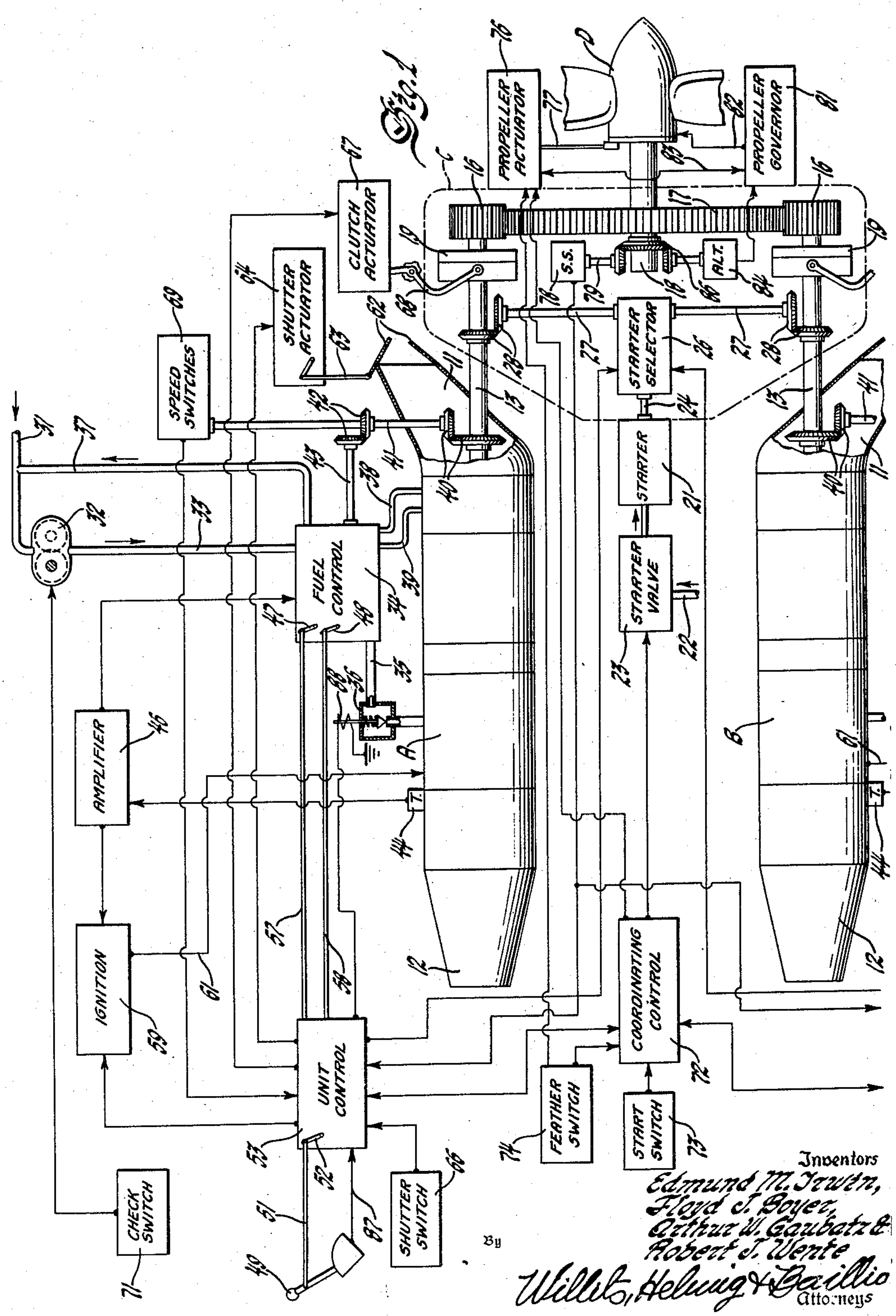
CONTROL SYSTEM FOR A VARIABLE PITCH PROPELLER AND ITS DRIVING TURBINES

Filed Nov. 8, 1950 9 Sheets-Sheet 1



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CONTROL SYSTEM FOR A VARIABLE PITCH PROPELLER
AND ITS DRIVING TURBINES
