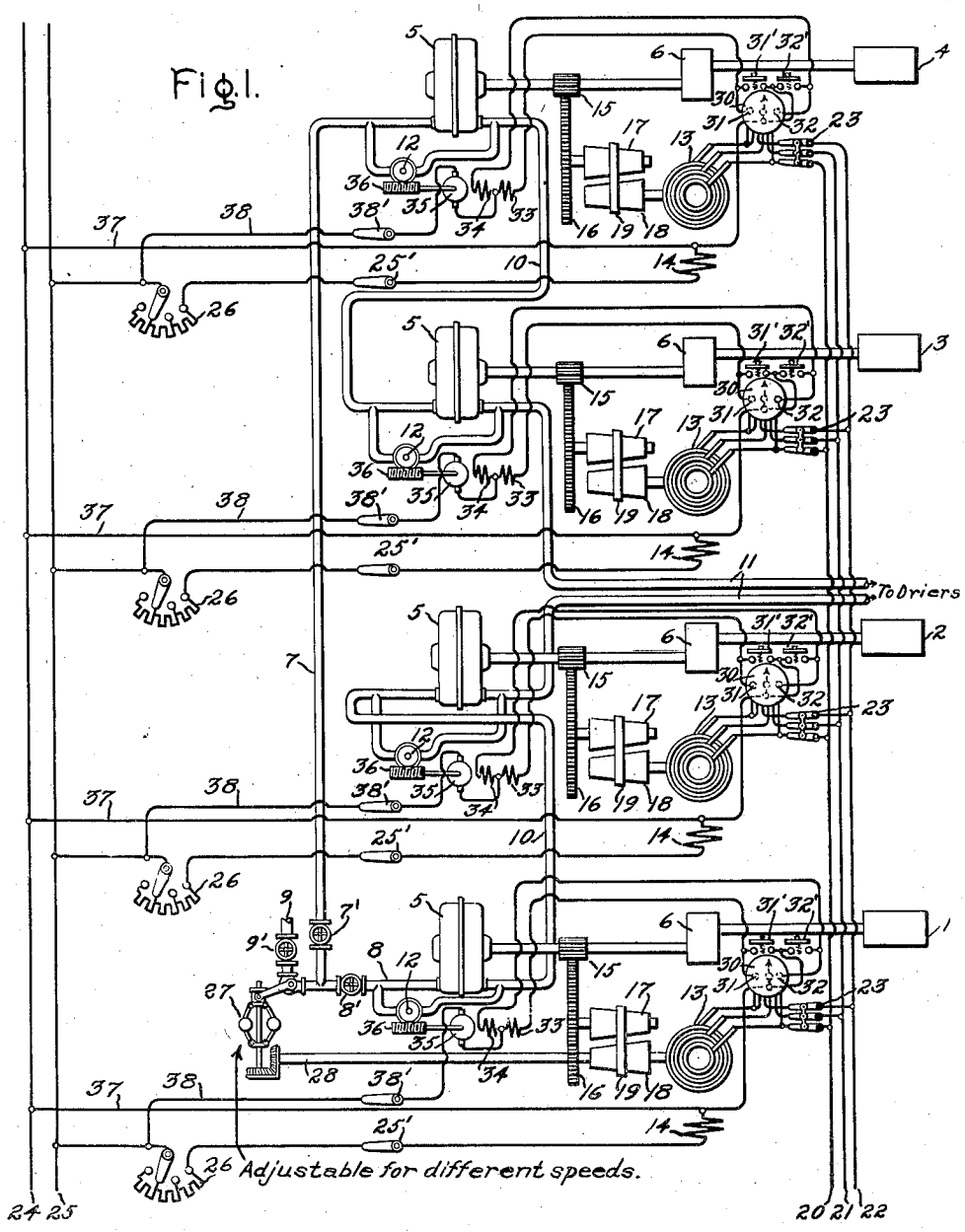
April 14, 1925. 1,533,655

W. L. MERRILL

SEGREGATED DRIVE FOR PAPER MACHINES AND THE LIKE

Filed Feb. 9. 1920 4 Sheets-Sheet 1

Fig. 1.



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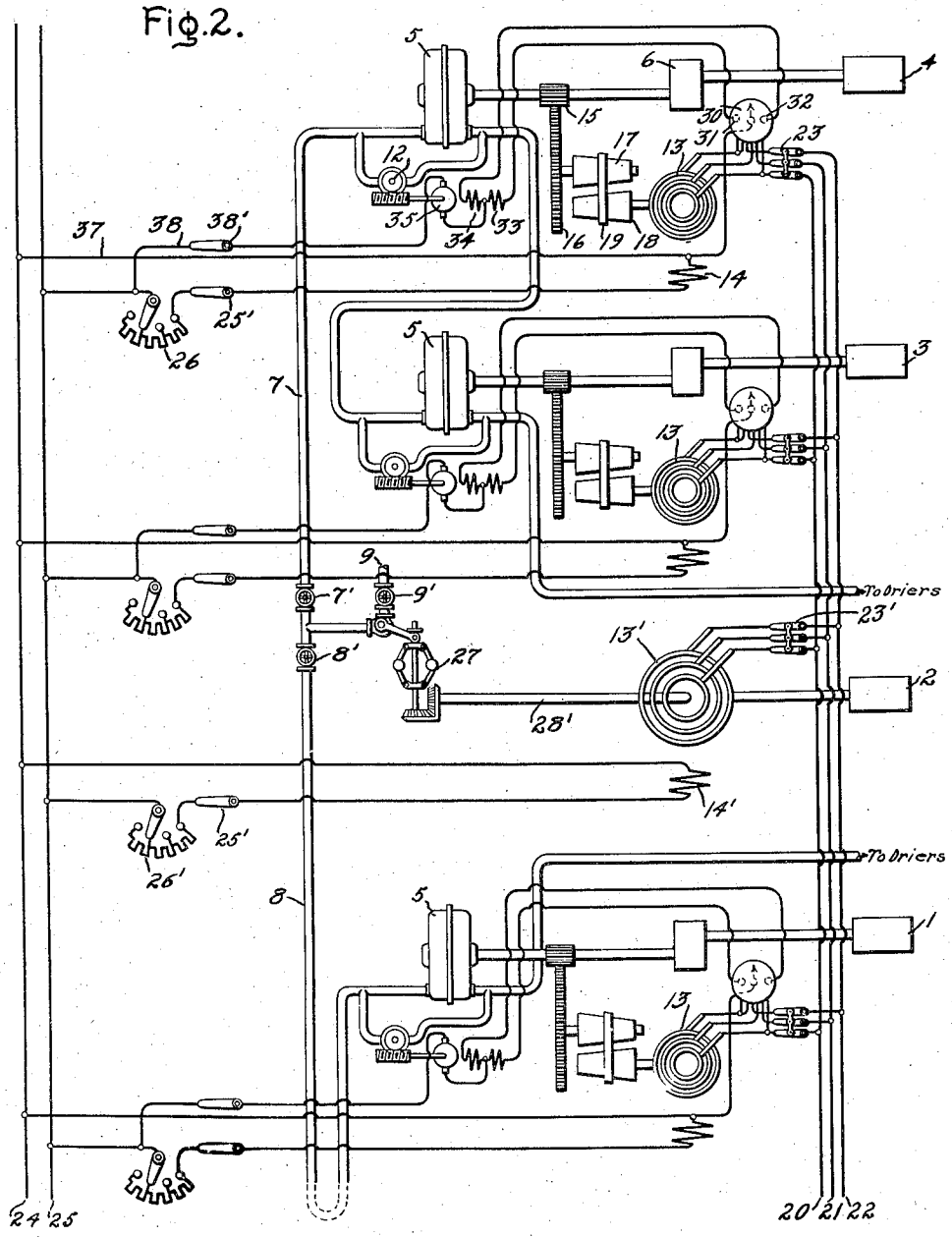
Filed Feb. 9. 1920 4 Sheets-Sheet 2

