

March 21, 1967

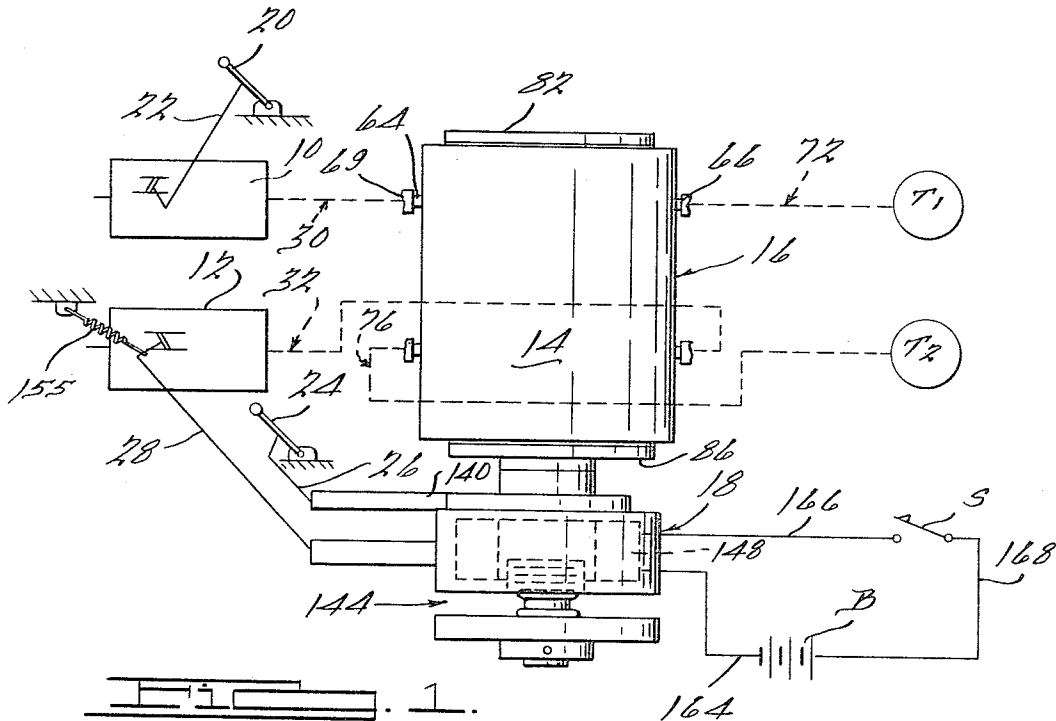
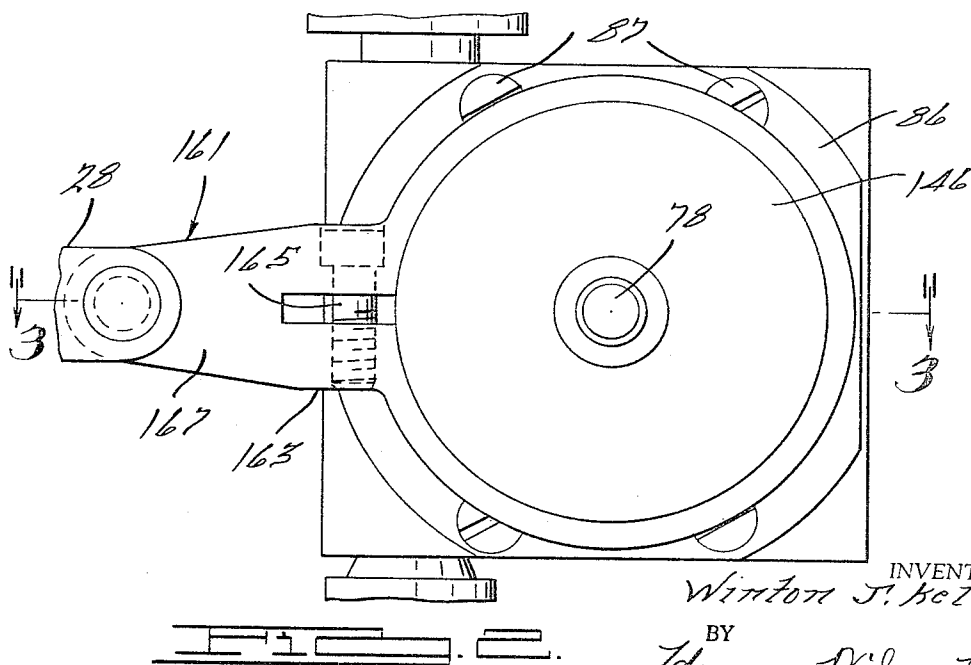
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3,309,871