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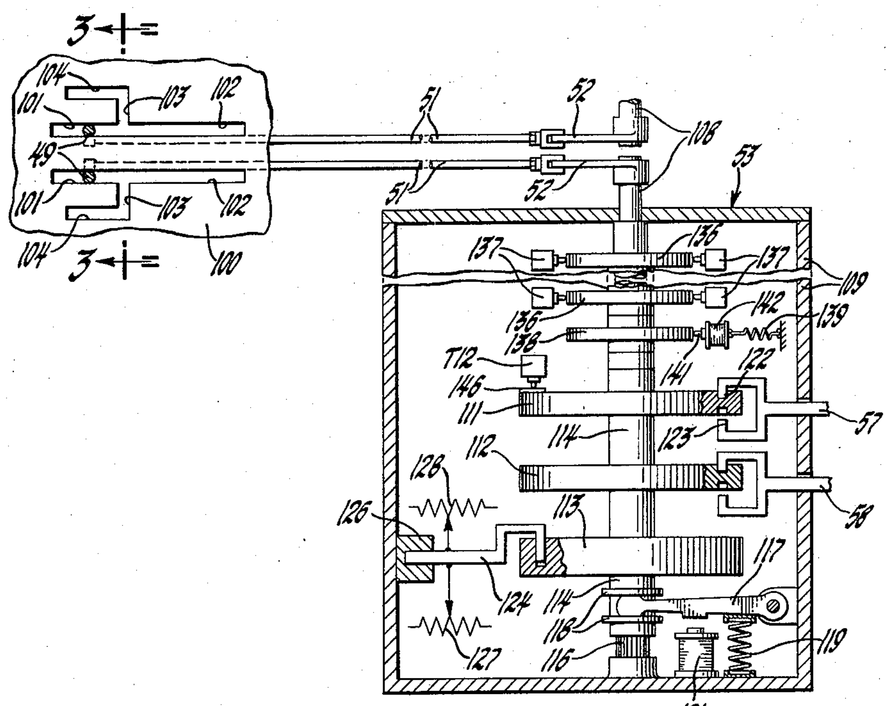

Fig. 2

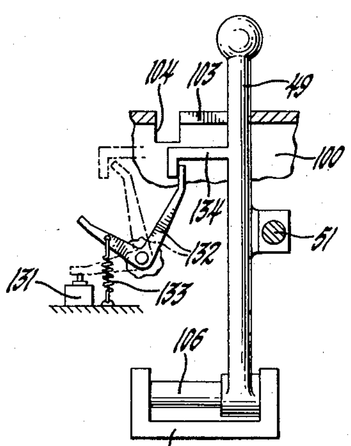

Fig. 3

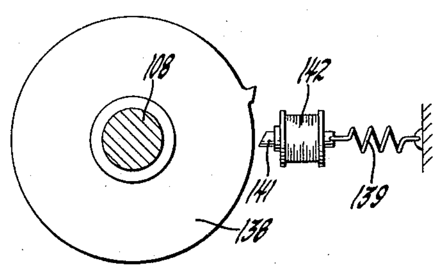

Fig. 2a

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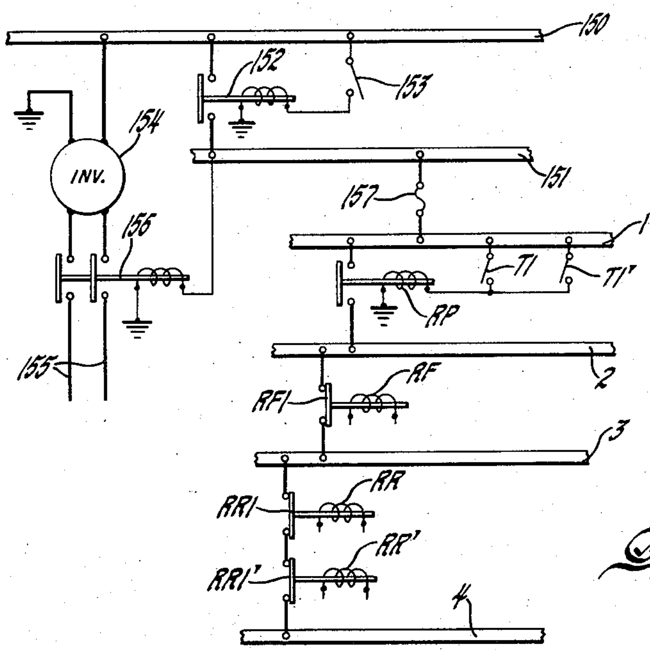