Fig.2.



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SEGREGATED DRIVE FOR PAPER MACHINES AND THE LIKE

Filed Feb. 9. 1920 4 Sheets-Sheet 3

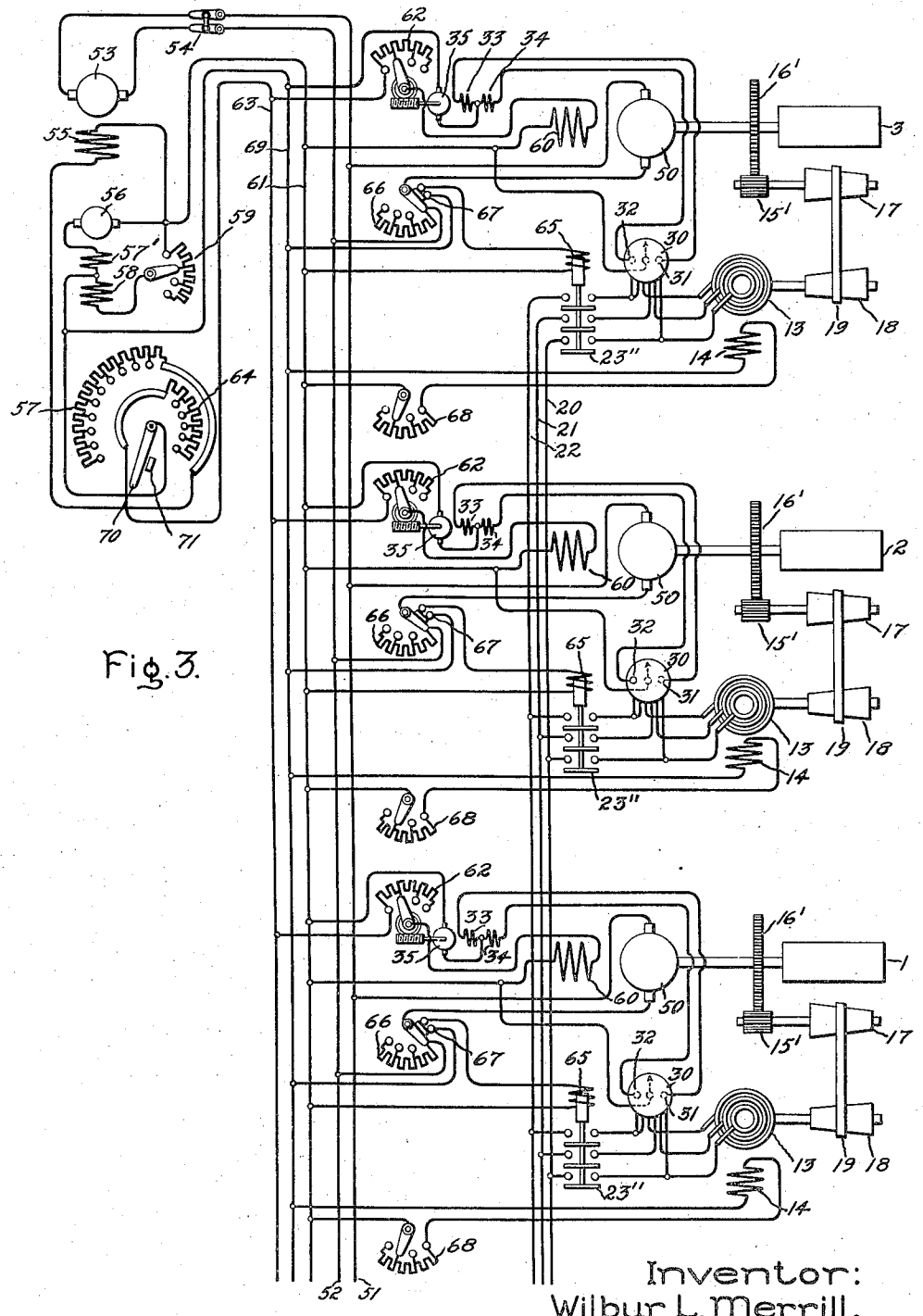

Fig. 3.