ENGINE SYNCHRONIZING MECHANISM

Filed Jan. 7, 1964

3 Sheets-Sheet 1



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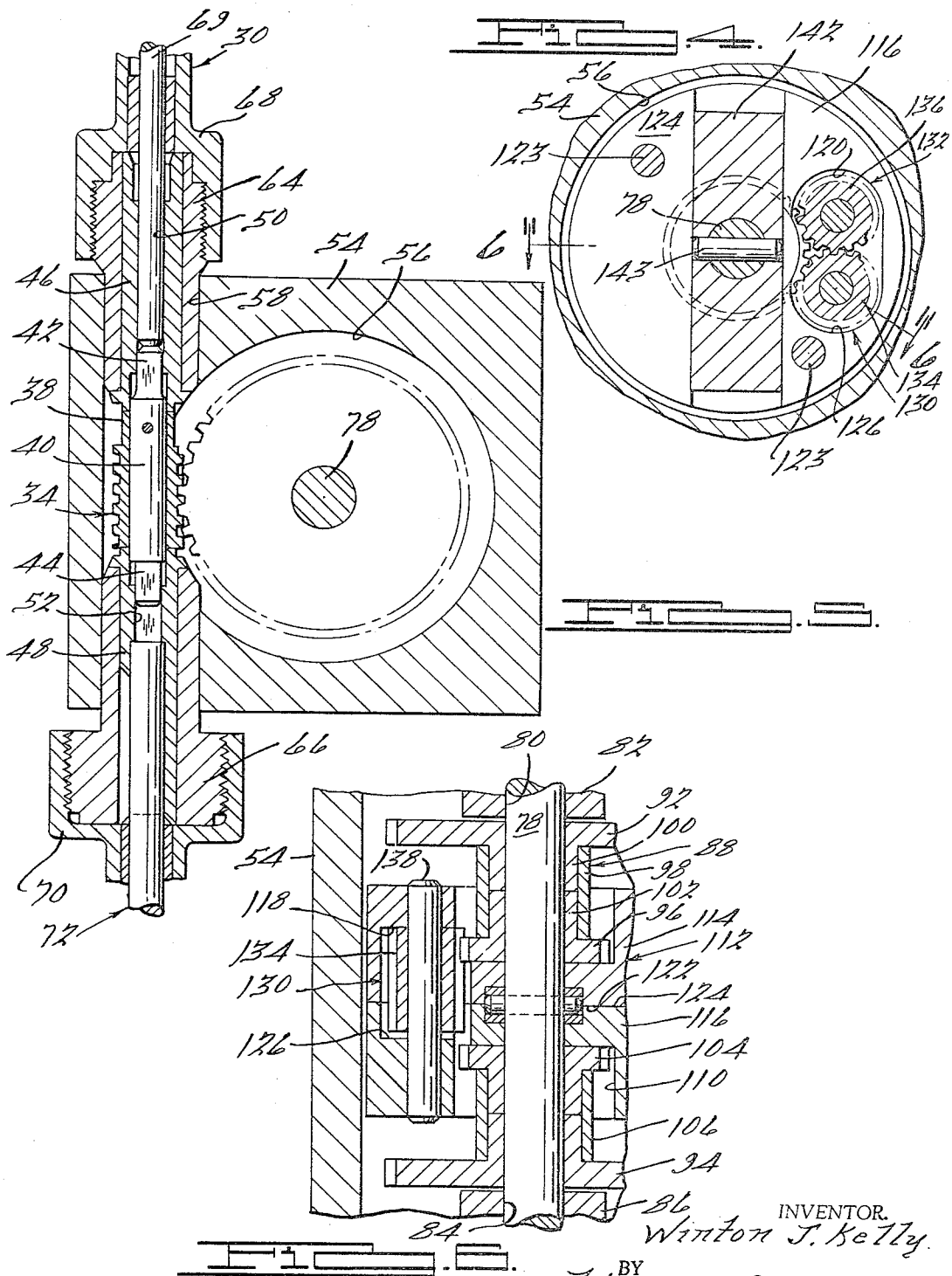
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3,309,871 ENGINE SYNCHRONIZING MECHANISM

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Filed Jan. 7, 1964, Ser. No. 336,310

11 Claims. (Cl. 60—97)

This invention relates to control systems and apparatus for controlling the relative speeds of a pair of prime movers delivering rotative energy.

More specifically the present invention is shown and described as a control system for controlling the relative speeds of a pair of internal combustion engines for marine use or the like. When a pair of engines are utilized together to propel a boat it is important that both engines be operated in synchronism or at the same speed. Where separate throttle controls for each engine are provided it is common to determine engine synchronization by the use of tachometer readings. These, however, are inaccurate and make engine synchronism difficult; the use of tachometers is also awkward when synchronism is desired over a wide range of engine speeds since separate throttle adjustments must be made at each speed. With the present invention synchronism can be attained automatically and substantially simultaneously at any desired speed over the operating speed range of the engines. It is a general object of the present invention to provide apparatus for controlling the relative speeds of a pair of prime movers delivering rotative energy. It is another object of the present invention to provide apparatus for automatically and substantially simultaneously synchronizing a pair of engines at any speed within the operating speed range of the engines.

In the present invention, the engines can be either operated in synchronism from a single throttle control or each can be operated individually through separate throttle controls. Thus it is another object of this invention to provide apparatus for controlling the speed of a pair of engines which has one mode of operation in which the engines are operated in synchronism through a single throttle control and a second mode in which each engine can be operated through its own throttle control.

In the control system of the present invention a novel differential gear assembly is used in a novel combination which provides the meritorious results briefly noted above. Therefore it is another general object of this invention to provide a differential gear assembly of a novel construction. It is a further object of this invention to provide a novel combination for controlling the speed of a pair of engines which combination includes a differential gear assembly.

Other objects, features, and advantages of the present invention will become apparent from the subsequent description and the appended claims, taken in conjunction with the accompanying drawings, in which:

FIGURE 1 is a combined electrical and mechanical schematic diagram with the control assembly of the present invention shown in elevation and shown in operative relationship with other members of a working system shown pictorially and in block form;

FIGURE 2 is an end view of the control assembly of FIGURE 1;

FIGURE 3 is a sectional view with some parts shown broken away of the control assembly of FIGURE 2 taken substantially along the line 3—3;

FIGURE 4 is a sectional view of the control assembly of FIGURE 3 taken substantially along the line 4—4;

FIGURE 5 is a sectional view of the control assembly of FIGURE 3 taken substantially along the line 5—5; and

FIGURE 6 is a sectional view of the control assembly

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of FIGURE 3 taken substantially along the line 6—6 in FIGURE 4.

