

July 17, 1962

H. REINSCH

3,045,158

SYNCHRONIZING ARRANGEMENT

Filed Nov. 5, 1956

4 Sheets-Sheet 1

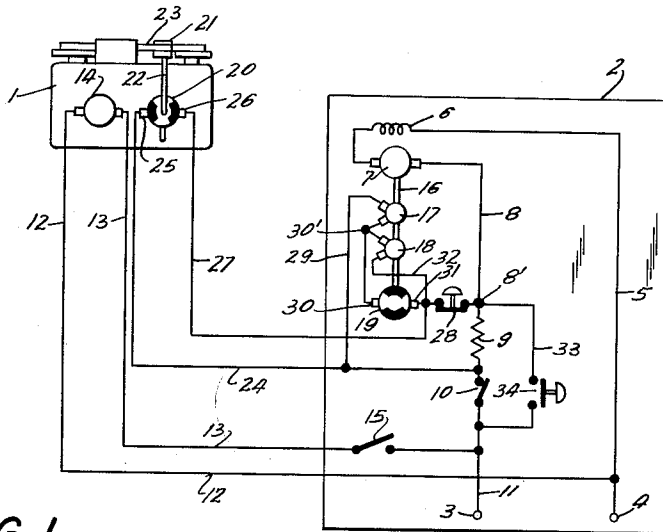


FIG. 1

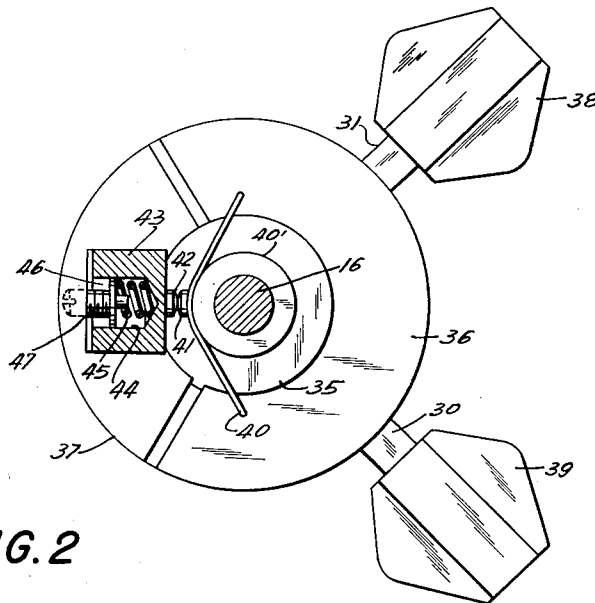


FIG. 2

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4 Sheets-Sheet 2

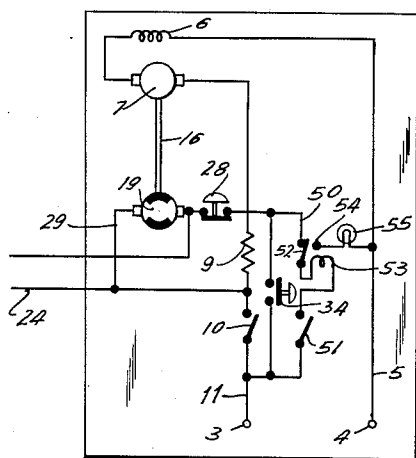


FIG. 3

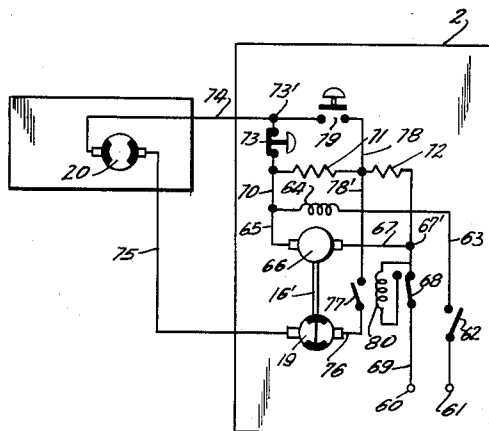


FIG. 4

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4 Sheets-Sheet 3

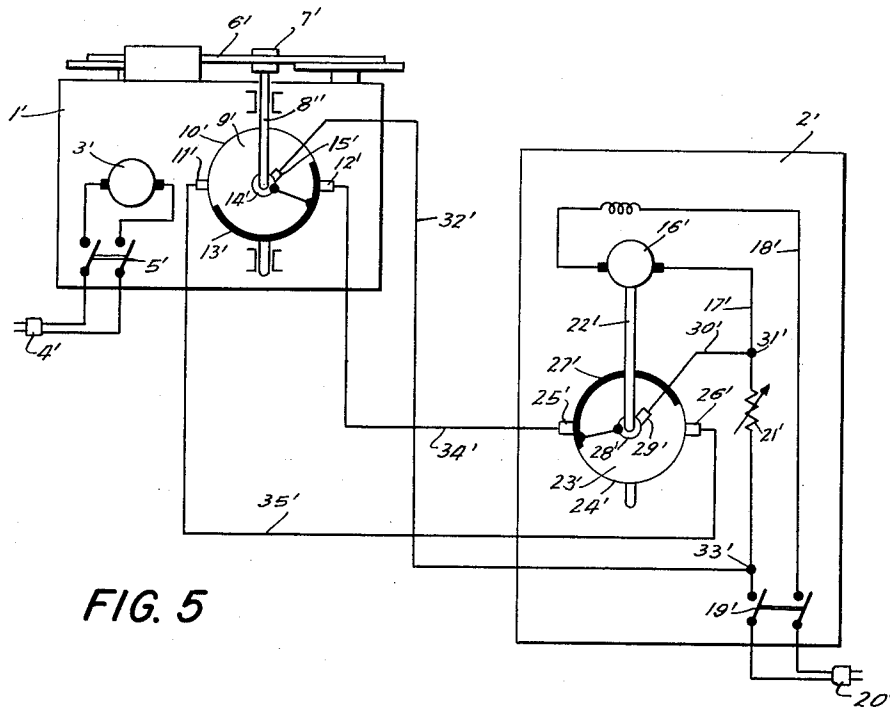


FIG. 5

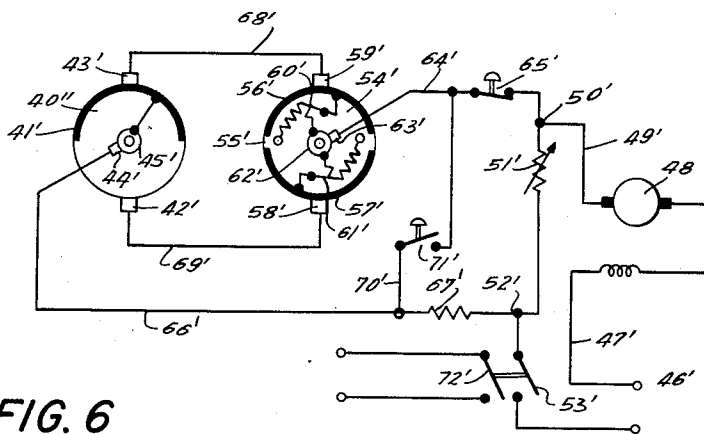


FIG. 6

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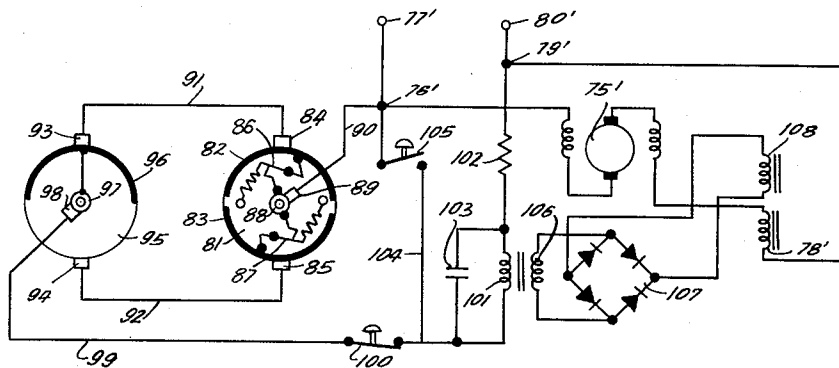