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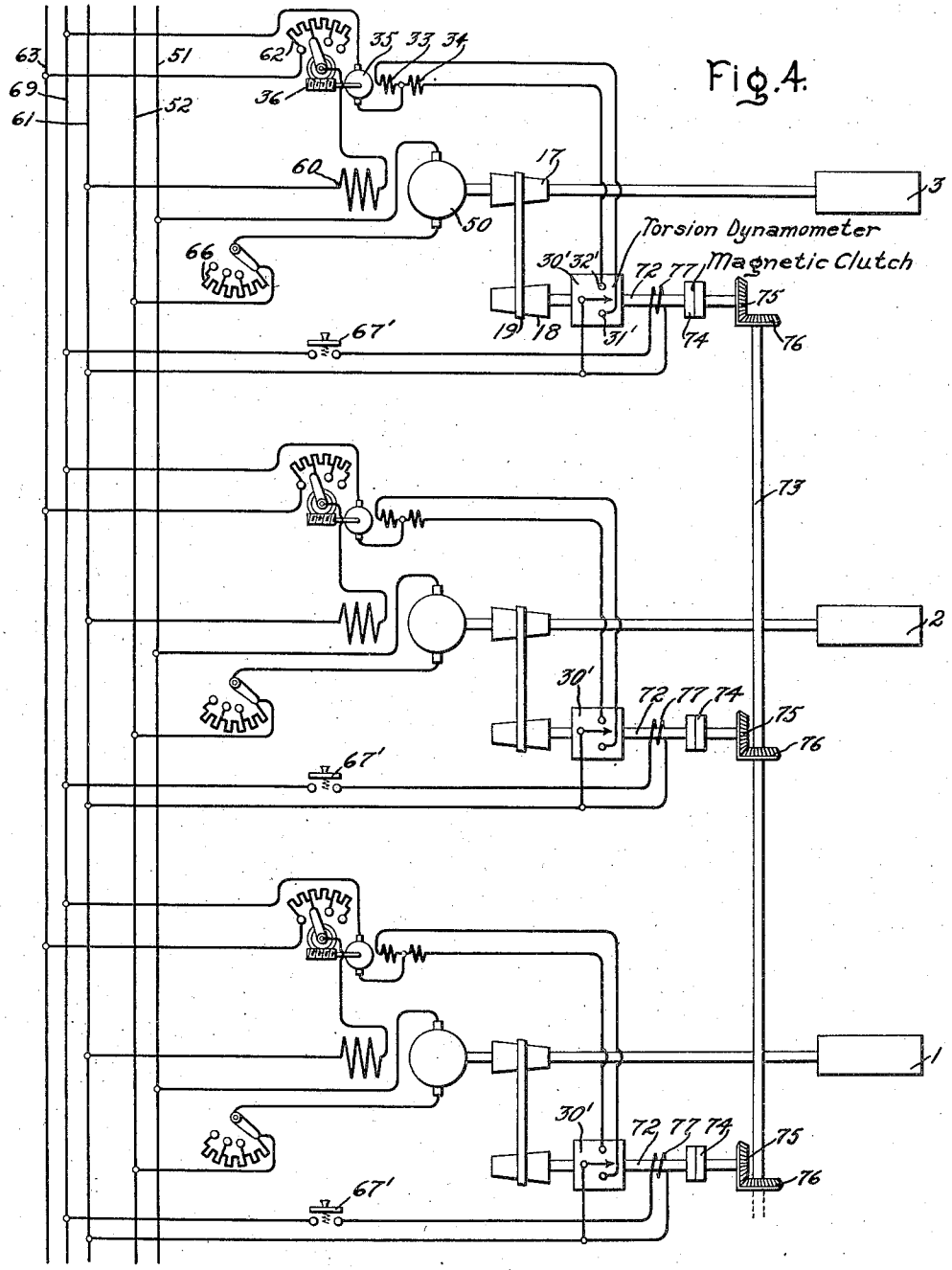
SEGREGATED DRIVE FOR PAPER MACHINES AND THE LIKE

Filed Feb. 9. 1920 4 Sheets-Sheet 4

Fig. 4.



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His Attorney.

Patented Apr. 14, 1925. 1,533,655

UNITED STATES PATENT OFFICE.

WILBUR L. MERRILL, OF SCHENECTADY, NEW YORK, ASSIGNOR TO GENERAL ELECTRIC COMPANY, A CORPORATION OF NEW YORK.

SEGREGATED DRIVE FOR PAPER MACHINES AND THE LIKE.

Application filed February 9, 1920. Serial No. 357,219.

To all whom it may concern:

Be it known that I, WILBUR L. MERRILL, a citizen of the United States, residing at Schenectady, in the county of Schenectady, State of New York, have invented certain new and useful Improvements in Segregated Drives for Paper Machines and the like, of which the following is a specification.

My invention relates to a segregated drive for paper machines and the like in which a plurality of the driven elements are normally required to operate in fixed speed relation and in which it is essential that the speed of any individual element of the machine, as well as of the machine as a whole, be readily adjustable.

An object of my invention is to provide an efficient form of segregated drive which will eliminate all back-line drive shafting and the various belts commonly used therewith, and in which the speed relation of the various machine elements is maintained absolutely fixed, while at the same time this fixed speed relation may be readily adjusted and this accomplished without the use of speed adjusting devices transmitting large amounts of power.

A further object of my invention is to provide an apparatus which from the source of power to the winders is rugged and substantial and in which no complicated or delicate governing or regulating machine is employed, whereby the apparatus may be adjusted and operated by the ordinary mill force and without the attention of skilled electricians.

My invention will be better understood from the following description taken in connection with the accompanying drawings, and its scope will be pointed out in the appended claims.