In general and looking now to FIGURE 1, a pair of internal combustion engines 10 and 12, whose speeds or rotational velocities are to be synchronized, are shown connected to a control assembly 14 which comprises a differential gear assembly 16 and a clutch and lever assembly 18. The engine 10 is the master engine and has a throttle lever 20 which is representatively shown to be connected to its throttle via a linkage 22 whereby the speed of the engine 10 can be varied by manipulation of the lever 20. The engine 12 is the follower or slave engine and has a throttle lever 24 which is representatively shown to be connected to the clutch and lever assembly 18 via linkage 26 and thence to the throttle of slave engine 12 via linkage 28. As will be seen the control assembly 14 has one mode of operation in which the throttle of the slave engine 12 is actuated only by manipulation of the throttle lever 24 and a second mode of operation in which the throttle of the slave engine 12 is disconnected from the lever 24 and is actuated to maintain the speed of the slave engine 12 in synchronism with the speed of the master engine 10. The rotational outputs of the engines 10 and 12 are connected to one end of flexible cable assemblies representatively shown by the dotted lines 30 and 32, respectively, which have their opposite ends connected to the differential gear assembly 16 of the control assembly 14, whereby indications of the rotational speeds of the two engines are provided to the control assembly 14. In the second mode of operation the difference in speed between engines 10 and 12 is sensed and the throttle of the slave engine 12 is automatically actuated by the control assembly 14 to bring the speed of the slave engine 12 into synchronism with the speed of the master engine 10. Thus as the speed of the master engine 10 is varied by manipulation of the throttle lever 20, the speed of the slave engine 12 is automatically similarly varied and brought into synchronism.

Looking now to FIGURES 1 and 3, the flexible cables 30 and 32 are connected to worm shaft assemblies 34 and 36, respectively, which form a part of the differential gear assembly 14. Since the worm shaft assemblies 34 and 36 are identical only the details of one will be described. Looking now to FIGURE 5, the worm shaft assembly 34 comprises a tubular worm member 38 which is fixed upon a shaft 40 having square section end portions 42 and 44 which extend axially outwardly on opposite sides of the worm member 38. A pair of brass tubular supporting sleeves 46 and 48 have square bores 50 and 52, respectively, and matably receive the end portions 42 and 44 respectively. Thus the sleeves 46, 48, worm member 38, and shaft 40 rotate together. The worm assemblies 34 and 36 are supported in an elongated body member 54 having a circular bore 56 extending longitudinally therethrough and are located in transversely extending, parallel, longitudinally spaced bores 58 and 60, respectively, which intersect and communicate with the radial extremity of the bore 56. The worm member 38 of assembly 34 and worm member 62 of assembly 36, are located at these areas of intersection and extend partially within the bore 56. Considering the worm assembly 34, the sleeves 46 and 48 are journaled within male connector members 64 and 66, respectively, which members are supported in opposite ends of the bore 58. The male connector members 64 and 66 are of a conventional construction and terminate in threaded portions which are engageable with complementarily threaded female connectors 68 and 70, respectively. The female connector 68 is a part of the flexible cable assembly 30 and includes a flexible cable 69 which cable terminates in a square section portion which fits matably

within the similarly shaped bore 50 whereby rotation of the cable 69 rotates the worm assembly 34 via the sleeve 46. Thus the worm shaft 34 is rotated by the engine 10 either at the speed of the engine or at a speed which is in direct proportion therewith depending on the means by which the cable assembly is connected to the engine 10. A female connector 70 is connected to male connector member 66 and is a part of a flexible cable assembly 72 which is similar in construction to the flexible cable assembly 30 and which is shown to be connected to a tachometer T1 whereby the rotational speed of the worm assembly 34 and hence of the master engine 10 can be read directly.

The worm assembly 36, which is similar in construction to worm assembly 34, is connected in a similar manner to slave engine 12 via the flexible cable assembly 32. A flexible cable assembly 76 is connected from the opposite side of the worm assembly 36 to a tachometer T2 whereby the speed of the worm assembly 36 and hence of the slave engine 12 can be read directly. The flexible cable assemblies 32 and 76 are similar in construction to the flexible cable assembly 30 and hence are not described in detail. Note that the flexible cable assemblies 30 and 32 are connected to their respective worm shaft assemblies 34 and 36 at opposite sides of the body member 54 whereby the assemblies 34 and 36 are rotated in opposite directions.

A main drive shaft 78 extends coaxially of the bore 56 and has its rearward end journaled within a bore 80 in an end plate 82 which is fixed to the rearward end of the body member 54 and is journaled within and extends substantially longitudinally beyond a through bore 84 in an end plate 86 which is fixed to the forward end of the body member 54. End seals 89 and 91 are located between end plates 82 and 86, respectively, and the respective ends of the body member 54 with the plates 82, 86 being fixed to the body member 54 by bolts such as 87. A pair of identical worm gear assemblies 88 and 90 are located within the bore 56 in the body member 54 and are journaled for rotation upon the main drive shaft 78 and include worm gears 92 and 94, respectively, which are engageable with the worm members 38 and 62, respectively. The worm gear 92 is fixed to a differential side gear 96 by means of a sleeve 98 which is concentrically disposed over and welded to confronting sleeve portions 100 and 102 of the worm gear 92 and side gear 96, respectively. In a like manner, the worm gear 94 is fixed to a differential side gear 104, which is identical to side gear 96, via a sleeve 106. The side gears 96 and 104 are located within oppositely facing side bores 108 and 110, respectively, located on opposite axial sides of a generally circularly sectioned pinion carrier assembly 112 which is concentrically fixed upon the drive shaft 78 between the side gears 96 and 104.

The carrier assembly 112 is made with identical, annular housing sections 114 and 116 which are secured together by screws such as 123 and with the halves assembled with their respective bores 108 and 110 facing oppositely outwardly. Looking now to FIGURES 3, 4 and 6, the housing sections 114 and 116 have axially extending bores 118 and 120 in their respective confronting surfaces 122 and 124 which bores are radially spaced from the central axis of the assembly 112 and partially radially intersect and communicate with the associated one of the outwardly facing side bores 108 and 110. The surface 124 has a second axial bore 126 (see FIGURES 4 and 6) which extends axially to a lesser extent than and radially intersects the bore 120. An axial bore 128 in surface 122 similarly radially intersects bore 118.

On assembling the identically formed sections 114 and 116 each of the bores of the pair of bores 118, 126 and of the pair of bores 120, 128 is located coaxially oppositely from the other of that pair; the pairs of bores 118, 126 and 120, 128 define thereby a pair of axially offset, radially communicating chambers 130 and 132, respectively, in

which differential pinions, 134 and 136, respectively, are rotatably mounted via pins 138 and 140, respectively. Since the chambers 130, 132 are axially offset, the pinions 134 and 136 are axially staggered relative to each other and have their inner end portions in meshed engagement with each other via the opening radially communicating chambers 130 and 132 and have their outer end portions in meshed engagement with side gears 96 and 104, respectively, via the openings radially communicating bore 120 with side bore 110 and bore 118 with side bore 108.