FIG. 7

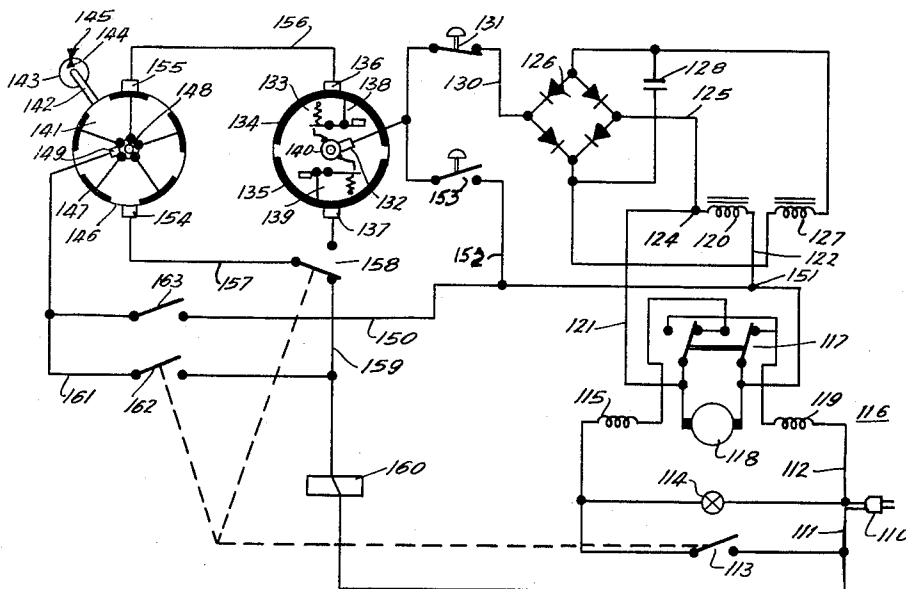


FIG. 8

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SYNCHRONIZING ARRANGEMENT

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Claims priority, application Germany Apr. 23, 1955
4 Claims. (Cl. 318—75)

The present invention relates to a synchronizing apparatus. More particularly, the present invention relates to an apparatus for synchronizing the speeds of a motion picture projector and the sound track which may be recorded on a different tape from the film.

This application is a continuation-in-part application of my copending U.S. patent application, Serial No. 579,819, filed on April 23, 1956 now Patent No. 2,967,987.

In conventional rotational speed synchronizing apparatus it is common practice to use relay arrangements which control the various motors which are being synchronized. For this purpose it is usually necessary to provide a separate energy source for the relays and of course, the relays themselves absorb a substantial amount of power which would be highly objectionable in the cheaper types of apparatus.

The present invention overcomes the disadvantages of the prior art by providing rotary circuit breakers synchronized with the rotary speeds of the respective motors and connected directly in the energizing circuit of one of the motors.

It is accordingly an object of the present invention to overcome the disadvantages of the prior art arrangements.

A second object of the present invention is to provide a new and improved apparatus for maintaining a predetermined relationship between the rotational speeds of independent rotary members.

Another object of the present invention is to provide a new and improved apparatus for synchronizing the rotational speeds of independent rotary members.

A further object of the present invention is to provide a new and improved apparatus for synchronizing the motion picture film transport mechanism with a sound track transport mechanism for the film.

Still another object of the present invention is to provide a new and improved apparatus which is relatively inexpensive to construct and which accurately synchronizes the rotational speeds of independent rotary members.

Still a further object of the present invention is to provide a synchronizing apparatus for independent rotary members which permits the rotary members thereof to be quickly brought up to the desired speed before the synchronizing action is commenced.

With the above objects in view the present invention relates to an apparatus for maintaining a predetermined relationship between the rotational speeds of independent rotary members and including energizing means for energizing the rotary members to cause the same to rotate, and switching means movable between circuit-opening and circuit-closing positions by the rotary members and connected in circuit between the energizing means and one of the rotary members, for regulating the energization of the one rotary member so that the respective rotational speeds of the rotary members are maintained in a predetermined relationship whereby the switching means maintain a circuit in circuit-closed position when the predetermined speed relationship is not yet achieved and in circuit-open position when the predetermined speed relationship is surpassed, and vice versa.

In another embodiment of the present invention two different switching means are used. The switching means are connected in parallel with each other and in circuit

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between the energizing means and one of the rotary members.

In a preferred embodiment, the present apparatus is used for synchronizing the rotational speeds of two independent rotary members and includes a regulating means which is rendered ineffective by the switching means when the two rotary members are rotating at a speed ratio under a desired value and renders the regulating means effective when they rotate at a speed ratio over the desired value.

In still another embodiment of the present invention time delay means are used for preventing the operation of the switching means until the expiration of a predetermined time period. In addition, visual indication means may be provided for indicating when the predetermined time period has expired.

The novel features which are considered as characteristic for the invention are set forth in particular in the appended claims. The invention itself, however, both as to its construction and its method of operation, together with additional objects and advantages thereof, will be best understood from the following description of specific embodiments when read in connection with the accompanying drawings, in which:

FIG. 1 is an electrical schematic diagram showing the interconnection of the electrical synchronizing apparatus and showing the film projector and sound track mechanism in diagrammatic form;

FIG. 2 is a plan view of a rotary switch arrangement used with the apparatus shown in FIG. 1;

FIG. 3 is a partial electrical schematic view of another embodiment of the present invention;

FIG. 4 is an electrical schematic diagram of still another embodiment of the present invention;

FIG. 5 is an electrical schematic diagram showing the interconnection of the electrical synchronizing apparatus and showing the film projector and sound recording reproducer in diagrammatic form;

FIG. 6 is an electrical schematic diagram of another embodiment of the present invention;

FIG. 7 is an electrical schematic diagram of an embodiment of the present invention using saturable reactors; and

FIG. 8 is an electrical schematic diagram of a further embodiment of the present invention using saturable reactors.

Referring to the drawings and more particular to FIG. 1 it can be seen that the sound track transport mechanism is diagrammatically mounted on a housing 1 such as used for a magnetic tape recorder and sound reproducer. Similarly, the motion picture projector is diagrammatically shown as a housing 2.

Near the bottom of the diagrammatic showing of the housing 2 is provided terminals 3 and 4 which are adapted to be connected to a source of energizing potential. The terminal 4 is connected on a conductor 5 to the field winding 6 of a driving motor 7 for the film transport. The other side of the motor 7 is connected on conductor 8 to a junction 8'. The junction 8' is connected to one terminal of a resistor 9, the other terminal of which is connected through a switch 10 and a conductor 11 to the second supply terminal 3.

