Nov. 12, 1940. G. SCHMIDT 2,221,112

SYNCHRONIZING AND PHASING DEVICE

Filed April 2, 1938 2 Sheets-Sheet 1

Fig. 1

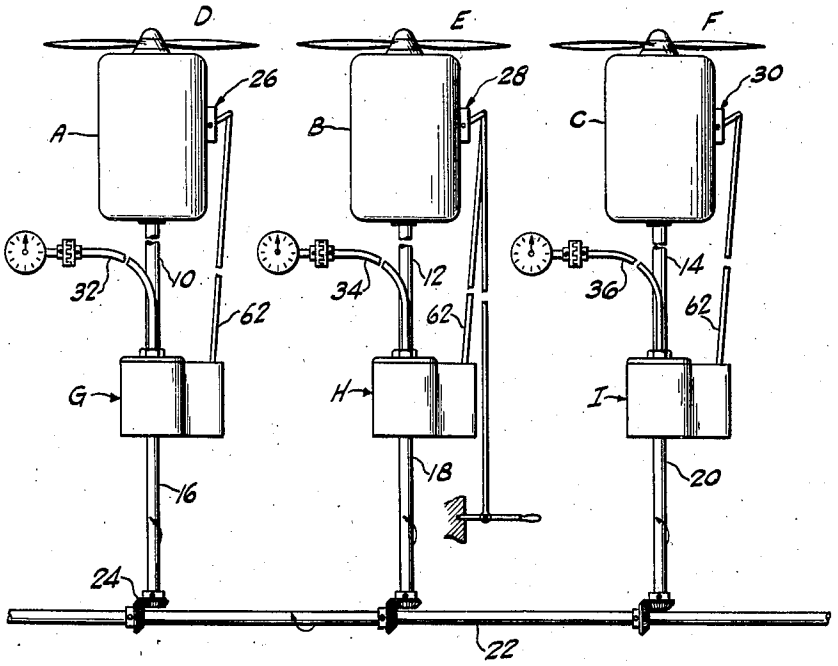

Fig. 6

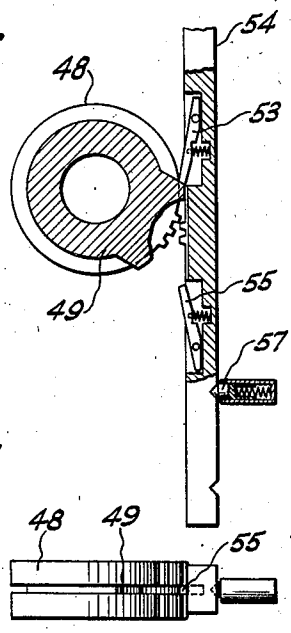

Fig. 7

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Fig. 2

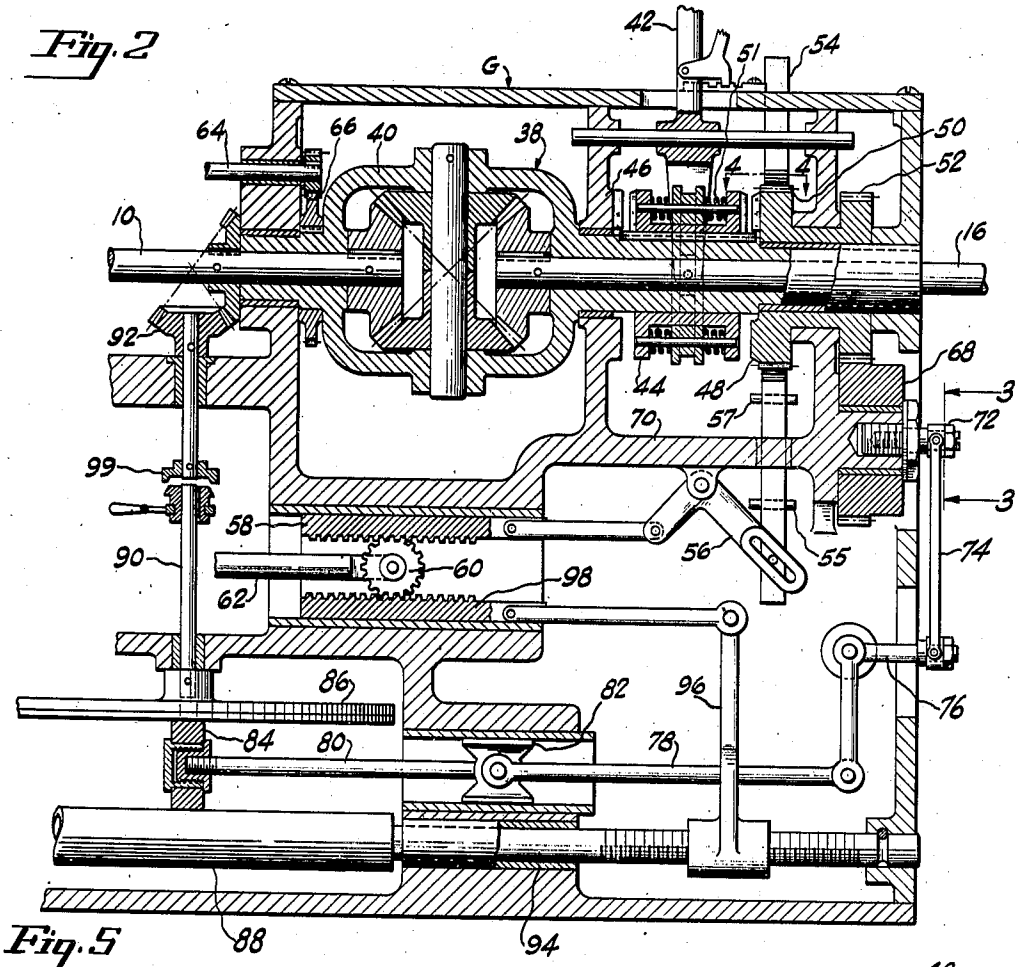


Fig. 5

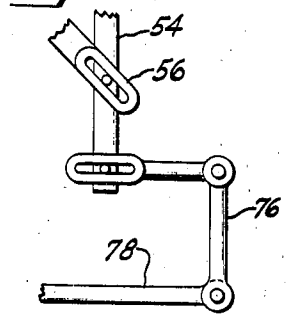


Fig. 3

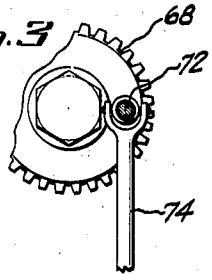
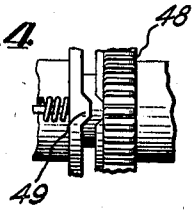


Fig. 4



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UNITED STATES PATENT OFFICE

2,221,112

SYNCHRONIZING AND PHASING DEVICE

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Application April 2, 1938, Serial No. 199,565

12 Claims. (Cl. 60—97)

This invention relates to improvements in apparatus for causing two or more motors to operate in synchronism and has particular reference to an improved apparatus of the character described effective to maintain a plurality of motors in synchronism as to speed and in a predetermined phase relation.

An object of the invention resides in the provision of an improved synchronizing apparatus of the character described adapted to maintain an engine in a condition of speed and phase coincidence with the speed and phase condition of a master engine or reference speed device.

Other objects and advantages will be more particularly pointed out hereinafter or will become apparent as the description proceeds.

In the accompanying drawings there has been illustrated a suitable mechanical embodiment of one possible application of the invention to the purpose specified. The drawings, however, are for the purpose of illustration only and are not to be taken as limiting the invention, the scope of which is to be measured by the scope of the appended claims.

In the drawings—

Fig. 1 is a schematic illustration of a plurality of motors equipped with the improved synchronizing and phasing apparatus constructed according to the invention.

Fig. 2 is a sectional view through one of the speed synchronizing and phasing units.