A locking key or bar 142 is pinned to the main shaft 78 via pin member 144 and fits matably within a pair of diametrically extending, confronting slots in faces 122 and 124 whereby rotation of the pinion carrier assembly 112 results in rotation of the main shaft 78.

As will be seen, the main shaft 78 will rotate only when the worm assemblies 34 and 36 rotate at different speeds in opposite directions. Thus when the rotational speeds of worm assemblies 34 and 36 are equal and opposite the rotational speeds of worm gears 92, 94 and side gears 96 and 104 are equal and opposite and likewise the rotational speeds of the differential pinions 134 and 136 are equal and opposite; in this condition the pinion carrier assembly 112 and hence main shaft 78 are stationary. If the rotational speed of the worm assembly 34 exceeds that of the worm assembly 36 the pinion carrier assembly 112 will rotate in the direction of rotation of the worm gear assembly 88 and at one-half of the absolute difference in rotational speeds between worm gear assemblies 88 and 90. Similarly, the carrier 112 will rotate in an opposite direction if the rotational speed of the worm assembly 36 exceeds that of the worm assembly 34. Thus the main shaft 78 will provide a rotational output signal via the pinion carrier assembly 112 by rotating in one direction when the speed of the master engine 10 exceeds that of the slave engine 12 and by rotating in an opposite direction when the converse is true. Because of the high speeds of the engines involved and in order to provide for a relative low speed of rotation of the shaft 78, a substantial gear ratio is provided between worms 38 and 62 and their respective worm gears 92 and 94.

In conventional differential constructions it is common to use bevel gears. In the differential gear assembly 16 of the present invention except for the worms 38 and 62 all of the other gears are spur gears. This latter feature permits a simpler construction since it eliminates the need to take up thrust loads which are present in a bevel gear construction. Note also that the corresponding components of the worm assemblies 34, 36, the worm gear assemblies 88, 90, the pinions 134, 136 and housing sections 114, 116 are identical thus simplifying construction and assembly of the differential gear assembly 16.

The forward end of the shaft 78 is connected to the clutch and lever assembly 18 which, in the second mode of operation to be described, is actuated responsively to rotation of the shaft 78 for controlling the throttle of the slave engine 12.

Considering first the first mode of operation, a manual throttle control lever 140 is located adjacent the forward end plate 86 upon the shaft 78 and can be pivoted thereon and is held axially on its rearward side by the end plate 86 and on its forward side by a collar 142 which is pinned to shaft 78. As shown in FIGURE 1 the manual lever 140 is connected to the throttle lever 24 for the slave engine 12 via linkage 26 whereby the manual lever 140 can be pivoted about shaft 78 by manipulation of the lever 24. A magnetic clutch assembly 144 is located on the shaft 78 adjacent the manual lever 140 and includes a magnet assembly 145 supported for axial movement on shaft 78 and a flat circular clutch plate 146 which is fixed at the forward termination of the shaft 78. The axially movable magnet assembly 145 includes an annularly wound magnetic coil 148 located between inner and outer annular shells 150 and 152, respectively. The inner shell 150 has a radially outwardly extending flange portion

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154 at its rearward end which is radially matable against the inner surface of the outer shell 152 and which axially engages a radially inwardly extending lip 156 at the same end of the outer shell 152. An annular washer 158 is located between the shells 150 and 152 at their forward ends. The washer 158 is made of plastic for a purpose to be presently seen. The outer shell 152 has its forward face 153 located slightly axially beyond the forward extremities of the inner shell 150 and the washer 158 for a purpose to be seen.

The inner shell 150 is fixed upon a bearing sleepe 160 which is rotatably supported on the shaft 78. Thus the movable magnet assembly 145 is supported on the shaft 78 for axial movement and is free to pivot about the shaft 78. A coil spring 159 is located about the shaft 78 between the clutch plate 146 and the forward end of the bearing sleeve 160 and is under a compressive preload and urges the movable magnet assembly 145 towards the manual throttle control lever 140 to a position at which the opposite end of the bearing sleeve 160 is in engagement with the stop collar 142. A radial slot 162 is formed in the lip 156 of the outer shell 152 which with the movable magnet assembly 145 in its rearward position engageably receives the manual throttle control lever 140. Thus, with the magnet assembly 145 in its rearward position and with the manual throttle control lever 140 located within the slot 160, the lever 140, as it is rotated about the shaft 78, similarly rotates the magnet assembly 145.

An automatic throttle control lever 161 is fixed to the magnet assembly 145 by a split ring portion 163 which is located about the outer shell 152 and which is drawn together into engagement with the outer shell 152 by means of a bolt 165 which engages both halves. An arm portion 167 of lever 161 is connected to the linkage 28 which is in turn connected to the throttle of the slave engine 12. Thus with the magnet assembly 145 and manual control lever 140 rotatably locked together, the throttle of the slave engine 12 can be manually controlled by manipulation of the throttle lever 24. Note that at this time the magnet assembly 145 is movable separately from the shaft 78 and hence the throttles of the master engine 10 and slave engine 12 can be controlled independently of each other. This, then, is the first mode of operation previously described. Note that in this mode of operation the rotation of the shaft 78 has no effect on the throttle of either engine 10 or 12 and that in the case of a difference in rotational speeds the shaft 78 simply rotates freely in the appropriate direction. As will be seen, the rotation of the shaft 78 is utilized in the second mode of operation.