The requirements for a satisfactory segregated drive for this type of machine are very severe. There are two separate and distinct conditions of operation imposing different requirements upon the segregated drive. One, a condition of operation and adjustment when the machine is not making paper, but is being adjusted to eliminate the "broke"; and the other, the condition of normal operation after the web has been passed through the elements or sections of the machine and paper is being made. After the machine has been started and brought approximately to the speed desired for making paper and the stock put on the wire, it is necessary that means be provided, whereby each section of the machine may be adjusted from the approximate speed at which it is running to the exact speed necessary to convey the paper from the preceding section to the section under adjustment without stretching sufficient to break the paper or retardation sufficient to allow the sheet to accumulate at the section in question. After the sheet has been properly adjusted through all of the elements or sections of the machine, it is essential that the speed relation of the various elements be maintained fixed regardless of changes in the load or other changes which tend to disturb the speed at which the driving motor for any individual element tends to run. It is also essential that the controlling means for maintaining the fixed speed relation in question shall operate upon any tendency of an individual element of the machine to vary its speed relation to the remaining elements, as distinguished from operating to correct a departure in speed which has taken place, since otherwise, the paper must in many cases be broken. In other words, the means controlling the fixed speed relation must anticipate the changes for which it must correct. If each element of the paper machine were provided with a regulator which required some change in the speed of the individual element to set it into operation the regulators of all of the machines would be required to be in almost continual operation. If a variation in load should occur on an individual element or section of the machine, this change in load would change the total load required to drive the paper machine as well as the load on the individual element. This would cause an operation of the governor of the steam unit or other source of power for the generator supplying the various motors, where electric motors are used to drive the individual elements of the machine, and consequently, each individual regulator would function. Not only would all of the regulators be in practically continuous operation, but if each of the various regulators did not function in absolute synchronism, one or several breaks in the paper might occur.

According to my invention, all of the motors driving the various elements of the paper machine are not only maintained in

fixed speed relation while the machine is making paper, but the variation in angular movement of any given motor is so slight as to produce the same effect as would be produced if each of the sections of the machine were geared directly from one shaft. Means are also provided whereby the speed of any individual element of the machine, as well as the speed of the machine as a whole, may be readily adjusted. According to my invention, moreover, this speed adjustment of the individual elements of the machine is accomplished without the transmission of large amounts of power as distinguished from an arrangement in which the full torque required to operate each element of the machine is transmitted through a adjustable speed mechanism such for example as the well known belt and cone pulley drive.

Referring to the accompanying drawings, Fig. 1 represents an embodiment of my invention, in which motors represented as steam turbines are arranged to drive the elements on sections of a paper machine or the like; Fig. 2 represents a modification of the arrangement of Fig. 1, in which one of the driving turbines is omitted; Fig. 3 represents a segregated electric drive for the same type of machine; and Fig. 4 represents an arrangement disclosing a modified form of means for maintaining a fixed speed relation between the machine elements.

Referring to Fig. 1: 1, 2, 3 and 4 represent various elements or sections of the paper machine. Each element of the machine is represented as driven by a steam turbine 5. It is obvious that reciprocating engines might be used instead of turbines if desired. Each turbine is connected to the corresponding section of the machine through reduction gearing 6 to permit of high speed turbines being used. Each turbine is in fixed speed relation to the machine element driven thereby as distinguished from an arrangement in which speed adjusting mechanism is interposed between the driving motor and the driven element. A disconnecting clutch is ordinarily inserted between each element of the machine and its driving shaft, but inasmuch as my present invention is not concerned with such features, they are not illustrated. The turbines 5 are represented as arranged in two groups; steam being supplied to the respective groups through steam mains 7 and 8, which are supplied from a common main 9. Valves 7′ 8′ and 9′ are provided respectively in the mains 7, 8 and 9. While but two turbine driven machine elements are represented in each group, it is evident that my invention is not limited to a machine having any particular number of elements either as a whole or in each group. In this figure, the turbines in each group are represented as connected in series, the steam from the first turbine in each group discharging through a pipe 10 into the second turbine of each group. The exhaust from the last turbine in each group is represented as being led through a pipe 11 to the driers. While the turbines have been represented as connected in series, it is obvious that my invention is not limited in this respect and that the steam motors may be connected in parallel if desired. Where the turbines are connected in series as shown, it is necessary to provide a by-pass 12 to permit independent speed adjustment of any particular turbine.

In order to maintain an absolutely fixed speed relation between the various elements or sections of the machine a relatively small synchronous machine comprising an armature 13 and field winding 14 is provided for each element. Each armature 13 is represented as connected to the corresponding turbine shaft through speed reduction gearing 15, 16 and cone pulleys 17 and 18. An adjustable belt 19 is arranged upon each pair of cone pulleys to provide for adjusting the speed of each individual element of the machine with respect to the speeds of the remaining elements. It will be apparent, however, that my invention is not limited to any particular form of speed adjusting means. The armatures 13 of the various synchronous machines are shown connected through slip rings to the 3-phase synchronizing mains 20, 21 and 22, it will be understood however that this showing is conventional and that in actual practice the armatures will usually be made stationary and the fields rotatable. A switch 23 is provided for controlling the circuit connections between each armature 13 and the synchronizing mains. When the belt 19 is adjusted on its pair of cone pulleys, the relation between the speed of the associated driving motor and the frequency of the current in the synchronizing mains is varied. Each of the field windings 14 are supplied from any suitable direct current source, here represented by the mains 24, 25. A switch 25′ is provided for interrupting the circuit of each field winding 14. A rheostat 26 is arranged in circuit with each winding 14 to provide for controlling the field strength of each synchronous machine. In order to control the speed of the machine as a whole, a governor of any suitable type is provided for controlling the steam admission to the turbines. In the drawing this governor is represented as a fly-ball governor 27, controlling a valve in the supply main 9. This governor is represented as driven by the shaft 28 from one of the synchronous motor armatures 13. A wattmeter 30 is provided in the connections between each synchronous motor armature 13 and the synchronizing