Also connected to the junction 8', at the right hand side thereof, is a conductor 33 which is connected to one side of a normally open push button switch 34, the other side of which is connected to the conductor 11.

The junction 8' is also connected to one side of a normally closed push button switch 28, the other side of which is connected to a sliding contact 31 of a rotary switch 19, having a second sliding contact 30 connected to a junction 30'. The contact 31 is also connected to the junction 30' by means of conductor 32 and a cen-

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trifugally operated switch 18. The switch 18 is mounted on the shaft 16 of the motor 7.

Also mounted on the shaft 16 is the rotary switch 19 and a second centrifugally operated switch 17. The switch 17 has one of its contacts connected to the junction 30' and the other contact thereof connected on conductor 29 to a conductor 24 which has one of its ends connected to one terminal of the resistor 9 and the other of its ends connected to a sliding contact 25 of a second rotary switch 20. It can be seen that the rotary switch 20 is mounted on the shaft 22 of a rotary member 21 which is rotated by the magnetic tape 23 of the magnetic tape recorder and sound reproducer associated with housing 1.

Mounted in the housing 1 is the driving motor 14 which transports the magnetic tape through conventional means not illustrated in order to avoid unnecessarily complicating the drawing. One brush of the motor 14 is connected on a conductor 12 directly to the terminal 4. The other brush of the motor 14 is connected by a conductor 13 through a switch 15 to the conductor 11 and the terminal 3.

It can also be seen that the rotary switch 20, mounted in the housing 1, has a second sliding contact 26 which is connected by conductor 27 to the sliding contact 31 of the rotary switch 19.

Referring now to FIG. 2, the operation of the rotary switches 19 and 20 will be described. The sliding contacts 30 and 31, in FIG. 2, are shown respectively mounted in housing members 39 and 38. These housing members contain resilient means which resiliently urge the respective contacts 30 and 31 into engagement with the electrically conductive coatings 36, 37, respectively, on the periphery of the disk member 35. The disk member 35 is made out of electrically insulated material and is fixedly mounted on the shaft 16 so as to be rotatable therewith. A first electrical coating 36 is applied to a portion of the disk 35 covering a portion of the periphery thereof. A second electrically conductive coating 37 is also applied to substantially the remainder of the disk 35, including the respective peripheral portion thereof. The electrical coatings 36 and 37 are electrically insulated from each other. Similarly, the contacts 30 and 31 are also normally electrically insulated from each other.

It can be seen that the contacts 30 and 31 will be electrically connected to each other when they both contact the same electrical coating on the member 35. For example, in the illustrated position, it is clear that the electrical contact 30 is electrically connected to the contact 31 through the coating 36 on the member 35. As the shaft 16 rotates, however, the member 35 rotates therewith so that the contacts 30 and 31 make sliding contact with coatings 36 and 37 during different portions of the rotation cycle. In the embodiment illustrated in FIG. 2, the contacts 30 and 31 are spaced 90° angularly and the portions of the insulating member 35 coated with the coatings 36 (270°) and 37 (90°) are so arranged and chosen, respectively, that the contacts 30 and 31 are connected together electrically for exactly one-half of the rotational cycle of the shaft 16 and are insulated from each other during the remaining half of the rotation cycle.

An additional feature shown in FIG. 2 is the centrifugal switch arrangement. This includes a first contact 41 mounted on a member 40 which is mounted on the hub 40' of the disk 35. The member 40 makes electrical contact with the electric coating 36. A second contact 42 is shown abutting against the contact 41 and is mounted at one end of a weight 43. The weight 43 is slidably disposed in a rectangular opening in the disk 35 and coating 37 so that the edges of the opening guide the weight 43 as it slides in a radial direction.

The weight 43 includes a bore 44 in which is disposed a spring 45 which urges the weight 43 and the contact 42 radially inward into contact with the contact 41. The other end of the spring 45 bears against a disk 46 on the

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end of a screw 47 mounted in the disk member coating 37. The screw 47 also makes electrical contact with the electrical coating 37 on the disk 35. This electrical contact is carried from the disk 47 to the contact 42 by means of the electrically conductive weight 43 and disk 46.

In operation, the contacts 41 and 42 are in contact with each other so that coatings 36 and 37 are electrically connected together for all speeds below a predetermined speed. This predetermined speed may be chosen to be the synchronizing speed desired for the apparatus or some speed below the same. As this predetermined speed is reached, the centrifugal force will urge the weight 43 in an outward direction against the action of the spring 45 so that the contacts 42 and 41 will be separated. Up until this point, the coatings 36 and 37 have been electrically connected to each other so that the contacts 30 and 31 have also been electrically connected to each other for the entire rotational cycle. However, when the contacts 41 and 42 are separated, the contacts 30 and 31 can only make electrical contact through the coating 36. Accordingly, contacts 30 and 31 are electrically connected only for one-half of the rotational cycle as soon as the contacts 41 and 42 are separated.

Referring now to FIGS. 1 and 2, the operation of the apparatus will be explained. The resistor 9 of the motor 7 is normally chosen so that the voltage applied to the terminals 3 and 4 will drive the motor 7 at a speed below the desired synchronized speed. On the other hand, the motor 14 of the sound track mechanism is preferably chosen to run at the synchronized speed when the voltage is applied to the terminals 3 and 4.

In operation, the switches 10 and 15 are closed to start energization of the motors 7 and 14, respectively. The centrifugal switch 18 is arranged so that the contacts thereof will remain closed until some speed below the desired synchronization speed is reached. Accordingly, the conductor 32 will be still connected to the junction 30' when the switch 10 is closed.

The centrifugal switch 17, also mounted on the shaft 16 of the motor 7, is arranged so that its contacts will remain closed until a speed somewhat higher than the desired synchronization speed is reached. Accordingly, until then the junction 30' will be directly connected to the conductor 29. It therefore can be seen that, at the start, when the switch 10 is closed, the resistor 9 is short-circuited by the circuit extending from the junction 8' through the normally closed switch 28, the conductor 32, the closed centrifugal switch 18, the closed centrifugal switch 17, the conductor 29 and the conductor 24.

With the resistor 9 short-circuited, the entire voltage is applied across the field winding 6 of the motor 7 so that the motor 7 is accelerated and quickly reaches a speed near the desired synchronization speed. At some point below this desired speed, the centrifugal switch 18 will open. This removes the short circuit across the resistor 9 due to the opening in the conductor 32. However, the rotary switch 19 which is rotating with the shaft 16 provides an electrical connection between the sliding contacts 30 and 31 thereof for one-half of the rotational cycle of the shaft 16. It can be seen that when the sliding contacts 30 and 31 are electrically connected together, the resistor 9 will again be short-circuited. However, since the contacts 30 and 31 are electrically connected for only one-half of the cycle, the rotary switch will short circuit the resistor 9 only for that one-half of the cycle.

On the other hand, the rotary switch 20 mounted on the rotating shaft 22 and driven by the motor 14 is also rotating and connected in parallel with the rotary switch 19 and across the resistor 9. The rotary switch 20 may be constructed in the same manner as the switch 19, as illustrated in FIG. 2, and accordingly its sliding contacts 25 and 26 will be electrically connected to each other for one-half of the rotational cycle of the shaft 22. If the shafts 16 and 22 are rotating at exactly the same rota-

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tional speed and the rotary switches 19 and 20 are out of phase 180° with each other, the resistor 9 will be short-circuited for the entire rotational cycle of the shafts 16 and 22.