Looking now to FIGURE 1, one side of the coil 148 is electrically connected to one side of a battery B via a conductor 164 and the other side of coil 148 is connected to the opposite side of the battery B via conductors 166 and 168 which are serially connected by a switch S. With switch S opened the coil 148 is not energized and the magnet assembly 145 is located in its rearward position as shown in FIGURE 3. The outer and inner shells 150, 152 and clutch plate 146 are of a material having a relatively high permeability as compared to the material of the annular washer 158 such that when the coil 148 is energized the lines of flux created thereby flow from one end of the coil 148 through the washer 158 and air gap between the washer 158 and the clutch plate 146 and pass through the clutch plate 146 and back to the opposite end of the coil 148. Thus a magnetic force is created attracting the movable magnet assembly 145 towards the clutch plate 146. When switch S is closed the coil 148 is energized and the magnet assembly 145 is moved axially forwardly on the main shaft 78 until the forward surface 153 of the outer shell 152 engages the clutch plate 146. At the same time, with the magnet assembly 145 in its forward position, the slot 162 is located away from the manual control lever 140 thereby disengaging the magnet assembly 145 and lever 140. Thus manipulation of con-

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trol lever 140 by lever 24 will not affect the position of the automatic lever 161 and hence of the throttle for the slave engine 12. However, with the magnet assembly 145 in engagement with the clutch 146, the magnet assembly 145 and automatic lever 161 are moved in accordance with the rotation of the shaft 78. As previously noted, the shaft 78 will rotate in one direction or the other depending upon which of the engines 10 and 12 is rotating the fastest with the speed of rotation of the shaft 78 being a direct function of the magnitude of the difference in speeds. The linkage 28 is connected to the throttle of the slave engine 12 and the automatic control lever 161 such that rotation of shaft 78 and of lever 161 will always be in a direction such as to operate on the throttle of the slave engine 12 to bring the speed of the slave engine 12 into synchronism with that of the master engine 10.

Thus in the second mode of operation, the switch S is closed energizing the coil 148 thereby actuating the magnet assembly 145 into engagement with the clutch 146 whereby the assembly 145 is rotated with the shaft 78. Rotation of shaft 78 and hence of the automatic lever 161 is in a direction to actuate the throttle of the slave engine 12 via the linkage 28 to bring the slave engine 12 to the same speed as the master engine 10. Corrective rotation of the shaft 78 continues until the rotational speeds of both engines 10 and 12 are equal; at this time the carrier 112 of the differential gear assembly 16 does not rotate and the shaft 78 is stationary. By manipulating the throttle lever 20 for the master engine 10, the speed of the master engine 10 can be selectively varied. As the speed of master engine 10 is increased the rotational speed of worm assembly 34 is increased relative to that of the worm assembly 36. This difference in rotational speed results in rotation of the carrier 112, shaft 78, and lever 161 in one direction to increase the speed of the slave engine 12. In a similar manner, when the speed of master engine 10 is decreased, the speed of worm assembly 34 is decreased relative to that of the worm assembly 36 resulting in rotation of the carrier 112, shaft 78, and lever 161 in an opposite direction to decrease the speed of the slave engine 12. Thus the speed of the slave engine 12 is automatically synchronized with that of the master engine 10 as the speed of the latter engine is varied by manipulation of the lever 20.

Note that the forward surface 153 frictionally engages the clutch 146; thus in the event that either of the engines 10 or 12 loses speed due to stalling, etc., and the automatic control lever 161 is moved to its corresponding extreme position the surface 153 and clutch 146 can slip, thereby avoiding damage to the parts. As an additional safety measure, a spring member 155 (FIGURE 1) is connected to the throttle of the slave engine 12 and is normally under tension and acting in a direction to urge that throttle to a closed position; thus in the event that either of the linkages 26 or 28 break with the apparatus in the first mode of operation or if linkage 28 breaks with the apparatus in the second mode of operation, the slave engine will automatically be brought to a closed throttle condition. If separate manual control of the engines 10 and 12 is desired the switch S is opened de-energizing the coil 148 with the coil spring 159 moving the magnet assembly 145 rearwardly whereby the manual control lever 140 can again engage the slot 162 and whereby the throttle of the slave engine 12 can be controlled by manipulation of the lever 24; this again places the apparatus in the first mode of operation in which operation of the differential gear assembly 16 has no effect on the automatic lever 161 and hence on the throttle of the slave engine 12.

In the apparatus shown, the control assembly 14 has been described to have a second mode of operation to automatically bring the speed of the slave engine 12 to the speed of the master engine 10. By providing a difference in gear ratios in the differential gear assembly 16

the control assembly 14 in the second mode of operation would automatically bring the speed of the slave engine 12 to some selected ratio of the speed of the master engine 10.

Thus the control assembly 14 of the present invention provides two modes of operation for controlling the speeds of a pair of engines, a first mode permitting individual control of the speeds of each engine and a second mode which provides for automatic synchronization of the speed of one engine as the speed of the other engine is varied. As has been shown, the invention makes use of a differential gear assembly 16 which is of a novel construction and which is economical to manufacture.

While it will be apparent that the preferred embodiment of the invention disclosed is well calculated to fulfill the objects above stated, it will be appreciated that the invention is susceptible to modification, variation and change without departing from the proper scope or fair meaning of the subjoined claims.

What is claimed is:

1. A control assembly for controlling the rotational speed of master and slave prime movers having master and slave control mechanisms, respectively, operable for determining their speeds, comprising: first means connected to the master control mechanism and being selectively actuable for actuating the master control mechanism, second means connectible to the slave control mechanism of the slave prime mover and being selectively actuable when connected for actuating the slave control mechanism, a rotatable member, differential gear means including said rotatable member and connected to the master and slave prime movers for sensing their speeds and for providing a first rotational signal varying in magnitude in accordance with variations in the magnitude of the rotational speed of the master and a second rotational signal varying in magnitude in accordance with variations in the magnitude of the rotational speed of the slave and for providing rotation of said rotatable member in one direction responsively to the magnitude of said first signal exceeding that of said second signal and in an opposite direction responsively to the magnitude of said second signal exceeding that of said first signal, connecting means actuable for connecting said rotatable member to the slave control mechanism and for actuating the slave control mechanism for increasing and decreasing the rotational speed of the slave prime mover in accordance with rotation of said rotatable member in said one and opposite directions, respectively, and actuating means selectively actuable to one condition for connecting said second means to the slave control mechanism and for deactuating said connecting means and to a second condition for disconnecting said second means from the slave control mechanism and for actuating said connecting means.