mains 20, 21 and 22. This wattmeter is connected and arranged to indicate both ways from zero, whereby an inspection of the instrument makes it possible to determine the direction of transfer of energy between the coresponding synchronous machine 13 and the synchronizing mains 20, 21 and 22. That is to say, the instrument indicates whether the corresponding synchronous machine is operating as a motor or a generator and also indicates the amount of energy being transferred to or from the synchronous machine. In some cases it may be desirable, automatically to control the amount of power transferred to or from the synchronous machines 13 as will be more fully set forth hereinafter in connection with the description of the operation of the machine. For this purpose contacts 31 and 32 are provided on the wattmeter, connected respectively to field windings 33 and 34 of pilot motor 35, which is arranged to operate the by-pass valve 12 as for example, by means of a worm 36. The needle of the wattmeter is shown connected by lead 37 to main 24 and when the needle engages one of the contacts 31 or 32, a circuit is completed from main 24 through lead 37, the wattmeter contacts, one of the pilot motor field windings 33 or 34, the pilot motor armature winding 35, and the lead 38 to main 25. A switch 38′ is provided in lead 38 to render the pilot motor inoperative whenever desired. The windings 33 and 34 are arranged and connected to produce opposite magnetizations in the field structure of the pilot motor, so that this motor runs in one direction or the other to close or open the by-pass 12, according to whether the circuit is completed at contact 31 or contact 32. It is obvious that my invention is not limited to any particular arrangement of contacts on the wattmeter nor to any particular connections for the pilot motor, since pilot motors controlled by contact making instruments are well known in the art. While I have not illustrated limit switches for limiting the travel of the pilot motor in its respective directions, it is obvious to those skilled in the art that such well known accessories are intended to be used.

The operation of the embodiment of my invention disclosed in Fig. 1, is as follows:

First. Assume that it is desired to operate one individual element of the machine alone, for example, for the purpose of washing the felts. If this machine is in the group supplied from steam main 7, the turbines in the other group may be rendered inoperative by closing valve 8′ and the other turbines in the group supplied from steam main 7 may be rendered inoperative by opening the corresponding by-pass valves. The turbine of the element to be individually operated may then be turned over slowly by operating either the valve 7′ or the valve 9′ as a throttle, but this operation will ordinarily be effected by controlling the valve or valves of the individual turbine. During this operation the switch 23 of the corresponding synchronous motor will be opened. A shut-off valve in addition to the by-pass valve will, of course, be provided for each turbine, inasmuch however, as the piping and valves required for operating turbines in series are well known and form no part of my invention, it is unnecessary to disclose all such features in detail.

Second. Assume that it is desired to start the entire machine into operation from rest. The switches 23 will be closed. The switches 25′ will be closed thus energizing the field windings 14 of the synchronous machine. The valves 7′ and 8′ being open, the valve 9′ will gradually be opened to admit steam to all of the turbines, the by-pass valves 12 of each of which have been previously closed, and upon the opening of valve 9′ the turbines 5 will all start into operation. Inasmuch as the armatures 13 of the synchronous machines are positively driven from the respective turbines 5 and at the same time electrically connected to the synchronizing mains 20, 21 and 22, it is obvious that the various turbines 5 must accelerate in synchronism, since, as is well known a synchronous dynamo-electric machine tends to keep in step with other synchronous machines on the same circuit unless the load imposed exceeds the capacity of the machine. I construct the synchronous machines so as to have approximately 15% or 20% of the capacity of the turbines 5, which capacity is ample to keep the machines in synchronism during normal conditions of starting and operation. When normal speed has been reached, the governor 27 assumes control and maintains the speed of the machine as a whole at any desired value. The speed of the machine as a whole may be readily adjusted by adjusting the governor 27 as is well known in the art. Inasmuch as such features are old and well known, I deem it unnecessary to describe or illustrate any particular form of speed adjusting mechanism. Since the various elements of the machine are caused to run in fixed speed relation by means of the small synchronous motors connected to the synchronizing mains, it is possible mechanically to drive the speed governor from any one of these machines, and it is obvious to those skilled in the art that if desired, this governor might be driven by a small independent synchronous motor supplied from the synchronizing mains.

The paper machine now having been started and brought up approximately to the speed desired for making paper, the stock is put on the "wire" and it then becomes necessary to bring each section of

the machine from the approximate speed at which it is running to the exact speed necessary to convey the paper from any previous section to the succeeding section without stretching and without sag. This comparatively small speed adjustment is accomplished by adjusting the position of the belt 19 upon the cone pulleys 17 and 18, thereby varying the relation between the speed of the particular section of the machine with reference to the frequency of the current in the alternating current synchronizing mains 20, 21 and 22. This adjustment permits the corresponding turbine and element of the paper machine to be changed in speed, while the speed of the armature of the corresponding synchronous machine remains unchanged. Inasmuch as the capacity of the synchronous machine is but a fraction of that of the main driving turbine, the belt and cone pulleys are much smaller and less expensive than would be necessary for transmitting the entire power for operating the element of the paper machine. The elimination of such full-power cone pulleys has long been desired in the paper making art, since these pulleys occupy much needed space and are expensive in first cost and upkeep. An important feature of my invention resides in the fact that I have made the elimination of such full-power cone pulleys possible, while still retaining a segregated drive comprising means for maintaining the various elements of the machine in absolutely fixed speed relation.