However, since the motor 7 is normally arranged to run at slightly below the synchronized speed with the resistor 9 connected in series therewith, the short-circuiting of the resistor 9 will tend to increase the speed of the motor 7 above the synchronized speed. Therefore, the rotational speed of the shaft 16 will slowly increase. When this occurs the 180° angular relation between the rotary switches 19, 20 will be changed. Therefore for short periods of the rotational cycle, the contacts 30 and 31 will be electrically insulated from each other during the same time interval as the contacts 25 and 26. Therefore the resistor 9 will no longer be short-circuited for the short time intervals.

When the resistor 9 is inserted for short portions of the rotational cycle, the speed of the motor 7 will tend to decrease thereby making these portions smaller and smaller until the speed of the motor 7 is slightly below synchronism with the speed of the motor 14 and the resistor 9 will be short-circuited for a greater part of the rotational cycle. At this point, the speed of the motor 7 will again tend to slowly increase until the rotary switches are again more out of phase with each other and the cycle will be repeated with diminishing amplitude.

In the above manner a very accurate synchronization is attained between the motors 7 and 14 since the control provided by the rotary switches 19 and 20 is a very fine control. That is, the resistor 9 will be rendered effective when the relative phase relationship between the rotary switches 19 and 20 are only a few degrees away from the desired position.

Since the rotary switches 19 and 20 provide such a fine synchronization control, some coarser control means are provided. These coarser control means include the centrifugal switches 17 and 18. In addition coarse accelerating and decelerating controls are respectively provided by the push button switches 34 and 28. That is, at the start of the motors 7 and 14, when the switches 10 and 15 are initially closed, the push button switch 34 may be operated. When this occurs, it can be seen that the resistor 9 is short-circuited by the closed switch 34 so that the rotary switching means 19 and 20 are rendered ineffective and inoperable. When the desired synchronized rotational speed of the motors 7 and 14 is reached, the push button 34 may be released and its restoring spring will restore it to its normally open position. At this point the fine control means afforded by the rotary switches 19 and 20 is then rendered effective to short-circuit the resistor 9 at the exact synchronized speed.

In the event that the push button switch 34 has been closed so long and the motor 7 has been permitted to reach a speed substantially higher than the desired synchronized speed, before the switch 34 is released, the centrifugal switch 17 will be opened. This will place the resistor 9 effectively in series with the motor 7 and render the rotary switches 19 and 20 ineffective for synchronization control. With the resistor 9 in series with the motor 7, the speed of the motor 1 will be decreased until the desired synchronized speed is reached. At this point, the centrifugal switch 17 again closes and the rotary switches 19 and 20 regain effective control of the resistor or regulating means 9 for the motor 7.

Similarly, the opening of the normally closed switch 28 will also render ineffective the centrifugal switches 17, 18 and the rotary switches 19, 22. With the push button switch 28 opened, the resistor 9 will be effectively in series with the motor 7 and thereby cause the motor to run slower if it is above the synchronization speed.

It is of course apparent that the motors 7 and 14 need not be exactly synchronized with each other by the use of the fine control arrangement of the rotary switches 19 and 20. That is, the angular arrangement of the con-

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tacts and coatings on the switches 19 and 20 may provide an arrangement whereby one of the motors will run slower or faster than the other motor and this predetermined speed relationship between the two motors may be maintained by the rotary switches 19 and 20.

Instead of introducing the resistor 9 in order to slow down the motor 7, it might also be possible to open the energization circuit of the motor 7 by means of the switches 19 and 22. However, this might provide too sharp a change for the desired smooth running projector motor 7. Therefore, the resistor 9 arrangement, used as regulating means for the motor 7, is to be preferred.

Referring now to FIG. 3, another embodiment of the speed regulation arrangement of the present invention is shown. In this embodiment, the parts which are numbered with numbers corresponding to FIG. 1, have the same function as they do in FIG. 1.

It can be seen that in FIG. 3, there are no centrifugal switches mounted on the rotating shaft 16 of the motor 7. Also, the sound track transport means such as the magnetic tape recorder 1, is not shown since it corresponds to that shown in FIG. 1 for this embodiment.

In FIG. 3, a second switch 51 is provided substantially in parallel with the switch 10, and has one terminal connected to the conductor 11 and the other terminal connected to one side of a heater winding 53. The other side of the heater winding 53 is connected to a thermal sensitive switch element 52, such as a bi-metallic element. The element 52 in its normal position is connected to the conductor 50 and when the heater winding 53 has reached a certain temperature, the thermal sensitive element 52 is deflected into contact with the contact 54. Connected to the contact 54 is one terminal of a lamp 55, the other terminal of which is connected to the conductor 5 and the terminal 4.

In operation, the switch 51 is closed at the same time as the switch 10. Therefore, the resistor 9 is short-circuited by the switch 51, the heater winding 53, the thermal sensitive element 52 and the conductor 50. As current flows through the heater winding, the temperature surrounding the thermal sensitive element 52 increases until the element 52 is deflected out of contact with the conductor 50 and into contact with the contact 54. At this point, the short circuit across the resistor 9 is removed and the lamp 55 is energized. The operator, seeing the lamp in energized condition, opens the switch 51 thereby removing the flow of current through the heater winding 53 and the lamp 55. At this point, the resistor 9 can no longer be short-circuited by the thermal sensitive element 52. Therefore, the rotary switches 19 and 20 are again able to provide their fine synchronization control explained hereinabove with respect to FIG. 1.

It is apparent that since the heater winding 53 takes a predetermined period of time in order to heat up sufficiently for actuating the thermal sensitive element 52, that the motor 7 will be able to reach its synchronizing speed by the time the element 52 is actuated. Accordingly, the arrangement of FIG. 3 provides a time delay means which renders the rotary switches 19 and 20 ineffective and the resistor 9 ineffective for a substantially predetermined time. It is also clear that instead of a lamp 55 some other visual indicating means may be provided or that a relay may be used which automatically opens the switch 51.

Referring now to FIG. 4, still another embodiment of the present invention is provided. In this embodiment, the energizing voltage is applied to supply terminals 60 and 61. The terminal 61 is connected to one side of a switch 62, the other side of which is connected by conductor 63 to one side of a field winding 64, the other side of which is connected by conductor 65 to one brush of the motor 66. The other side of the motor 66 is connected by conductor 67 to junction point 67'. It is clear that the motor 66 corresponds to the motor 7 of

FIG. 1 and is used for driving the transport mechanism in the motion picture projector 2.

The junction 67' is connected to one side of a switch 68, the other side of which is connected by conductor 69 to the supply terminal 69. The switch 68 has a normally open contact connected to one side of a heater winding 80, the other side of which is connected to the normally closed contact thereof.

The junction 67' is also connected to one side of a resistor 72, the other side of which is connected to one side of a resistor 71. Resistor 72 is also connected by conductor 78 to one side of a normally open push button switch 79, the other side of which is connected to a junction 73'. The junction 73' is connected to one side of a normally closed push button switch 73, the other side of which is connected to the resistor 71 and by conductor 70 to the field winding 64. The junction between the resistor 72 and the resistor 71 is also connected by a conductor 78' to a fixed contact of a normally open switch having a thermal sensitive element 77, the other side of which is connected by conductor 76 to one sliding contact of the rotary switch 19. The other sliding contact of this switch is connected by a conductor 75 to one contact of the rotary switch 20. The other contact of the rotary switch 20 is connected by conductor 74 to junction 73 as is the other contact of the rotary switch 20.