2. A control assembly for controlling the rotational speed of master and slave prime movers having master and slave control mechanisms, respectively, operable for determining their speeds, comprising first means connected to the master control mechanism and being selectively actuable for actuating the master control mechanism, second means connectible to the slave control mechanism and being selectively actuable when connected for actuating the slave control mechanism, a rotatable member, differential gear means including said rotatable member and connected to the master and slave prime movers for sensing their speeds and for providing a first rotational signal varying in magnitude in accordance with variations in the magnitude of the rotational speed of the master and a second rotational signal varying in magnitude in accordance with variations in the magnitude of the rotational speed of the slave and for providing rotation of said rotatable member in one direction responsively to the magnitude of said first signal exceeding that of said second signal and in an opposite direction responsively to the magnitude of said second signal exceeding that of

said first signal, connecting means actuable for connecting said rotatable member to the slave control mechanism and for actuating the slave control mechanism for increasing and decreasing the rotational speed of the slave prime mover in accordance with rotation of said rotatable member in said one and opposite directions, respectively, and actuating means selectively actuable to one condition for connecting said second means to the slave control mechanism and for deactuating said connecting means and to a second condition for disconnecting said second means from the slave control mechanism and for actuating said connecting means, said actuating means comprising a clutch assembly having a first member fixed to said rotatable member for rotation therewith and a second member supported on said rotatable member for rotation relative thereto and being normally axially spaced from said first member and energizing means selectively actuable for moving said second member axially into frictional engagement with said first member whereby said first member and said second member are rotated together with said rotatable member, said second means including a first lever member fixedly connected to said second member for movement therewith, first linkage means connecting said first lever member to the slave control mechanism, a second lever member supported on said rotatable member for rotation relative thereto and being engaged with said second member for rotation therewith when said second member is in its position axially spaced from said first member whereby said second lever member and said second member rotate together and being disengaged from said second member when said second member is in engagement with said first member, and selectively operable means connected to said second lever member for selectively rotating said second lever member about said rotatable member.

3. A control assembly for controlling the rotational speed of master and slave prime movers having master and slave control mechanisms, respectively, operable for determining their speeds, comprising: first means connected to the master control mechanism and being selectively actuable for actuating the master control mechanism, second means connectible to the slave control mechanism and being selectively actuable when connected for actuating the slave control mechanism, a rotatable member, differential gear means including said rotatable member and connected to the master and slave prime movers for sensing their speeds and for providing a first rotational signal varying in magnitude in accordance with variations in the magnitude of the rotational speed of the master and a second rotational signal varying in magnitude in accordance with variations in the magnitude of the rotational speed of the slave and for providing rotation of said rotatable member in one direction responsively to the magnitude of said first signal exceeding that of said second signal and in an opposite direction responsively to the magnitude of said second signal exceeding that of said first signal, connecting means actuable for connecting said rotatable member to the slave control mechanism and for actuating the slave control mechanism for increasing and decreasing the rotational speed of the slave prime mover in accordance with rotation of said rotatable member in said one and opposite directions, respectively, and actuating means selectively actuable to one condition for connecting said second means to the slave control mechanism and for deactuating said connecting means and to a second condition for disconnecting said second means from the slave control mechanism and for actuating said connecting means, said actuating means comprising a clutch assembly having a first member fixed to said rotatable member for rotation therewith and a second member supported on said rotatable member for rotation relative thereto and being normally axially spaced from said first member and energizing means selectively actuable for moving said second member axially into frictional engagement with said first member whereby said first member and said second member are

rotated together with said rotatable member, said second means including a first lever member fixedly connected to said second member for movement therewith, first linkage means connecting said first lever member to the mechanism of the slave engine, a second lever member supported on said rotatable member for rotation relative thereto and being engaged in said second member for rotation therewith when said second member is in its position axially spaced from said first member whereby said second lever member and said second member rotate together and being disengaged from said second member when said second member is in engagement with said first member, and selectively operable means connected to said second lever member for selectively rotating said second lever member about said rotatable member, said clutch assembly being a magnetic clutch and having a coil fixedly located in said second member and being energizable for moving said second member axially into engagement with said first member, and said energizing means including a source of electrical potential and a switch connected across said coil.

4. A control assembly for controlling the rotational speed of master and slave prime movers with each prime mover having a mechanism operable for controlling its speed, comprising: a rotatable member, differential gear means including said rotatable member and connected to the master and slave prime movers for sensing their speeds and for providing a first rotational signal substantially reduced in magnitude relative to the magnitude of the sensed speed and varying in magnitude in accordance with variations in the magnitude of the rotational speed of the master and a second rotational signal substantially reduced in magnitude relative to the magnitude of the sensed speed and varying in magnitude in accordance with variations in the magnitude of the rotational speed of the slave and for providing rotation of said rotatable member in one direction responsively to the magnitude of said first signal exceeding that of said second signal and in an opposite direction responsively to the magnitude of said second signal exceeding that of said first signal, and means connecting said rotatable member to the mechanism for controlling the rotational speed of the slave prime mover and for actuating that mechanism for increasing and decreasing the rotational speed of the slave prime mover in accordance with rotation of said rotatable member in said one and opposite directions, respectively, said differential gear means including first and second worms connected for rotation in opposite directions by the master and slave prime movers, respectively, a pinion carrier assembly fixed to said shaft and having first and second pinions in mutual engagement, first gear means connecting said first worm and said first pinion by geared engagement, second gear means connecting said second worm and said second pinion by geared engagement, said pinion carrier assembly including a housing fixed to said rotatable member for rotation therewith and supporting said first and second pinions for rotation about axes located eccentrically relative to the axis of said rotatable member.