If during normal operation of the machine while making paper, a change of load occurs on any given element, this change of load will cause a slight angular variation in the position of the rotating element of the corresponding synchronous machine with reference to the rotating elements of the other synchronous machines; but by using a multipolar synchronous machine and arranging it to run at a higher speed than the corresponding driven element of the paper machine, the angular variation of the synchronous machines corresponds to a much smaller angular variation of the driven elements. By my arrangement of the synchronizing machines, the angular variations permitted to take place may thus be made so small as to make the variations in tension on the paper wholly negligible. The slightest angular variation is accompanied by an immediate exchange of current and energy between the synchronous machines in question and the remaining machines connected to the synchronizing mains, and this interchange of energy limits the angular variation. The tendency of any element to change in speed is thus checked in its very incipiency and no change in the predetermined fixed speed relation is permitted to take place. If, for example, the load on one machine element increases, the synchronous machine corresponding to this element will operate as a motor to assist the turbine in driving the additional load. The motor may secure its energy from any or all of the remaining synchronous machines. In other words, the cynchronous machines of the heavily loaded elements operate as motors, while the synchronous machines of the lightly loaded elements operate as generators. The watt-meters 30 indicate the direction and amount of power being exchanged between the synchronous machines and if the operator observes that any one machine is continuously operating as a motor, for example, this condition may be corrected by adjusting the by-pass 12 for the corresponding turbine, where the turbines are in series as here shown. By adjusting the steam admission to the turbine, the increased load may be transferred to the turbine, thus returning the watt-meter to its zero indication. This adjustment of the by-pass valve may be accomplished by manually completing one of the circuits to the pilot motor or by mechanically disconnecting the pilot motor from the valve and operating it by hand in any of the ways well known in the art. For manually completing the pilot motor circuits push buttons 31′, 32′ may be used. In order to prevent such overloading of the relatively small synchronous machines as might cause them to fall out of step the watt-meters are provided with the contacts 31 and 32 hereinbefore referred to. These contacts may be made adjustable in position in a manner that is well known in connection with contact making instruments thus these contacts may be set so as to cause a circuit to be completed whenever the power transferred in either direction exceeds a predetermined amount. If, for example, an increase of load tends to cause the completion of a circuit at contact 31, the pilot motor armature 35 will be operated in a direction to close the by-pass 12, so that the load carried by the turbine 5 will be increased. Since the automatic control for the by-pass valve is caused to operate only when the power transferred to or from the corresponding synchronous machine exceeds a certain predetermined limit, it is obvious that the automatic regulators will be in operation, but infrequently. No great sensitiveness is required and the contact making regulating devices will be reliable and not likely to require skilled attention. Where certain of the machine elements only are subject to wide changes in load, the automatic control for the driving motor input may, if desired, be arranged for such elements only.

It has heretofore been set forth how one element of the machine may be operated alone if desired. It is also possible to op-

erate one element of the machine at a speed independent of that of the other elements while the entire machine is running. To accomplish this it is merely necessary to open the switch 23 of the element to be independently operated after which the speed of this element may be adjusted by controlling the steam admission to the turbine.

Fig. 2 illustrates a modification of my invention particularly adapted for the operation of a machine comprising an odd number of elements. Where such a machine is driven by turbines arranged in two groups with the turbines in each group arranged in series, there will be an unequal number of turbines in each group which is undesirable. To overcome this objection, I may drive one of the elements of the machine by means of a synchronous motor connected to the synchronizing mains. This arrangement is shown in Fig. 2. The mechanical and electrical connections to the elements 1, 3 and 4 of Fig. 2 are identical with the corresponding parts of Fig. 1. The steam is supplied to the respective groups of turbines 5 through branch steam mains 7 and 8 supplied from a steam main 9 through cut-off valves 7′ and 8′, as in Fig. 1. In Fig. 2 the break in steam main 8 indicates that another turbine is assumed to be connected in series with turbine 5 in the lower group. As heretofore indicated, any desired number of turbines may be provided in each group. In Fig. 2 the element 2 of the paper machine or the like is driven solely by the synchronous motor 13′ connected to the synchronizing mains 20, 21 and 22 by the switch 23′. This machine is provided with a field winding 14′ connected across the direct current mains 24 and 25 through rheostat 26′. Inasmuch as the synchronous machine driving the element 2 must carry the full load imposed by this element, the rotor 13′ has been shown considerably larger than the rotors 13. The governor 27 for controlling the steam admission is in this case represented as driven from the shaft of the rotor 13′ through the shaft 28′.

The operation of the arrangement shown in Fig. 2 will be obvious from the detailed description given in connection with Fig. 1. The only difference is that the power for driving the synchronous motor 13′ comes from the synchronizing mains 20, 21 and 22 which necessitates that some of the remaining synchronous machines be continually supplying energy to the synchronizing mains. Inasmuch, however, as there are a number of these synchronous machines, the power required from each is relatively small and the omission of the driving turbine from the element driven by the synchronous motor will, therefore, not ordinarily entail an increase in size in the remaining synchronous machines. It is obvious that in this arrangement the synchronizing connections not only furnish the power required to operate one element of the machine, but that they also cause the various elements of the machine to maintain an absolutely fixed speed relation. It is apparent that with the arrangement shown in Fig. 2 it is not possible to operate the element 2 alone since at least one of the remaining elements must be in operation to furnish the power necessary to operate this element.

The arrangement shown in Fig. 3 represents a modification in which a segregated electric motor drive is substituted for the turbine drive of Fig. 1. In this arrangement the elements 1, 2 and 3 of the paper machine are represented as directly driven by motors 50, represented in this case as direct current motors connected to mains 51 and 52 supplied from a generator 53 through a disconnecting switch 54. The generator is provided with a field winding 55 supplied from an exciter 56 and an adjustable resistance 57 is provided in the circuit of the generator field winding 55 to adjust the voltage of the generator. The exciter is provided with a cumulative series field winding 57′ and a shunt field winding 58 in the circuit of which an adjustable resistance 59 is provided. The voltage impressed by the generator 53 upon the mains 51 and 52 will ordinarily be varied by adjusting the resistance 57. This arrangement constitutes one form of the well-known "Ward Leonard system" for controlling the voltage applied to the various motors. Each motor is provided with a field winding 60. One terminal of each field winding 60 is connected to the excitation main 61 which leads directly to one terminal of the exciter 56. The other terminal of each field winding 60 is connected through an adjustable resistance 62 to the excitation main 63 which leads to the other terminal of the exciter through the variable resistance 64 and exciter series field winding 57′. Any well-known arrangement of switch may be provided in the circuits leading from the exciter. An adjustable resistance 64 is provided in the connection from main 63 to the exciter, whereby the voltage of the excitation mains 61 and 63 may be simultaneously adjusted to control the strength of the various field windings 60. I have shown a single arm 70 arranged to control both resistances 57 and 64, this arm being shown in the "off" position resting against stop 71. In this position the circuit of generator field winding 55 and the circuit supplying motor field windings 60 are broken. As the arm is rotated in a clockwise direction it is arranged to complete the circuits of the motor and generator field windings and then remove resistance 57 from the generator field circuit to bring the generator up to full voltage, after which

more or less resistance 64 may be cut into circuit to control the field strength and speed of the motors 50. It is apparent, however, that my invention is not limited to any particular arrangement of circuits for supplying energy to the driving motors.