The resistor 71 is chosen to be larger than the resistor 72. Therefore, in operation, when the switches 62 and 68 are closed so that the swinding 80 is connected between the conductor 69 and the junction 67', the entire voltage applied to the supply terminals 60 and 61 is connected across the motor 66. The resistance of the heater winding 80 is kept proportionally small. Therefore, the motor 66 quickly accelerates towards its synchronizing speed. It should be apparent that the unillustrated motor of the magnetic tape recorder also accelerates towards its synchronizing speed in the same manner as described hereinabove with respect to FIG. 1 by operation of the unillustrated switch 15.

When the heater winding 80 has raised the temperature of the temperature sensitive element 77, sufficiently, the element 77 closes the switch in which it is connected so that the rotary switches 19 and 20 are connected into the circuit. If the motors of the film projector and the sound track transport mechanism are rotating at nearly the same speed, the resistor 71 will be short-circuited for every half rotational cycle of the shaft 16' of the motor 66 when the rotary switches 19 and 20 are in phase. The constance of the motor 66, the resistor 72 and the field winding 64 are chosen so that, with resistor 71 short-circuited in this way, the motor 66 will run at a speed slightly below the desired synchronous speed.

Therefore, with the resistor 71, short-circuited by the rotary switches 19 and 20, the speed of the motor 66 will decrease until the rotary switches 19 and 20 are no longer in phase. At this point, the resistor 71 will be placed in series with the resistor 72 for a greater portion of the rotational cycle. For this portion, a greater amount of current will flow through the resistor 71, since the larger resistor 71 will have been placed in circuit parallel to the motor 66. This will increase the rotational speed of the motor 66 until the desired synchronism between the rotary switches 19 and 20 is again achieved.

The push button switches 73 and 79 again provide manually operated controls independent of the synchronized rotary switches 19 and 20. That is, if the normally open switch 79 is closed, the resistor 71 will be short-circuited regardless of the operation of the switches 19 and 20 and the motor 66 will tend to run slower. On the other hand, if the normally closed switch 73 is opened, the resistor 71 will remain in circuit parallel to the motor 66 and the motor 66 will run faster regardless of the relative positions of the rotary switches 19 and 20.

It is of course apparent that the rotary switches need not be mounted directly on the rotary shafts of the driv-

ing motors but may be coupled thereto so as to have some predetermined speed relationship therewith. Of course, it is desirable that any coupling between the rotary switch and the shafts of the driving motors should be a non-slip type of coupling. Also, those switches which are not push button switches can be arranged to be operated by the same shaft so that a single movement of the switch will start the energization of the motors or stop the same.

As indicated hereinabove, the embodiments illustrated in FIGS. 1 and 3, the resistor 9 need not be used. However such an arrangement should only be provided for very light loads.

It will be possible to synchronize the speed of more than two rotary members if the proper rotary switches are provided having the proper angular spacing between their contacts and the coatings on their respective insulating members are also properly defined.

Referring now to FIG. 5, another embodiment using different types of rotary switch members will be described. In this embodiment the recorded sound reproducer 1' which may be a magnetic tape recorder, for example, includes a driving motor 3' which is adapted to be connected to an energizing source through a double pole switch 5' and a plug member 4'.

The magnetic tape 6', itself, can be rotated in a manner which is not further described since it forms no part of the present invention. A roller 7' is rotatably mounted on the tape recorder housing 1' and is adapted to be rotated by the moving magnetic tape 6'. It can be seen that the roller 7' is mounted at one end of a shaft 8'' which rotates at a speed proportional to the rate of movement of the magnetic tape 6'.

Fixedly mounted on the shaft 8'' is a rotary switch member 9' having a disc-shaped insulating member 10'. Around a portion of the periphery of the disc 10' is arranged an electrically conductive coating 13' which is adapted to make sliding contact with the fixed contacts 11' and 12' of the switch member. Also included in the switch member 9' is an annular member 14' in the form of a slip ring which makes sliding contact with a third fixed contact 15' of the switch 9'. It is clear that the three fixed contacts 11', 12', and 15' may be in the form of conventional brushes which make good electrical sliding contact with the movable portions of the switch 9'.

Referring now to the motion picture projector 2', it can be seen that a driving motor 16' is mounted on the housing thereof. Connected to one side of the motor 16' is a conductor 17' which is further connected through an adjustable resistor 21' and via one side of a switch 19' to a power plug 20' which is adapted to be connected to an energizing source for energizing and rotating the motor 16'. A second conductor 18' is connected to the other side of the motor 16' and is further connected to the other side of the switch 19' for completing the energizing circuit for the motor 16'.

The motor 16' is provided with a shaft 22' on which is mounted a second rotary switch member 23' having an insulated movable member 24' adapted to rotate with the shaft 22'.

Around a portion of the outer periphery of the insulated member 24' is arranged an electrically conductive coating 27' which is adapted to make sliding contact with the diametrically opposed fixed contacts 25' and 26' of the switch 23'. Also, the switch 23' has an electrically conductive annular member 28, in the form of a slip ring which makes sliding contact with the third fixed contact 29' of the switch 23'. It should be noted that in both the switches 9', 23', the center annular member 14' and 28' respectively is connected to the electrically conductive coating 13' and 27', respectively.

The fixed contact 29' of the switch 23' is connected by a conductor 30' to a first junction point 31'. The fixed contact 15' of the switch 9' is connected by a conductor 32' to a second junction point 33'. It can be seen that the junction points 31' and 33' are on opposite sides of the adjustable resistor 21'.

The contact 12' of the switch 9' is connected by a conductor 34' to the fixed contact 25' of the switch 23'. Also, the fixed contact 11' is connected by a conductor 35' to the fixed contact 26' of the switch 23'.

The resistance of the adjustable resistor 21' is so adjusted that the driving motor 16' of the motion picture projector rotates at a speed which is slightly lower than the desired synchronous speed of the magnetic tape recorder when the resistor 21' is connected in circuit with the motor 16'.

In operation, it can be seen that the switches 9' and 23' each have a plurality of contacts which are respectively connected to a plurality of contacts of the other switch member and that the two switch members 9' and 23' are connected in series between the energizing source for the driving motor 16' and the motor 16'.

To start the apparatus, the plugs 4' and 20' are connected to a suitable power source and the switches 5' and 19' are operated into their circuit closing position. The electrically conductive coatings 13' and 27' are arranged substantially 180° about the periphery of their respective insulating members. Accordingly, if the shaft 8'' and the shaft 22' are rotating at precisely the same rotational speeds and the switch members 9' and 23' are 180° out of phase with one another, it can be seen that the resistor 21' will be completely short-circuited. This is carried out in the following manner. From the junction point 31', the conductor 30' is connected to the fixed contact 29' which makes electrical contact with the slip ring 28'. The slip ring 28' is connected to the conductive coating 27' which makes contact with the fixed contact 25' and from there the conductor 34' is connected to the fixed contact 12'. The fixed contact 12' makes contact with the coating 13' which is connected to the slip ring 14' and the fixed contact 15'.