5. A control assembly for controlling the rotational speed of master and slave prime movers with each prime mover having a mechanism operable for controlling its speed, comprising a rotatable member, differential gear means including said rotatable member and connected to the master and slave prime movers for sensing their speeds and for providing a first rotational signal substantially reduced in magnitude relative to the magnitude of the sensed speed and varying in magnitude in accordance with variations in the magnitude of the rotational speed of the master and a second rotational signal substantially reduced in magnitude relative to the magnitude of the sensed speed and varying in magnitude in accordance with variations in the magnitude of the rotational speed of the slave and for providing rotation of said rotatable member in one direction responsively to the magnitude of said first

signal exceeding that of said second signal and in an opposite direction responsively to the magnitude of said second signal exceeding that of said first signal, and means connecting said rotatable member to the mechanism for controlling the rotational speed of the slave prime mover and for actuating that mechanism for increasing and decreasing the rotational speed of the slave prime mover in accordance with rotation of said rotatable member in said one and opposite directions, respectively, said differential gear means including first and second worms connected for rotation in opposite directions by the master and slave prime movers, respectively, a pinion carrier assembly fixed to said shaft and having first and second pinions in mutual engagement, first gear means connecting said first worm and said first pinion by geared engagement, second gear means connecting said second worm and said second pinion by geared engagement, said pinion carrier assembly including a housing fixed to said rotatable member for rotation therewith and supporting said first and second pinions for rotation about axes located eccentrically relative to the axis of said rotatable member, said first gear means comprising a first worm gear and first side gear fixed together and supported on said rotatable member for rotation relative thereto with said first worm gear and said first side gear being in engagement with said first worm and said first pinion, respectively, said second gear means comprising a second worm gear and second side gear fixed together and supported to said rotatable member for rotation relative thereto with said second worm gear and said second side gear being in engagement with said second worm and said second pinion, respectively.

6. A control assembly for controlling the rotational speed of master and slave prime movers with each prime mover having a mechanism operable for controlling its speed, comprising: a rotatable member, differential gear means including said rotatable member and connected to the master and slave prime movers for sensing their speeds and for providing a first rotational signal substantially reduced in magnitude relative to the magnitude of the sensed speed and varying in magnitude in accordance with variations in the magnitude of the rotational speed of the master and a second rotational signal substantially reduced in magnitude relative to the magnitude of the sensed speed and varying in magnitude in accordance with variations in the magnitude of the rotational speed of the slave and for providing rotation of said rotatable member in one direction responsively to the magnitude of said first signal exceeding that of said second signal and in an opposite direction responsive to the magnitude of said second signal exceeding that of said first signal, and means connecting said rotatable member to the mechanism for controlling the rotational speed of the slave prime mover and for actuating that mechanism for increasing and decreasing the rotational speed of the slave prime mover in accordance with rotation of said rotatable member in said one and opposite directions, respectively, said differential gear means including first and second worms connected for rotation in opposite directions by the master and slave prime movers, respectively, a pinion carrier assembly fixed to said shaft and having first and second pinions in mutual engagement, first gear means connecting said first worm and said first pinion by geared engagement, second gear means connecting said second worm and said second pinion by geared engagement, said pinion carrier assembly including a housing fixed to said rotatable member for rotation therewith and supporting said first and second pinions for rotation about axes of said first and second pinions located eccentrically relative to the axis of said rotatable member, said first gear means comprising a first worm gear and first side gear fixed together and supported on said rotatable member for rotation relative thereto with said first worm gear and said first side gear being in engagement with said first worm and said first pinion, respectively, said second gear means comprising a second worm gear and second side gear fixed

together and supported on said rotatable member for rotation relative thereto with said second worm gear and said second side gear being in engagement with said second worm and said second pinion, respectively, said housing comprising a pair of identical housing sections joined together at confronting surfaces and having opposite end surfaces, each of said opposite end surfaces having an axially extending recess concentric with said rotatable member and receiving one of said first and second side gears, each of said confronting surfaces having a pair of axially extending openings therein with each of said openings of one pair being located coaxially with one of said openings of the other pair to define a pair of cavities eccentrically located relative to said rotatable member, each of said cavities housing one of said pinions and being in radial communication with each other whereby said pinion gears are mutually engaged and being axially offset relative to each other with one of said cavities being in radial communication with one of said recesses and with the other of said cavities being in radial communication with the other of said recesses whereby said first and second pinions are engaged with said first and second side gears, respectively.

7. A control assembly for controlling the rotational speed of master and slave prime movers having master and slave control mechanisms, respectively, operable for determining their speeds, comprising: first means connected to the master control mechanism and being selectively actuatable for actuating the master control mechanism, second means connectible to the slave control mechanism and being selectively actuatable when connected for actuating the slave control mechanism, a rotatable member, differential gear means including said rotatable member and connected to the master and slave prime movers for sensing their speeds and for providing a first rotational signal varying in magnitude in accordance with variations in the magnitude of the rotational speed of the master and a second rotational signal varying in magnitude in accordance with variations in the magnitude of the rotational speed of the slave and for providing rotation of said rotatable member in one direction responsively to the magnitude of said first signal exceeding that of said second signal and in an opposite direction responsively to the magnitude of said second signal exceeding that of said first signal, connecting means actuatable for connecting said rotatable member to the slave control mechanism and for actuating the slave control mechanism for increasing and decreasing the rotational speed of the slave prime mover in accordance with rotation of said rotatable member in said one and opposite directions, respectively, said differential gear means including first and second worms connected for rotation in opposite directions by the master and slave prime movers, respectively, a pinion carrier assembly fixed to said shaft and having first and second pinions in mutual engagement, first gear means connecting said first worm and said first pinion by geared engagement, second gear means connecting said second worm and said second pinion by geared engagement, said pinion carrier assembly including a housing fixed to said rotatable member for rotation therewith and supporting said first and second pinions for rotation about axes located eccentrically relative to the axis of said rotatable member, said first gear means comprising a first worm gear and first side gear fixed together and supported on said rotatable member for rotation relative thereto with said first worm gear and said first side gear being in engagement with said first worm and said first pinion, respectively, said second gear means comprising a second worm gear and second side gear fixed together and supported on said rotatable member for rotation relative thereto with said second worm gear and said second side gear being in engagement with said second worm and said second pinion, respectively, said housing comprising a pair of identical housing sections joined together at