In order to maintain the various elements of the paper machine in absolutely fixed speed relation, synchronous motors 13, 14 are provided as in the modifications shown in Fig. 1. The motors 13 are connected through cone pulleys 17 and 18 to the shafts of the respective motors 50. The pulley 17 is driven from the motor shaft through gearing 15', 16' arranged to increase the speed of the synchronous machine with reference to the driving motor speed for the purpose heretofore set forth in connection with Fig. 1. The synchronous machines are connected to the synchronizing mains 20, 21 and 22 by means of switches 23'', in this case represented as controlled by solenoids 65. A starting resistance 66 is provided in the circuit of each motor armature 50. After the motors 50 have been started and the resistance of the starting rheostats 66 has been all cut out, the contacts 67 may be closed in any desired way to energize the coils 65 thus closing the switches 23'' to connect the synchronizing machines to the synchronizing mains. Any well known synchronism indicating means may be employed to indicate the proper time to close the contacts 67. The speed of any individual element of the machine may be varied with respect to the speeds of the remaining elements by adjusting the belt 19 along the cone pulleys 17 and 18, as described in connection with Fig. 1. Watt-meters 30 controlling pilot motors 35 are arranged as in the modification shown in Fig. 1 although the push button control is illustrated in Fig. 1 only. These pilot motors are here arranged, however, to control the resistances 62 to vary the field strength and, thereby, the input of the individual direct current driving motors. One terminal of each of the field windings 14 is connected through an adjustable resistance 68 to the excitation main 51 which leads directly to one terminal of the exciter 56. The other terminal of each of the field windings 14 leads to excitation main 69 which leads to the other terminal of the exciter. It will be noted that the adjustment of the resistance 64 does not affect the strength of field windings 14.

The operation of the elements shown in Fig. 3 will be in part obvious from the preceding description given in connection with the modifications shown in Figs. 1 and 2. The arrangement shown in Fig. 3 may be set into operation by starting the machines 50 either simultaneously or in succession. If the machines are to be started simultaneously, the exciter and generator armatures 56 and 53 are brought up to speed and the exciter brought up to normal voltage. Voltage will thus be applied to the excitation mains 61 and 69. This will energize the field windings 14 of the synchronous machines. The cut-out switch 54 will be open and the field 55 of the generator either de-energized entirely or reduced to a very low value, depending upon the position of the arm 70 controlling resistance 57. The resistance 66 will be cut out and the contacts 67 closed to energize the solenoids 65 and connect the rotors 13 of the synchronous machines to the synchronizing mains 20, 21 and 22. The switch 54 will then be closed and the voltage of the generator 53 gradually increased by increasing the strength of the generator field winding 55 by reducing the resistance 57. Each of the motors 50 being connected across the mains 51 and 52 to which the generator is connected, the gradual increase of voltage on these mains causes the motors 50 gradually to increase in speed and, since the synchronizing machines 13 are connected to the synchronizing mains, the motors 50 necessarily accelerate together and in fixed speed relation. It is apparent, however, that instead of starting the elements of the machine simultaneously I may, if desired, start the machines in succession by the starting rheostats 66. It is also apparent that if for any reason it becomes desirable to operate one of the machines independently of the others, this may be done by opening the contacts 67 to open the synchronizing connections at the switch 23'', after which the speed of the individual motor 50 may be controlled either by using the resistance 66 as a speed regulating resistance, or by controlling the voltage applied to its field or armature or both by adjusting the rheostat arm 70. The strength of the various motor field windings 60 may be simultaneously controlled by varying the position of the arm 70 so that speed adjustments of the machine as a whole may be readily produced. The speed of any individual element of the machine with respect to the remaining machine elements may be adjusted by adjusting the position of the belt 19 as heretofore indicated in connection with Figs. 1 and 2.

In the modifications of my invention heretofore described, I have represented the means for insuring the fixed speed relation between the various machine elements as comprising synchronous dynamo-electric machines. While I prefer to use such synchronous machines to perform this function, my invention is not, however, limited in this respect.

Fig. 4 represents a modification of my invention in which other synchronizing means are substituted for the synchronous dynamo electric machines shown in Figs. 1.

2 and 3. In Fig. 4 the machine elements 1, 2 and 3 are represented as driven by direct current motors 50 provided with field windings 60. The armatures of the motors are shown connected across mains 51, 52 through the adjustable resistances 66 as in Fig. 3. The field windings 60 are supplied from the excitation mains 61 and 63 as in Fig. 2. The mains 51, 52 and the mains 61, 63 and 69 are intended to be supplied as in the arrangement shown in Fig. 3 or its equivalent. Adjustable resistances 62 are arranged in the circuits of the field windings 60, and these resistances are arranged to be operated by pilot motors 35 as in the modifications heretofore described. The means for causing the elements 1, 2 and 3 to run in fixed speed relation comprises a member represented as a shaft 72, connected to be driven positively from the shaft of each machine element through speed adjusting means including cone pulleys 17 and 18 with belt 19 as in Figs. 1, 2 and 3. The members 72 are arranged to be coupled together to run in synchronism by means of the shaft 73. Each shaft 72 is adapted to be connected in positive driving relation to the shaft 73 through a clutch 74 and bevel-gears 75 and 76. It is apparent that any mechanical equivalent of the shaft 73 may be substituted in the combination shown in Fig. 4. The clutch 74 is represented as a magnetic clutch controlled by the coil 77 supplied from mains 61 and 69 through the circuit controller 67', although any suitable form of clutch may be used. A torsion dynamometer 30' is shown arranged in the shaft 72 to measure the torque transmitted through this shaft. This dynamometer which may be of any well known construction, performs the same function in the arrangement shown in Fig. 4 that the wattmeters perform in the arrangements heretofore described. That is to say, these dynamometers indicate whether power is being transmitted to or from the corresponding machine element. The torsion dynamometers are represented as provided with contacts 31'' 32'' connected respectively to the field windings 33 and 34 of the pilot motors 35.