Fig. 3 is a fragmentary end view of an element of the device as indicated by the line 3—3 of Fig. 2.

Fig. 4 is a detailed view of a clutch element for manually changing the operation of the device, the view being taken along the line 4—4 of Fig. 2, looking in the direction of the arrows.

Fig. 5 is a fragmentary partly schematic view of a modified arrangement for operating the phase relation maintaining portion of the device.

Fig. 6 is a detailed view of a modified arrangement for allowing overtravelling of the speed synchronizing gear with respect to the rack bar which operates the speed controlling mechanism and,

Fig. 7 is a side elevational view of the structure shown in Fig. 6.

Referring to the drawings in detail there is shown in Fig. 1 a plurality of engines arranged for simultaneous operation, three engines being shown as indicated at A, B and C. While the engines may be used for any purpose to which they are adapted, they have been shown as provided with aeronautical propellers for converting their power into propulsive effort for an aircraft. The propellers are indicated respectively at D, E and F and if desired, may be controllable pitch or constant speed propellers of any one of several forms well-known to the art.

In Fig. 1 the engine B has been shown provided with the manual control for the master engine. It is to be understood, however, that any one of the various engines may be selected as the master or speed-controlling engine or that that function may be performed by a separate device, such for instance, as a small controllable speed electric motor, used for that purpose only.

Each of the engines has associated therewith a synchronizing unit as generally indicated at G, H and I respectively, each synchronizing unit being connected with its respective engine by an engine-driven shaft, as indicated at 10, 12 and 14 respectively, and connected with the other engines of the group by the respective shafts 16, 18 and 20 and the common shaft 22. The common shaft 22 is connected with each of the respective shafts 16, 18 and 20 by suitable means such as the pairs of bevel gears 24.

Each of the engines A, B and C is provided with a speed-controlling device, as generally indicated at 26, 28 and 30 respectively, which devices may be adjusting means for the governors of constant speed propellers, means for adjusting the engine throttles, means for varying the gear ratio in a gear drive between the engine and its associated propeller, or any other applicable means for controlling the speed of the engine. Each of the synchronizing units G, H and I is equipped with an indicator as indicated at 32, 34 and 36 respectively, effective to indicate the instantaneous speed difference or phase relationship between a particular controlled engine and the master engine or reference speed device.

It has been stated that the synchronizing units G, H and I are effective to maintain the various engines in phase coincidence as well as speed synchronization. The manner in which the synchronizing units are constructed and in which they operate to accomplish this function is particularly illustrated in Fig. 2.

As the synchronizing units are all similar in construction and operation, it has been considered that a detailed description of only one such unit is sufficient for the purpose of this disclosure.

Assuming, for example, that the synchronizing unit, illustrated in detail in Fig. 2, is the unit generally indicated at G in Fig. 1; the shaft 10

leads from the engine A to the synchronizing unit and the shaft 16 leads to the common shaft 22 by which it is connected with the master engine B. The shafts 10 and 16 are coaxial and between their adjacent ends there is disposed a differential unit generally indicated at 38 having a rotatably mounted cage 40. As long as the shafts 10 and 16 rotate at the same speed in opposite directions, the cage 40 will not rotate, but upon any difference in the speeds of the shafts 10 and 16 a rotation of the cage will take place.

In the arrangement illustrated the master engine is selected by locking the associated synchronizing unit in such a manner that the common shaft is driven positively by that engine. This may be accomplished by moving the manual lever 42 to a position such that the clutch 44 engages the fixed member 46 thereby restraining the respective cage 40 against rotation. The clutch and associated fixed member are each provided with a single locking tooth or dog so that the cage will always be locked in the same relative position. Since there is then a positive driving connection from the master engine to one end of the synchronizing unit associated with the controlled engine and a positive driving connection from the other end of the synchronizing unit to the controlled engine, the rotational position of the cage in the synchronizing unit associated with the controlled engine will be definitely related to the phase relationship between the controlled engine and the master engine so that the phase relationship between the two engines can be maintained constant by maintaining the cage in the same relative rotational position. It is, therefore, apparent that when two or more engines are operating together, if the cage in the synchronizing unit associated with any controlled engine is stationary and occupies a definite rotational position, the controlled engine will be in speed synchronization with and in a predetermined phase relation with the master engine.