Fig. 4

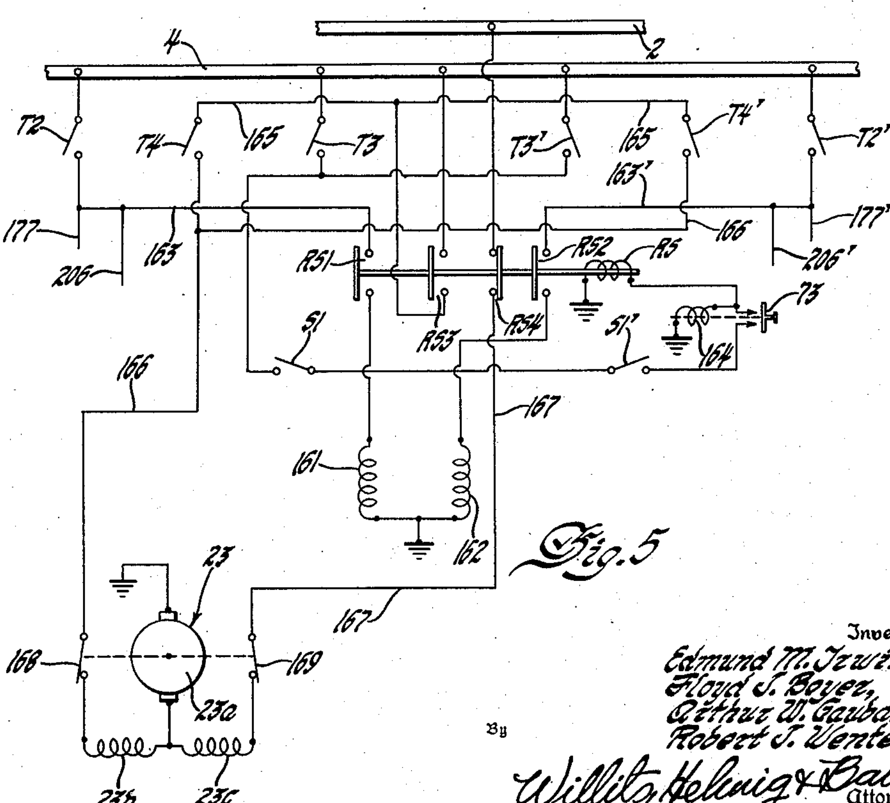

Fig. 5

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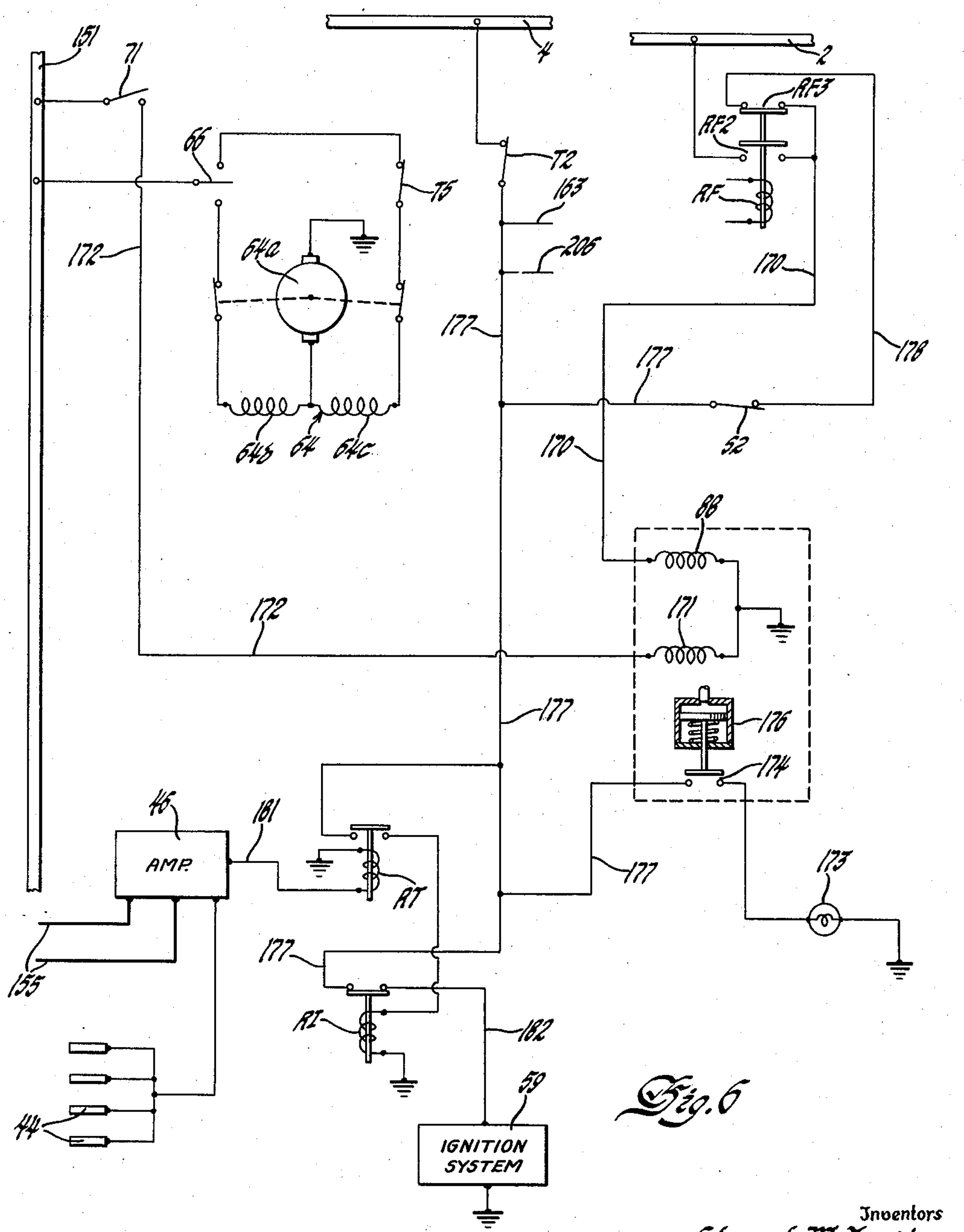