The operation of the arrangement shown in Fig. 4 will be obvious from the preceding description. During normal operation the clutches 74 are engaged and the shaft 73 for synchronizing the shafts 72 causes the machine elements 1, 2 and 3 to run in absolutely fixed speed relation. The angular variation in the position of any rotating machine elements with respect to the synchronizing shaft 73 is merely that permitted by the corresponding torsion dynamometer and this variation can be reduced to a negligible value. When any torsion dynamometer indicates that the torque being transmitted therethrough is above any desired amount the resistance 62 may be adjusted, either at will, or automatically by the dynamometer, just as in the modifications heretofore described.

While I have represented a torsion dynamometer interposed in each of the shafts 72, it is apparent that this instrument may be omitted with its function if desired. When an electric drive is used a careful observation of the instruments in the circuits of the driving motors 50 will enable a rough determination to be made of the amount and direction of energy transfer through the synchronizing means.

It is obvious that the various elements of the machine may be started into operation either simultaneously or in succession as in the arrangement shown in Fig. 3. To start the machines simultaneously the switches 67' are closed to engage the clutches 74 where magnetic clutches are employed. The resistances 66 will be cut out and the voltage applied to the motor armatures and fields as in the arrangement shown in Fig. 3. To operate any machine individually it is merely necessary to disconnect the clutch 74. When any machine is to be started individually the motor 50 is first brought up to speed by cutting out the resistances 66 and, when the speed of the individual element of the machine corresponds approximately to that of the shaft 73, the clutch 74 is engaged.

It is apparent that the arrangement shown in Fig. 4 possesses many of the advantages of the arrangements shown in Figs. 1, 2 and 3, since the amount of power transmitted through the speed adjusting means and the synchronizing means is but a fraction of the power transmitted from each driving motor 50 to the corresponding machine element. This synchronizing energy is merely that necessary to take care of small variations in the load of the respective machine elements.

The arrangement of Fig. 4 is described and claimed specifically in a divisional application Serial No. 598,405, filed November 1, 1922, and assigned to the same assignee as this application.

While I have described several embodiments of my invention with considerable detail, it is obvious that many variations and modifications may be made within the scope of my invention and I aim to cover all such changes in the appended claims.

What I claim as new and desire to secure by Letters Patent of the United States, is:—

1. An apparatus of the class described wherein a plurality of elements are required to run in fixed but adjustable speed relation, characterized by the fact that motors are arranged to drive said elements and means arranged to be coupled together to run in synchronism are connected to each

of said elements, and by the fact that speed adjusting means is provided in at least one of said connections whereby the speed relation of said elements may be varied.

2. In an apparatus of the class described, a plurality of driven elements, a driving motor for each of a plurality of said elements, and means for causing the various elements to run in fixed speed relation, comprising a member connected in positive driving relation to each element, means arranged to couple said members together to run in synchronism and speed adjusting means between a plurality of said elements and said members, whereby the speed relation of said elements may be varied.

3. In an apparatus of the class described, a plurality of driven elements, separate driving motors for said elements, and means for causing said elements to run in fixed speed relation, comprising members interconnected to run in synchronism adapted to be connected in positive driving relation to said elements and speed adjusting means between said elements and said members.

4. In an apparatus of the class described, a plurality of driven elements, a driving motor for each element, a synchronous dynamo electric machine connected in positive driving relation to each element, a set of mains to which each synchronous machine is arranged to be connected, whereby the speed relation of said synchronous machines is fixed, and speed adjusting means between a plurality of said elements and said synchronous machines whereby the speed relation of said driven elements may be varied.

5. In an apparatus of the class described, a plurality of driven elements, a motor in fixed speed relation to each element for driving the same, a synchronous dynamo-electric machine of small capacity with relation to the driving motor connected in positive driving relation to each element, synchronizing connections adapted to produce a fixed speed relation between the synchronous machines, and speed adjusting means between each of said elements and said synchronous machines whereby the speed relation of said driven elements may be adjusted with respect to one another.

6. In an apparatus of the class described, a plurality of driven elements, a motor in fixed speed relation to each element for driving the same, a synchronous dynamo-electric machine of small capacity with relation to the driving motor connected in positive driving relation to each element, synchronizing connections adapted to produce a fixed speed relation between the synchronous machines, speed adjusting means between each of said elements and said synchronous machines whereby the speed relation of said driven elements may be adjusted with respect to one another, and means arranged to measure the power flowing in the synchronizing connections of at least one of the synchronizing machines, and means controlled thereby for controlling the power input of the corresponding driving motor to prevent overloading of the synchronous machine.

7. In an apparatus of the class described, a plurality of driven elements, a driving motor for each element, a synchronous dynamo-electric machine of small capacity with respect to the driving motor connected in positive driving relation to each of a plurality of said elements and arranged to run at a higher speed than the corresponding element, alternating current mains arranged in circuit relation with said synchronous machines to supply energy to or receive energy from said machines to maintain a fixed speed relationship between the driven elements and means whereby the relation between the speed of any machine and the frequency of the current in said alternating current mains may be adjusted.

8. In combination, a paper machine comprising a plurality of rolls, a plurality of direct current electric motors adapted to operate said rolls, a plurality of alternating current synchronous motors each connected to one of said direct current motors, means for interconnecting said synchronous motors in parallel, and means for varying the speed of any selected direct current motor.

9. In a segregated drive for a paper making machine or the like, a plurality of driven elements, a driving motor for each element, an alternating current synchronous motor mechanically connected to each of said elements, synchronizig electrical connections between said synchronous motors for preserving a predetermined speed relation of the driving motors by an interchange of power between the synchronous motors through the synchronizing connections, and means for varying the relation between the speed of any of said driving motors and the frequency of the current in the said synchronizing connections while the machine is operating to adjust the speed relation of the driven elements of the machine to be automatically maintained through said synchronizing connections.

In witness whereof, I have hereunto set my hand this 7th day of February, 1920.

WILBUR L. MERRILL.