In the case of the controlled engine the manual lever 42 is positioned so that the clutch 44 engages the rotatable element 48. The clutch and the rotatable element are each provided with a single tooth or dog 49 so that the cage 40 will always occupy a definite rotational position with respect to the rotatable element. The rotatable element, in the construction illustrated in Fig. 2, comprises two externally toothed gear members 50 and 52 for actuating the speed and phase controlling elements of the unit. The gear element 50 cooperates with a rack 54 which is connected at one end to a bell crank lever 56 connected in turn to a rack bar 58 having teeth meshing with the teeth of a gear 60 carried upon one end of a link 62 operatively connected with the engine speed controlling device, such as the throttle 26 of the engine A.

The operation of this portion of the mechanism is believed to be self evident. If the controlled engine goes out of speed synchronization with the master engine the cage 40 will be rotated resulting in a rotation of the gear 50 which will slide the rack bar 54 and, through the medium of the bell crank lever 56, slide the second rack bar 58 to roll the gear 60 in a direction to move the link 62 to adjust the engine speed controlling device in a direction to bring the controlled engine back into speed synchronization with the speed of the master engine. Since the difference in the speed of the controlled engine and the master engine is a function of the rotational speed of the cage 40 this speed difference may be indicated by the instrument 32 driven by the cage through the shaft 64 and meshing gear train 66.

With the speed synchronization mechanism alone operative the cage 40 may be left in any rotational position when the two engines are brought back into speed synchronization, which would mean that, although the engines are synchronized as to speed, they are out of phase with each other. Additional mechanism has therefore been provided to return the controlled engine to a predetermined phase relation with the master engine.

The gear 52 of the element 48, in the construction illustrated in Fig. 2 meshes with a second gear 68 of the same diameter rotatably supported upon the casing 70. The gear 68 carries, eccentrically thereof, a pin 72, particularly illustrated in Fig. 3 connected by means of a universally attached link 74 with one end of a bell crank lever 76 also supported on the casing 70 and connected at its opposite end, through the links 78 and 80 and cross head 82, with a roller 84 positioned between a disc 86 and a cylinder 88. The disc is driven through a shaft 90 and beveled gear train 92 from the shaft 10 driven by the controlled engine. The cylinder 88 is carried upon one end of a rotatable shaft 94 provided for a portion of its length with external screw threads threaded into an aperture in one end of a slide member 96 the opposite end of which is connected with a rack bar 98 having teeth meshing with the pinion gear 60 upon the opposite side thereof from the rack bar 58. When the roller 84 is exactly in the center of the disc 86 the roller will not be rotated by the disc. This position of the roller corresponds to the in-phase position of the cage 40. If the cage 40 occupies a rotational position other than the specified in-phase position the roller 84 will be displaced to one side or the other of the center of the disc 86 and will be rotated thereby, its direction of rotation depending upon the side to which it is displaced. If rotated the roller 84 will rotate the cylinder 88 with the result that the slide member 96 will be moved along the screw threaded portion of the shaft 94 and will, in turn, move the rack bar 98 to roll the pinion 60 in a direction to move the link 62 to adjust the engine speed controlling device until the controlled engine has been brought back into a predetermined phase relation with the master engine.