confronting surfaces and having opposite end surfaces, each of said opposite end surfaces having an axially extending recess concentric with said rotatable member and receiving one of said first and second side gears, each of said confronting surfaces having a pair of axially extending openings therein with each of said openings of one pair located coaxially with one of said openings of the other pair to define a pair of cavities eccentrically located relative to said rotatable member, each of said cavities housing one of said pinions and being in radial communication with each other whereby said pinion gears are mutually engaged and being axially offset relative to the other with one of said cavities in radial communication with one of said recesses and with the other of said cavities in radial communication with the other of said recesses whereby said first and second pinions are engaged with said first and second side gears, respectively, and actuating means selectively actuatable to one condition for connecting said second means to the slave control mechanism and for deactuating said connecting means and to a second condition for disconnecting said second means from the slave control mechanism and for actuating said connecting means, said actuating means comprising a clutch assembly having a first member fixed to said rotatable member for rotation therewith and a second member supported on said rotatable member for rotation relative thereto and being normally axially spaced from said first member and energizing means selectively actuatable for moving said second member axially into frictional engagement with said first member whereby said first member and said second member are rotated together with said rotatable member, said second means including a first lever member fixedly connected to said second member for movement therewith, first linkage means connecting said first lever member to the mechanism of the slave engine, a second lever member supported on said rotatable member for rotation relative thereto and being engaged with said second member for rotation therewith when said second member is in its position axially spaced from said first member whereby said second lever member and said second member rotate together and being disengaged from said second member when said second member is in engagement with said first member, and selectively operable means connected to said second lever member for selectively rotating said second lever member about said rotatable member.

8. A differential gear assembly comprising a rotatable shaft, a pinion carrier assembly fixed to said shaft and having first and second pinions in mutual engagement, said pinion carrier assembly including a housing fixed to said rotatable shaft for rotation therewith and supporting said first and second pinion for rotation about first and second axes, respectively, with said axes located eccentrically relative to the axis of said rotatable shaft, first gear means connected to said first pinion by geared engagement for rotating said first pinion about said first axis, second gear means connected to said second pinion by geared engagement for rotating said second pinion about said second axis, said housing comprising a pair of identical housing sections joined together at confronting surfaces and having opposite end surfaces, each of said opposite end surfaces having an axially extending recess concentric with said rotatable member and receiving one of said first and second gear means, said confronting surfaces having axially extending openings therein with said openings confronting each other to define a pair of cavities located side by side and eccentrically relative to said rotatable shaft, each of said cavities housing one of said pinions and being in radial communication with each other whereby said pinion gears are mutually engaged, said cavities being partially axially offset relative to each other with one of said cavities being in radial communication with one of said recesses and with the other of said cavities being in

radial communication with the other of said recesses whereby said first and second pinions are engaged with said first and second gear means, respectively.

9. A differential gear assembly comprising a rotatable shaft, first and second worms, a pinion carrier assembly fixed to said shaft and having first and second pinions in mutual engagement, first gear means connecting said first worm and said first pinion by geared engagement, second gear means connecting said second worm and said second pinion by geared engagement, said pinion carrier assembly including a housing fixed to said rotatable shaft for rotation therewith and supporting said first and second pinions for rotation about axes located eccentrically relative to the axis of said rotatable shaft, said first gear means comprising a first worm gear and first side gear fixed together and supported on said rotatable shaft for rotation relative thereto with said first worm gear and first said side gear being in engagement with said first worm and said first pinion, respectively, said second gear means comprising a second worm gear and second side gear fixed together and supported on said rotatable shaft for rotation relative thereto with said second worm gear and said second side gear being in engagement with said second worm and said second pinion, respectively, said housing comprising a pair of identical housing sections joined together at confronting surfaces and having opposite end surfaces, each of said opposite end surfaces having an axially extending recess concentric with said rotatable shaft and receiving one of said first and second side gears, each of said confronting surfaces having a pair of axially extending openings therein with each of said openings of one pair being located coaxially with one of said openings of the other pair to define a pair of cavities eccentrically located relative to said rotatable member, each of said cavities housing one of said pinions and being in radial communication with each other whereby said pinion gears are mutually engaged and being axially offset relative to each other with one of said cavities being in radial communication with one of said recesses and with the other of said cavities being in radial communication with the other of said recesses whereby said first and second pinions are engaged with said first and second side gears, respectively.

10. The assembly of claim 9 with said worm gears, said side gears, and said pinions all being spur gears.

11. A control assembly for controlling the rotational speed of master and slave prime movers with each prime mover having a control mechanism operable for determining its speed, comprising: spring means including a spring member connected directly to the control mechanism of the slave prime mover for biasing that mechanism to a position at which the speed of the slave engine is a selected minimum speed, a rotatable member, differential gear means including said rotatable member and connected to the master and slave prime movers for sensing their speeds and for providing a first signal varying in magnitude in accordance with variations in the magnitude of the rotational speed of the master and a second signal varying in magnitude in accordance with variations in the magnitude of the rotational speed of the slave and for providing rotation of said rotatable member in one direction responsively to the magnitude of said first signal exceeding that of said second signal and in an opposite direction responsively to the magnitude of said second signal exceeding that of said first signal, and means connecting said rotatable member to the control mechanism of the slave prime mover and for actuating that mechanism unaffected by the bias of said spring means for increasing and decreasing the rotational speed of the slave prime mover in accordance with rotation of said rotatable member in said one and opposite directions, respectively.

References Cited by the Examiner

UNITED STATES PATENTS

1,886,975	11/1932	Profitlich	60—97
2,100,059	11/1937	Morehouse	60—97
2,105,089	1/1938	Martin	60—97
2,217,971	10/1940	Smith	60—97
2,256,569	9/1941	Kennedy	60—97
2,262,329	11/1941	McNeil et al.	60—97
2,307,334	1/1943	Peek	60—97
2,339,989	1/1944	Glanville et al.	60—97
2,514,071	7/1950	Jusky	74—710
2,666,342	1/1954	Bell	74—710
2,782,601	2/1957	Hamilton	60—97

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