From the fixed contact 15', by conductor 32', the circuit is completed to the second junction point 33' thereby short circuiting the resistor 21'. It can be seen that when the conductive coatings of the two switches make respective contact with the other fixed contacts, that the same short circuiting circuit will be kept in circuit closed condition for short circuiting the resistor 21'.

Since the resistance of the resistor 21' has been adjusted so that the motor 16' will run slightly slower than the driving motor for the magnetic tape 6', it can be seen that if the resistor is short-circuited for the entire rotational period of the shafts 8'' and 22', that the motor 16' will soon be running faster than the shaft 8''. Accordingly the rotary switching member 23' will be moved out of the 180° phase relationship with the rotary switch member 9'. Therefore, for some portion of the cycle, the resistor 21' will not be short circuited and will be placed in series with the motor 16'. This will slow down the motor 16' until the 180° phase relationship is again achieved. When this is achieved, the motor 16' will again begin to run faster than the shafts 8'' so that the switching member 23' will again be moved out of the 180° phase relationship with the switch member 9'. It can be seen that this will provide a very fine control with the rotational speed of the motor 16' always being maintained at just about the proper speed with respect to the rotational speed of the shaft 8'.

It is clear that the synchronization between the shafts 8'' and 22' is automatically carried out by the relative phase relationships between the rotary switch 9' and the rotary switch 23'.

It can be seen that the number of times that the circuit containing the two switching members is maintained in circuit closed condition for a given time period is inversely proportional to the ratio between the speed at which the switching members are rotated. That is, when the two shafts 8'' and 22' are rotating in synchronism, the switches 9' and 23' will maintain their respective circuit in circuit closed condition once for the rotational periods of the shafts. However as the shaft 22' moves faster and

out of synchronism with the magnetic tape moving device, the switch member 23' will be moved out of this phase relationship with the switch member 9' so that the number of times that the circuit is moved between circuit closing and circuit opening conditions will increase the farther away from the rotational speed of the shaft 8' that the shaft 22' moves.

Referring now to FIG. 6, another embodiment will be described. In this embodiment the rotary switch member 40'' is arranged to be mounted on the shafts 8'' of the tape recorder. The shafts 8'' and 22' are left out of FIG. 6 in order not to unnecessarily complicate the drawing.

The rotary switch member 40'' is provided, as before, with an electrically conductive coating 41' arranged about substantially 180° of its periphery, an annular slip ring 45' which makes contact therewith and three fixed contacts 42', 43' and 44'.

A second rotary switch member 54' is provided and adapted to be mounted on the rotary shaft 22'. The insulated disc portion 55' of the rotary switch member 54' is provided with two electrically conductive coatings 56' and 57', respectively. The coatings 56' and 57' are electrically insulated from each other and make contact respectively with the centrally disposed annular member 62' through respective centrifugal switch members 60' and 61'.

The centrifugal switch 60' is normally closed, as shown, to connect the coating 56' with the slip ring 62'. Similarly, the normally closed centrifugally operated switch 61' connects the coating 57' with the slip ring 62'. The springs which keep the switches 60' and 61' in normally closed position are arranged so that the switch 60' will open when the rotational speed of the switch member 54' reaches a speed just below the synchronization speed. Similarly, the centrifugally operated switch 61' is arranged to open at a speed just above the synchronization speed.

The switch member 54' is further provided with three fixed contacts 58', 59' and 63'.

Also shown in FIG. 6 is the driving motor 48' for the motion picture projector, one side of which is connected by a conductor 47' and a field winding to the power supply terminal 46'. The other side of the motor 48' is connected by a conductor 49' to a junction point 50'. Also connected to the junction point 50' is one terminal of an adjustable resistor 51', the other terminal of which is connected to a junction point 52'. The junction point 52' is connected through a switch member 53' to the other terminal of the power supply. The junction point 52' is also connected to a resistor 67' and a conductor 66' to the fixed contact 44' of the rotary switch 40''.

The junction point 50' is further connected through a normally closed push-button switch 65' and a conductor 64' to the fixed contact 63' of the switch 54'. One side of the push-button switch 65' is also connected to the normally open push-button switch 71' the other side of which is connected by conductor 70' to the conductor 66'.

The switch members 40'' and 54' are further connected together by the following connections. The fixed contact 43' is connected by conductor 68' to the fixed contact 59'. Similarly, the fixed contact 42' of the switch 40'' is connected by conductor 69' to the fixed contact 58'.

Mechanically connected to the switch 53' is a second switch 72' which closes the circuit for the magnetic tape recorder so that the one switch member can simultaneously start both of the rotary members rotating.

As before, the resistance of the resistor 51' is adjusted so that the speed of the motor 48 will be below the desired synchronization speed when the resistor 51' is connected in the circuit of the motor 48.

In operation, the switches 53' and 72' are closed to start the rotary members in rotation and to rotate the switch members 40'' and 54'. Since the centrifugally operated switch 60' is closed, current flows through the motor 48 from the junction point 50' through either one of the conductive coatings 56' or 57' of the rotary switch

54' and to either one of the fixed contacts 42' and 43' back to the junction point 52'. Accordingly, the resistor 51' is completely short-circuited and the motor 48 quickly increases in speed until it reaches the speed just below the synchronization speed when the centrifugally operated switch 60' opens. This is equivalent to the circuit explained in FIG. 5 so that the motor 48 is regulated at substantially the synchronization speed desired.

If for any reason, the motor 48 suddenly runs substantially faster than the synchronization speed, the centrifugally operated switch member 61' will be opened to open the circuit between the junction points 50' and 52' and place the resistor 51' in the circuit of the motor 48. This will slow the motor down again to a point where the centrifugally operated switch 61' will close and the fine regulation control will be reinstituted.

It should be clear that the range between the operation of the centrifugally operated switches 60' and 61' need not be too great, in the order of 15-17 frames per second for the motion picture projector, since the control arrangement carried out in accordance with the present invention provides such a fine control that the motor 48 is always maintained in substantial synchronization with the driving member for the magnetic tape recorder.

With the embodiment of FIG. 6, in the event that the motion picture projector is greatly out of synchronism with the recorded sound in that the displayed film portion is far behind the recorded sound, it is merely necessary to close the normally open push-button switch 71' to substantially short circuit the resistor 51' and speed up the motor 48 until the film arrangement comes close to the recorded sound when the actual synchronizing control mechanism can take over. With this push-button switch 71' closed, the resistor 67' serves to limit the maximum current through the motor 48 as a safety device.

Similarly, if the film displayed by the projector is ahead of the recorded sound, by a large amount, it is merely necessary to open the normally closed push-button switch 65' so that the resistor 51' will always be in series with the motor 48 regardless of the positions of the rotary members 40' and 54'. The motor 48 will then slow down until a speed range is reached wherein the fine control mechanism can take over and bring the film into exact synchronism with the recorded sound.

Referring now to FIG. 7, a further control circuit will be described. In this embodiment, a driving motor 75' for the motion picture projector has one side thereof connected to a junction point 76' which in turn is connected to one pole 77' of a source of alternating current energization. The other terminal of the motor 75' is connected through a choke coil 78' to a second junction point 97' and a second terminal 80' of the alternating current source of energization.

The choke coil 78' may be a saturable reactor adapted to have its saturation varied by a second winding 108 which may be arranged on the same core as the coil 78'.