Operation of the disc 86 and the associated mechanism may be discontinued by means of a manually operable clutch 99 if desired. As a modified form of the arrangement the roller 84 may be actuated directly by the rack bar 54 by some form of direct connection, such as is illustrated by way of example in Fig. 5. In this modified form of the device the rack bar is extended beyond its connection with the bell crank 56 and is provided with a similar connection with the bell crank 76 which has been reversed from the position illustrated in Fig. 2. With this arrangement as the rack bar moves longitudinally in response to rotational movements of the cage 40, due to a non-synchronous condition of the engines, it moves both the bell crank 56 and the link rod 78 to actuate both the speed and phase controlling devices. With this arrangement when, after a condition of speed synchronization at the predetermined phase relationship has been attained, a speed difference occurs, the toothed racks 58 and 98 are initially moved in the same direction upon a longitudinal movement of the rack bar 54 to restore synchronism, when speed synchronism is again attained the action of the

speed synchronizing device is momentarily stopped but as the motors are then out of phase the action of the phase controlling device continues. This action of the phasing device causes a change in the motor such that the rack bar 58 is moved in the opposite direction to restore synchronism. This action continues until rack bar 58 reaches a neutral position, the rack bar 58 comes to rest and the two engines have been restored to speed synchronism and the predetermined phase relationship. In this arrangement it becomes necessary to set up a predetermined meshing relationship between the gear 48 and the rack bar 54.

As the gear 48 may tend to rotate for an interval greater than that necessary to move the rack bar 54 to one or the other of its limiting positions, as determined by the pins 55 and 57 in the construction shown in Fig. 2, suitable means are provided to release the gear drive when the bar has reached one or the other of its limiting positions. In the arrangement of Fig. 2 the clutch 44 is provided with a tooth 49, particularly shown in Fig. 4, which engages in an indentation in the face of the gear 46. This tooth has tapered sides arranged at an angle to provide a driving connection between the clutch and the gear of sufficient strength to operate the speed controlling mechanism but which will ride out of the indentation if the gear continues to be driven after the rack bar has reached a limiting position. The clutch springs 51 tend to hold the tooth in engagement in the indentation but permit the clutch to overrun the gear in either direction when the driving connection is subjected to unusual stress. With this arrangement the rack bar and the gear 48 are left in one or the other of their limiting positions although the clutch 44 continues to rotate. Since the clutch has but a single tooth, the reengagement of the clutch and the gear will take place in the same relative position with respect to the positions of the cage 38 and rack bar 54 when the engines are brought to a condition approaching synchronization.

The gear 48 may also be rendered rotationally free of the rack bar when the rack bar has reached a limiting position by other means such for instance as is illustrated by way of example in Fig. 6. In this arrangement the gear is made in the form of a mutilated gear having teeth along only a portion of its periphery. The rack is provided with an intermediate toothed portion at each end of which there is provided a latch mechanism, as indicated at 53 and 55. The latch mechanisms are so arranged that the gear may run off of the intermediate toothed portion and continue to rotate without moving the rack bar but upon a reversal of the rotation of the gear, the corresponding latch will engage the cam 49 located in a groove in gear 48 and move the rack bar to bring the correct gear tooth back into mesh with the rack teeth. In this form of the device the rack bar is resiliently retained in either one of its limiting positions and just out of contact with the gear teeth by suitable means such as the spring-pressed detent 57. In either form of the device, or in any other form which may be resorted to in which the synchronizing and phasing devices are both operated by the rack bar, it is important that the angular relation of the gear 48 to the longitudinal position of the rack bar be maintained, that is that the same gear teeth mesh at all times with the same corresponding rack teeth in order that the cage shall not be free to assume different relative positions with respect to a particular position of the speed and phase synchronizing mechanism.

The mechanism illustrated and described thus provides two cooperating adjusting mechanisms for the engine speed controlling device, one of which will bring the speed of the controlled engine into synchronism with the speed of the master engine or speed control and the other of which will simultaneously bring the controlled engine to a condition of predetermined phase relationship with the master engine or speed control.

While a particular mechanical arrangement has been illustrated and described for accomplishing this result it is to be understood that the invention is in no way limited to the particular mechanical elements or the arrangement of elements so illustrated and described but that various changes in the size, shape and rearrangement of parts may be resorted to without in any way exceeding the scope of the invention. Furthermore certain of the mechanical elements illustrated and described in the simplified arrangement shown by way of example may, within the scope of the invention, be replaced by hydraulic or electrical devices having an equivalent function.

