will vary the speed of one unit relative to the speed of the other units, and means responsive to a variation
60 in the ratio between the speeds of the input and output shafts of at least one of said transmissions for automatically correcting said variation.

9. The combination, with a plurality of machine units which require to be driven at proportional speeds, of a variable speed prime mover
65 for driving each of said units, an equalizing shaft connecting said prime movers together to synchronize the speeds thereof, means connecting each unit to one of said prime movers, each of certain of said means including a three legged differential having its first or output leg connected to the unit associated therewith to drive
70 the same and its second or input leg driven by the prime mover associated with that unit, a

variable speed transmission having its input shaft driven by said prime mover and its output shaft connected to the third or other input leg of said differential to drive the same and thereby enable said first leg to drive said unit, and
5 means for adjusting said transmission to vary the speed of its output shaft relative to the speed of its input shaft whereby adjustment of one transmission will vary the speed of one unit relative to the speeds of the other units.

10. The combination, with a plurality of machine units which require to be driven at proportional speeds, of a variable speed prime mover for driving each of said units, means for changing
15 the speeds of said prime movers simultaneously, an equalizing shaft connecting said prime movers together to synchronize the speeds thereof, means connecting each unit to one of said prime movers, each of certain of said means including a three legged differential having its
20 first or output leg connected to the unit associated therewith to drive the same and its second or input leg driven by the prime mover associated with that unit, a variable speed transmission having its input shaft driven by said
25 prime mover and its output shaft connected to the third or other input leg of said differential to drive the same and thereby enable said first leg to drive said unit, and means for adjusting said transmission to vary the speed of its output shaft relative to the speed of its input shaft
30 whereby adjustment of one transmission will vary the speed of one unit relative to the speeds of the other units and adjustment of said speed changing means will vary the speeds of all of said units.

11. The combination, with a plurality of machine units which require to be driven at proportional speeds, of a variable speed prime mover
40 for driving each of said units, means for changing the speeds of said prime movers simultaneously, an equalizing shaft connecting said prime movers together to synchronize the speeds thereof, means connecting each unit to one of said prime movers, each of certain of said means including a three legged differential having its
45 first or output leg connected to the unit associated therewith to drive the same and its second or input leg driven by the prime mover associated with that unit, a variable speed transmission having its input shaft driven by said prime mover and is output shaft connected to the third or
50 other input leg of said differential to drive the same and thereby enable said first leg to drive said unit, means for initially adjusting said transmission to vary the speed of its output shaft relative to the speed of its input shaft whereby adjustment of one transmission will vary the speed of one unit relative to the speeds of the other units and adjustment of said speed changing
55 means will vary the speeds of all of said units, and means responsive to a variation in the ratio between the speeds of the input and output shafts of at least one of said transmissions for automatically correcting said variation.

12. The combination, with a plurality of machine units which require to be driven at proportional speeds, of a variable speed prime mover for driving each of said units, an equalizing shaft
60 connecting said prime movers together to synchronize the speeds thereof, means connecting each unit to one of said prime movers, each of certain of said means including a three legged differential having its first or output leg connected to the unit associated therewith to drive
75

the same and its second or input leg driven by the prime mover associated with that unit, a variable speed transmission having its input shaft driven by said prime mover and its output shaft connected to the third or other input leg of said differential to drive the same and thereby enable said first leg to drive said unit, said differential being so constructed and proportioned that more than three-fourths of the power required to drive the unit connected thereto is transmitted through said second leg to thereby enable a relatively small transmission to drive said third leg, and means for adjusting said transmission to vary the speed of its output shaft relative to the speed of its input shaft whereby adjustment of one transmission will vary the speed of one unit relative to the speeds of the other units.

13. The combination, with a plurality of machine units which require to be driven at proportional speeds, of a variable speed prime mover for driving each of said units, means for changing the speeds of said prime movers simultaneously, an equalizing shaft connecting said prime movers together to synchronize the speeds thereof, means connecting each unit to one of said prime movers, each of certain of said means including a three legged differential having its first or output leg connected to the unit associated therewith to drive the same and its second or input leg driven by the prime mover associated with that unit, a variable speed transmission having its input shaft driven by said prime mover and its output shaft connected to the third or other input leg of said differential to drive the same and thereby enable said first leg to drive said unit, said differential being so constructed and proportioned that more than three-fourths of the power required to drive the unit connected thereto is transmitted through said second leg to thereby enable a relatively small transmission to drive said third leg, and means for adjusting said transmission to vary the speed of its output shaft relative to the speed of its input shaft whereby adjustment of one transmission will vary the speed of one unit relative to the speeds of the other units and adjustment of said speed changing means will vary the speeds of all of said units.

14. The combination, with a plurality of machine units which require to be driven at proportional speeds, of a variable speed prime mover for driving each of said units, means for changing the speeds of said prime movers simultaneously, an equalizing shaft connecting said prime movers together to synchronize the speeds thereof, means

connecting each unit to one of said prime movers, each of certain of said means including a three legged differential having its first or output leg connected to the unit associated therewith to drive the same and its second or input leg driven by the prime mover associated with that unit, a variable speed transmission having its input shaft driven by said prime mover and its output shaft connected to the third or other input leg of said differential to drive the same and thereby enable said first leg to drive said unit, said differential being so constructed and proportioned that more than three-fourths of the power required to drive the unit connected thereto is transmitted through said second leg to thereby enable a relatively small transmission to drive said third leg, means for initially adjusting said transmission to vary the speed of its output shaft relative to the speed of its input shaft whereby adjustment of one transmission will vary the speed of one unit relative to the speeds of the other units and adjustment of said speed changing means will vary the speeds of all of said units, and means responsive to a variation in the ratio between the speeds of the input and output shafts of at least one of said transmissions for automatically correcting said variation.

15. The combination, with two machine units which require to be driven at proportional speeds, of a drive, means for driving the first of said units from said drive at a speed proportional to the speed thereof, a three-legged differential having a first or output leg connected to the second of said machine units to drive the same and a second or input leg driven from said drive, a variable displacement pump driven from said drive at a speed proportional to the speed thereof, a hydraulic motor driven by liquid supplied thereto by said pump and having an output shaft connected to the third or other input leg of said differential to drive the same and thereby enable said first leg to drive said second unit, said differential being so constructed and proportioned that only a small fraction of the power required to drive the unit connected thereto need be transmitted through said third leg whereby a relatively small hydraulic motor is enabled to drive said first leg, and an auxiliary motor supplied with energy from a suitable source and operable from a remote point for varying the displacement of said pump between zero and maximum to effect a variation in the speed of said output shaft and thereby vary the speed of said second unit relative to the speed of said first unit.

WALTER FERRIS.