The winding 108 is connected to the opposite output terminals of a full wave bridge rectifier 107, the input terminals of which are connected to the secondary winding 106 of a transformer, having a primary winding 107.

In the embodiment of FIG. 7, a rotary switch member 95 adapted to be mounted on the recorder shaft is shown as is a rotary switch 81 which is adapted to be fixedly mounted on the shaft of the motion picture projector to rotate therewith. The switch 81 has a first electrically conductive portion 83 making sliding contact with a fixed contact 85 which is in turn connected by conductor 92 to the fixed contact 94 of the switch 95. The switch 95 has a slip ring 97 connected directly to the conductive coating 96 thereof and thereby (in the position of 95 as shown) to the fixed contact 93 which is connected by a conductor 91 to the second fixed contact 94 of the switch 87.

The switch 81 also has a second electrically conductive portion 82 which is shown making electrical contact with

the fixed contact 84 and with the slip ring 88 through a normally closed centrifugally operated switch 86. Also making electrical contact with the slip ring 88 is the electrically conductive coating 83 by means of a second normally closed centrifugally operated switch 87. The third fixed contact 89 of the switch 81 is in sliding contact with slip ring 88 and connected by a conductor 90 to the junction point 76'. The third fixed contact 98 of the switch 95 is in sliding contact with slip ring 97 and connected by a conductor 99 through a normally closed push-button switch 100 to one end of the primary winding 101. Across the primary winding is connected a capacitor 103 and in series with the primary winding is connected a resistor 102, the other end of which is connected to the junction point 79'.

Connected to the other junction point 76' is one side of a normally open push-button switch 105, the other end of which is connected by conductor 104 to one side of the normally closed push-button switch 100.

In operation, the rotary switches 81 and 95 operate in the same manner as described hereinabove with respect to FIG. 6. When current flows through the circuit including the switches 81 and 95, in this embodiment, it also flows through the primary winding 101. In this case, the voltage induced in the secondary winding 106 by the flow of current through the primary winding 101 is applied to the input terminals of the rectifier 107. The rectified output thereof is applied across the opposite terminals of the magnetizing winding 108.

The coil 78' and the magnetizing winding 108 cooperate in the manner of a magnetic amplifier wherein the degree of saturation of the core of the coil 78' determines the inductive reactance of this coil. Therefore, the flow of current through the direct current winding 108 reduces the inductive reactance of the coil 78' thereby causing the motor 75' to speed up.

The current flowing through the circuit of the switch members 81 and 95 and the primary winding 101 is limited by the resistor 102. Therefore it can be seen that the flow of current through this circuit is used to control the inductive reactance of the coil 78' in series with the motor 75' and maintain this reactance at some level which will keep the motor 75' in perfect synchronisation with the magnetic tape driving member. The capacitor 103 serves to eliminate any noise voltages appearing across the primary winding 101.

In FIG. 7, the push-button switches 100 and 105 can be operated to make the motor 75' run slower or faster, respectively, regardless of the respective positions of the switches 81 and 95.

Referring now to FIG. 8, a further embodiment will be described. In this arrangement the apparatus is energized by means of the plug 110 being connected to a proper source of energizing potential. Connected to the plug 110 is a first conductor 111 which is connected to one side of a switch member 113, the other side of which is connected to one side of a projection lamp 114 of the motion picture projector, the other side of the projection lamp 114 being connected to a conductor 112 which is connected to the other side of the plug 110.

The conductor 112 is connected to one side of a field winding 119 of a motor 116 for the motion picture projector. The other side of the winding 119 is connected through a reversing switch 117 to the armature 118 of the motor 116, the other side of the armature 118 being connected through the reversing switch 117 to a second field winding 115, the other side of which is connected back to the switch 113.

Also connected across the armature 118 by means of conductors 121 and 122 is a choke coil 120 which may be a saturable reactor whose magnetization is influenced by a magnetizing winding 127.

The opposite terminals of the magnetizing winding 127 are connected to the output terminals of a full-wave rectifier 126, one of the input terminals of the rectifier

being connected on the conductor 125 to a junction point 124 and to one end of the choke coil 120.

The other input terminal of the rectifier 126 is connected on the conductor 130 through a normally closed push-button switch 131 to a fixed contact 132 of a rotary switch member 133 which is adapted to be connected to the rotating shaft of the driving motor 116 for the motion picture projector.

The switch 133 is provided with electrically conductive portions 134 and 135 as well as two further fixed contacts 136 and 137. In addition, mounted on the switch 133 are two centrifugally operated switches 138 and 139. The switches 138 and 139 are normally open and are placed in circuit closing position by the centrifugal force exerted by the rotating switch member 133.

Also provided on the switch 133 is the annular slip ring 140 which makes continuous sliding contact with the fixed contact 132. It can be seen that the fixed contact 132 is further connected to one terminal of a normally open push-button switch 153 the other terminal of which is connected on a conductor 152 to a junction point 151 on the conductor 122.

A second rotary switch member 141 is provided and shown mounted on a rotatable shaft 142 at one end of which is an indexing means made up of a disc 143 having an indexing mark 144 thereon. The indexing mark 144 cooperates with a fixed indexing mark 145 on the housing of the tape recorder. It can be seen in the illustrated position that when the marks 144 and 145 are arranged opposite each other, the fixed contact 154 of the rotary switch 141 is on an insulated portion of the insulated member 146 of the switch 141.

The switch 141 has five electrically conductive portions 147 arranged equally spaced about the periphery thereof, each of these electrically conductive portions being connected to the annular slip ring 148 which makes sliding contact with a fixed contact 149 and which is thereby connected to normally open switches 162 and 163 by a conductor 161.

The other terminal of the switch 162 is connected to one end of a winding of a relay coil 160, the other end of which is connected to the conductor 111 of the energizing source plug 110.

The other end of the switch 163 is connected by a conductor 150 to the junction point 151. The relay winding 160 is also connected by a conductor 159 to a switch 158 which has two different positions, in the normally closed position of which a conductor 157 connects the switch 158 to the fixed contact 154 of the switch 141.

The switch 141 also has a fixed contact 155 which is connected by a conductor 156 to the fixed contact 136 of the switch 133. Actually, the relay 160 has three separate operating contacts 113, 158, and 162 connected thereto. The dotted lines connecting these three movable armatures of the relay 160 indicate that the three armatures are mechanically connected and operated by the relay winding 160. That is, when the relay 160 is energized, the normally open switches 113 and 162 are moved into circuit closing position and the normally closed contact of the switch 158 is opened while the normally open contact thereof is closed.

In operation, the plug 110 is connected to a suitable source of alternating current voltage. The indexing marks 144 and 145 are arranged in the illustrated position so that the fixed contact 154 of the switch 141 does not contact any of the electrically conductive portions 147 of the switch 141. The sound reproducer is separately energized by energizing means not shown to start the switch 141 and the shaft 142 rotating. The switch 163 is then closed so that current flows from the conductor 112 through the reversing switch 117 to the junction point 151 and from there through the conductor 150 through the closed switch 163 and the contact 149 to the slip ring 148. From the slip ring 148 current flows through the fixed contact 154 and intermittently through

the normally closed contacts of the switch 158 to the conductor 159 to energize the relay 160. This closes switches 113 and 162 and moves the movable armature of the switch 158 into its operating position wherein the normally open contacts thereof are closed and wherein the fixed contact 154 is directly connected to the fixed contact 137 of the switch 133 by the conductor 157.