While the instruments 32, 34 and 36 have been mentioned as speed difference indicating instruments these instruments might alternatively be utilized to indicate phase difference or might serve the double function of indicating both speed and phase difference, or the phase difference may be indicated, if desired, by the provision of proper indicia on the visible portion of the gear 68 or some element connected therewith.

Although certain particular constructional arrangements have been shown for illustrative purposes it is to be understood that the invention is in no way limited to the forms so illustrated and described but that such changes may be resorted to as come within the scope of the appended claims.

Having now described the invention so that other skilled in the art may clearly understand the same, what it is desired to secure by Letters Patent is as follows:

1. A control system for a plurality of motors comprising, in combination, means for maintaining said motors, when operated together, in speed synchronization with each other, and means automatically actuated upon departure of said motors from a predetermined phase relation cooperating with and modifying the action of said speed synchronizing means for restoring said motors to a pre-determined rotational phase relation with respect to each other.

2. An engine control for a multi-engined airplane, having a reference speed unit and one or more controlled engines comprising, a speed regulating device for each engine, means responsive to variation of engine speed from said reference speed operatively associated with each engine speed regulating device to maintain the engine speed in synchronism with said reference speed, an element responsive to differences in phase between said reference speed unit and each governed engine, and means operatively connected with each element and with the respective speed regulating device of said governed engine for modifying the speed of said governed engine as regulated by said speed variation responsive means to restore the engines to a predetermined

phase relation with respect to said reference speed unit.

3. Regulating means for maintaining an engine in an operating condition of speed synchronization and phase coincidence with a master speed control, comprising, a differential unit drivingly connected at one end with said engine and drivingly connected at the opposite end with said master speed control and having a rotatably mounted cage, means operative to change the speed of said engine actuated by rotation of said cage upon a variation in the speed of said engine with respect to the speed of said master control, and means actuated by the rotational position of said cage to temporarily vary the speed of said engine to correct an out of phase condition of said engine with respect to said master control.

4. Regulating means for maintaining an engine in an operating condition of speed synchronization and phase coincidence with a master speed control comprising, an engine speed regulating device operatively associated with said engine, a differential unit having a rotatably mounted cage rotatable upon a variation in the speed of said engine with respect to the speed of said master speed control, means operatively connected with said engine speed regulating device and with said cage to change the speed of said engine upon a rotational movement of said cage, and means also connected with said engine speed regulating device and actuated by a rotational displacement of said cage from a predetermined angular position to temporarily vary the speed of said engine to correct an out of phase condition of said engine with respect to said master control.

5. Regulating means for maintaining an engine in an operating condition of speed synchronization and phase coincidence with a master speed control comprising, a differential unit having a rotatably mounted cage rotatable upon a variation of the speed of said engine with respect to the speed of said master control, a speed regulating device operatively associated with said engine, means actuated by rotation of said cage to vary the speed of said engine until a condition of synchronism is re-established between said engine and said master speed control, means actuated by the rotational displacement of said cage from a predetermined angular position to vary the speed of said engine to restore said engine to a condition of phase coincidence with said master speed control, and means differentially connecting said speed synchronizing means and said phase correcting means to said engine speed regulating means.

6. Regulating means for maintaining an engine in an operating condition of speed synchronization and phase coincidence with a master speed control comprising, a differential unit having a rotatably mounted cage rotatable upon a variation of the speed of said engine with respect to the speed of said master speed control, a gear driven by said cage, a speed regulating device associated with said engine, means actuated by said gear to operate said engine speed regulating device to vary the speed of said engine to restore a condition of synchronization between the speed of said engine and the speed of said master speed control, and means operated by said gear and said engine for operating said engine speed regulating device to vary the speed of said engine to restore said engine to an operating condition of phase coincidence with said master speed control.

7. Regulating means for maintaining an engine in an operating condition of speed synchronization and phase coincidence with a master speed control comprising, a differential unit having a rotatably mounted cage rotatable upon a speed variation of the engine with respect to the master speed control, a speed regulating device operatively associated with said engine, means actuated by rotation of said cage to operate said speed controlling device to vary the speed of said engine to restore said engine to a condition of speed synchronization with respect to said master speed control, and means driven by said engine and actuated by said cage for varying the speed of said engine to restore said engine to a condition of phase coincidence with respect to said master speed control, including power actuated means having a neutral position corresponding to a predetermined rotational position of said cage, and means connecting said phase coincidence restoring means with said engine speed regulating means.

8. Regulating means for maintaining an engine in an operating condition of speed synchronization and phase coincidence with a master speed control comprising, a differential unit having a rotatably mounted cage rotatable upon a variation of the speed of said engine with respect to the speed of said master speed control, a speed regulating device operatively associated with said engine, means actuated by rotation of said cage operatively connected with said engine speed regulating device to vary the speed of said engine to restore said engine to a condition of speed synchronization with respect to said master speed control, and means driven by said engine and actuated by said cage connected with said engine speed regulating device to restore said engine to an operating condition of phase coincidence with respect to said master speed control, said phase coincidence restoring means comprising, a disk driven by said engine, a cylinder mounted on a rotatable shaft, a slide screw-threaded on said shaft and operatively associated with said engine speed regulating device, and a roller between said disk and said cylinder movable from a neutral position at the center of said disk upon a rotational displacement of said cage from a predetermined angular position.

9. In an engine control system having an engine speed regulating device, a reference speed device, and a speed difference responsive device in which the speed difference responsive device is operatively associated with said engine, with said reference speed device and with said engine speed regulating means to adjust said regulating means to correct variations of the speed of said engine from the speed of said reference speed device, the combination of, an engine driven power unit, an operative connection from said power unit to said engine speed regulating device rendering said power unit operative to adjust said speed regulating device, and mechanism responsive to an out of phase condition between said engine and said reference speed device operatively associated with said connection to regulate the application of power by said power unit to said speed regulating device to adjust said device.

10. In apparatus for maintaining a controlled engine in a condition of phase coincidence with a master engine or reference speed device and having a speed synchronizing coupling with said controlled engine including, a speed regulating device for the controlled engine, and a differen-

tial device operatively connected with the engine and the reference speed device having a rotatably mounted cage rotatable upon a variation of the speed of the controlled engine with respect to the speed of the master engine or reference speed device, and means actuated by rotation of said cage operatively connected with said speed regulating device to adjust said speed regulating device to correct any variation of the speed of the controlled engine with respect to the speed of the master engine or reference speed device, the combination of, a power driven disk, a cylinder mounted on a rotatable shaft, a slide screw-threaded on said shaft and operatively associated with said engine speed regulating device, and a roller between said disk and said cylinder movable from a neutral position at the center of said disk upon a rotational displacement of said cage from a predetermined angular position corresponding to a condition of phase coincidence between said controlled engine and said master engine or reference speed device.

11. A control system for a pair of motors at least one of which has a speed regulating device comprising, in combination, means operatively connected with said speed regulating device and both of said motors for maintaining said motors when operated together in speed synchronization with each other by actuation of said speed regulating device and means operatively connected with said speed regulating device and both of said motors and actuated by said speed synchronizing means cooperating with and modifying the action of said speed synchronizing means on said speed regulating device for restoring said motor to and maintaining said motors in a predetermined rotational phase relation with respect to each other.

12. A control system for a pair of motors at least one of which has a speed regulating device comprising, in combination, means operatively connected with said speed regulating device and both of said motors for maintaining said motors when operated together in speed synchronization with each other, and means operatively connected with said speed regulating device and both of said motors cooperating with and modifying the action of said speed synchronizing means for maintaining said motors in a predetermined rotational phase relation with respect to each other, including means for moving said speed regulating device whenever said motors are not in said predetermined rotational phase relation.

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