It should be noted that the closed switch 162 operates as a self-holding contact so that the opening of the normally closed position of the switch 158 does not deenergize the relay 160 but the energizing circuit of this relay is maintained complete with the closed switch 162.

The closing of the switch 113 completes the energization circuit for the motor 116 and starts the armature 118 thereof rotating as well as simultaneously lighting the projection lamp 114. At this stage, the circuit including the switches 133 and 141 lies between the junction points 124 and 151.

Since the centrifugal switches 138 and 139 are normally open, no current flows between these junction points until the motor 116 reaches a rotational speed which is just below the desired synchronization speed. Accordingly, until this point is reached, no current flows through the magnetizing winding 127 and the coil 120, connected in parallel with the armature 118 has its maximum inductive reactance so that the armature 118 rotates at its maximum speed.

Shortly before the desired synchronization speed is reached, the centrifugally operated switch 138 closes to connect the electrically conductive portion 134 of the switch 133 to the slip ring 140. Accordingly, the switches 133 and 141 regulate the current flowing through the circuit between the junction points 151 and 124 depending on the relative positions between the conductive portion 134 and the conductive portions 147.

In this embodiment the rotary members 138 and 141 are arranged so that the rotary switch 133 rotates with a rotational speed approximately five times as fast as the rotary switch 141. Depending on the relative phase position between the conductive portion 134 and the conductive portions 147, current will flow through the fixed contacts 136 and 137. In this manner the entire range of current flow in this portion of the circuit may be regulated between maximum current flow and zero current flow.

The stronger the flow of current through the circuit of the switches 133 and 141, the greater the amount of current flowing through the rectifier 126 and accordingly the greater amount of current is developed in the direct current magnetizing winding 127. The greater the flow of current through the winding 127, the lower the inductive reactance of a choke coil 120 and accordingly the lower the flow of current through the armature 118 of the motor 116. That is, since the choke coil 120 is in parallel with the armature 118, it can be seen that as the inductive reactance of the coil 120 increases, a greater proportion of the current will flow through the armature 118 and vice versa.

In the event that the armature 118 rotates at a speed higher than the desired synchronized speed, the centrifugal switch 139 will be moved from its normally open position to an operative closed position. Since the centrifugal switch 138 is already closed, the closing of the switch 139 will cause current to flow between the junction points 151 and 124 through the rotary switch 133.

This means that a continuous maximum current will be applied to the input of the rectifier 126 and a continuous maximum rectified current will be applied to the direct current winding 127. This will cause the impedance of the choke coil 120 to be decreased to its minimum value so as to take the greatest amount of current away from the armature 118, thereby slowing down the armature 118 until it again approaches the synchronized speed.

The function of the capacitor 128 connected across

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the output of the rectifier 126, is to smooth out the rectified current output from the rectifier.

It can be seen that by means of the reversing switch 117, it is possible to reverse the direction of rotation of the motor 116 so that it will be possible to synchronize the running of the film projector in the reverse running position with the sound recording medium.

If it is desired to stop the motion picture projector, the switch 163 is opened. This causes deenergization of the relay 160 thereby opening switches 113 and 162 and returning switch 158 to its normally closed position.

It is also possible in the embodiment of FIG. 8 to accelerate the rotational speed of the armature 118 and the motor 116 by opening the normally closed push-button switch 131 and thereby preventing any direct current from flowing through the magnetizing winding 127. Similarly, if it is desired to slow down the armature 118, the push-button switch 153 may be closed to cause continuous maximum current flow through the rectifier and the magnetizing winding 127.

It will be understood that each of the elements described above, or two or more together, may also find a useful application in other types of movement synchronizing arrangements differing from the types described above.

While the invention has been illustrated and described as embodied in a synchronizing arrangement for a motion picture projector and related sound track, it is not intended to be limited to the details shown, since various modifications and structural changes may be made without departing in any way from the spirit of the present invention.

Without further analysis, the foregoing will so fully reveal the gist of the present invention that others can by applying current knowledge readily adapt it for various applications without omitting features that, from the standpoint of prior art, fairly constitute essential characteristics of the generic or specific aspects of this invention and, therefore, such adaptations should and are intended to be comprehended within the meaning and range of equivalence of the following claims.

What is claimed as new and desired to be secured by Letters Patent is:

1. Apparatus for maintaining a predetermined relationship between the rotary speeds of rotary members driven by independent motors, respectively, comprising, in combination, first motor means for driving a first rotary member; second variable speed motor means for driving a second rotary member at a speed depending upon an adjustable characteristic of the current supplied to said second motor means; regulating means for varying said adjustable characteristic of said current and comprising a saturable choke coil means connected in parallel with said second motor means, and inductive means for reducing the reactance of said choke coil means; and control circuit means for controlling said regulating means and including a series-combination formed by interconnected first and second switching means independently operable between circuit-closing and circuit-opening positions by said first and second motor means, respectively, in such a manner as to vary, during each rotational period of said second motor means, the period of conductivity across said series-combination of switching means between zero duration and the duration of said rotational period of said second motor means, depending upon the prevailing speed relationship between said first and second motor means, said inductive means being coupled with said control circuit means for being energized thereby and for reducing the reactance of said choke coil means in proportion to the duration of said period of conductivity across said series-combination of switching means, and for thereby increasing and decreasing, respectively, the speed of said

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second motor means whenever the actual speed relationship of said first and second motor means differs in one or the other sense from said predetermined speed relationship.

2. An apparatus as claimed in claim 1, each of said switching means comprising a disc-shaped electrically insulating member respectively mounted on said rotary members and rotatable therewith, at least one electrically conductive coating partially covering the annular periphery of said insulating member, an electrically conductive annular member mounted on said insulating member and connected with said electrically conductive coating, a first and a second fixed contact being insulated from each other and making sliding contact with said annular periphery of said disc-shaped insulating member so as to make electrical contact with said electrically conductive coating at least once during each revolution of its respective rotary member, and a third fixed contact making continuous sliding contact with said electrically conductive annular member, said series-combination being established by interconnection of said first fixed contacts and by interconnection of said second fixed contacts of said first and second switching means, respectively, that one of said switching means which is operable by said second motor means further comprising at least one centrifugally operable switch connected in circuit between said electrically conductive annular member and at least one electrically conductive coating partially covering the annular periphery of the respective insulating member, said centrifugally operable switch being movable between a normal circuit-opening position and a circuit-closing position and being moved into circuit-closing position when the rotational speed of said second rotary member reaches a predetermined value.

3. An apparatus as claimed in claim 2, including indexing means cooperating with said first rotary member for indicating whether said first rotary member is in a predetermined starting position in which said first switching means operable by said first rotary member is in circuit-opening position, and means controllable by said first switching means for starting said second motor means only after said first motor means have been started and said first rotary member has been moved from said starting position so as to move said first switching means into at least one first circuit-closing position.

4. An apparatus as claimed in claim 1, including rectifier means connected between said inductive means and said series-combination of switching means so that, whenever both said switching means are simultaneously in circuit-closing condition, current flowing therethrough is rectified by said rectifier means and applied to said inductive means for charging the saturation of said saturable choke coil means and thereby changing the energizing current and rotational speed of said second motor means.

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