Fig. 6

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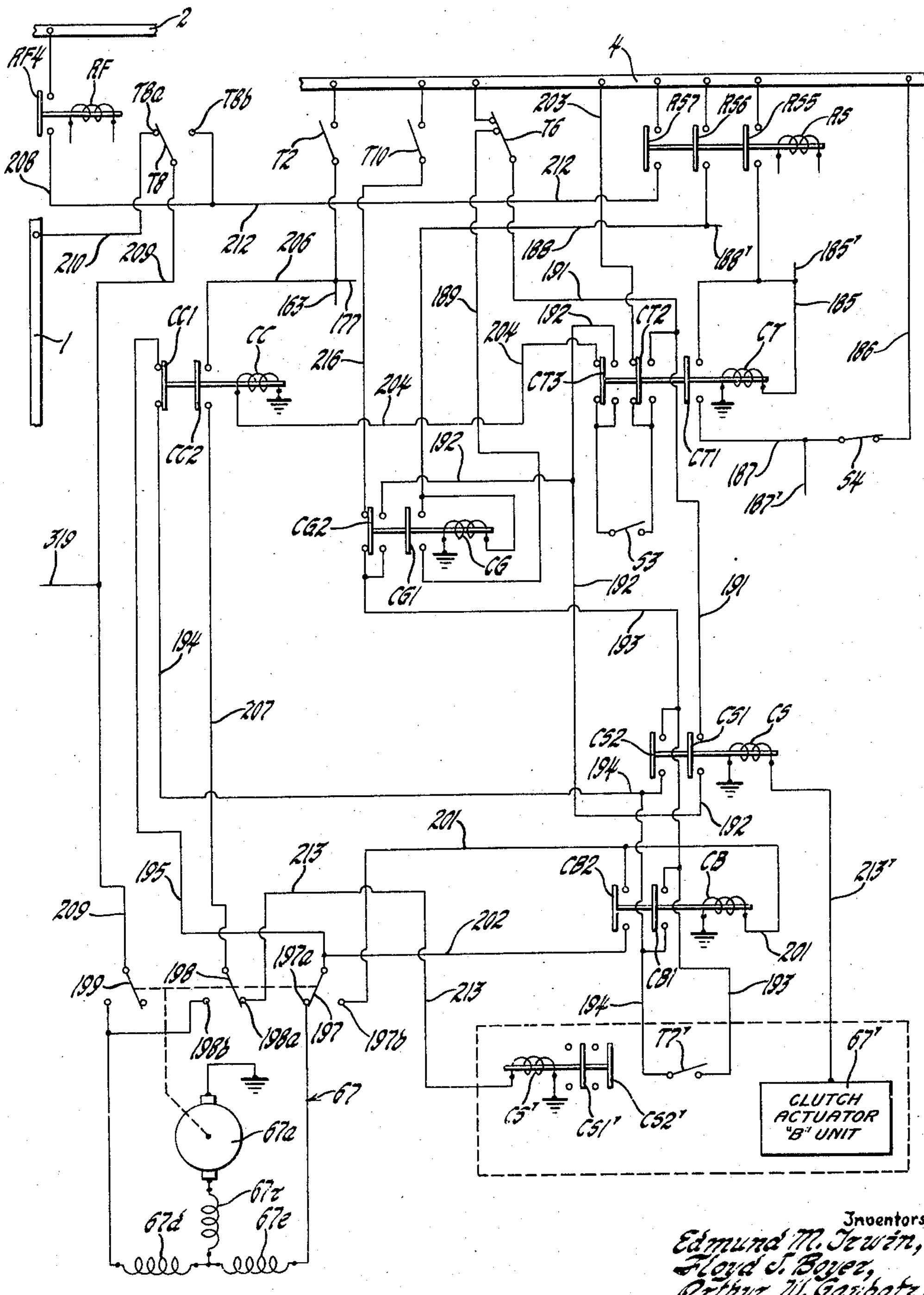

Fig. 7

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CONTROL SYSTEM FOR A VARIABLE PITCH PROPELLER AND ITS DRIVING TURBINES

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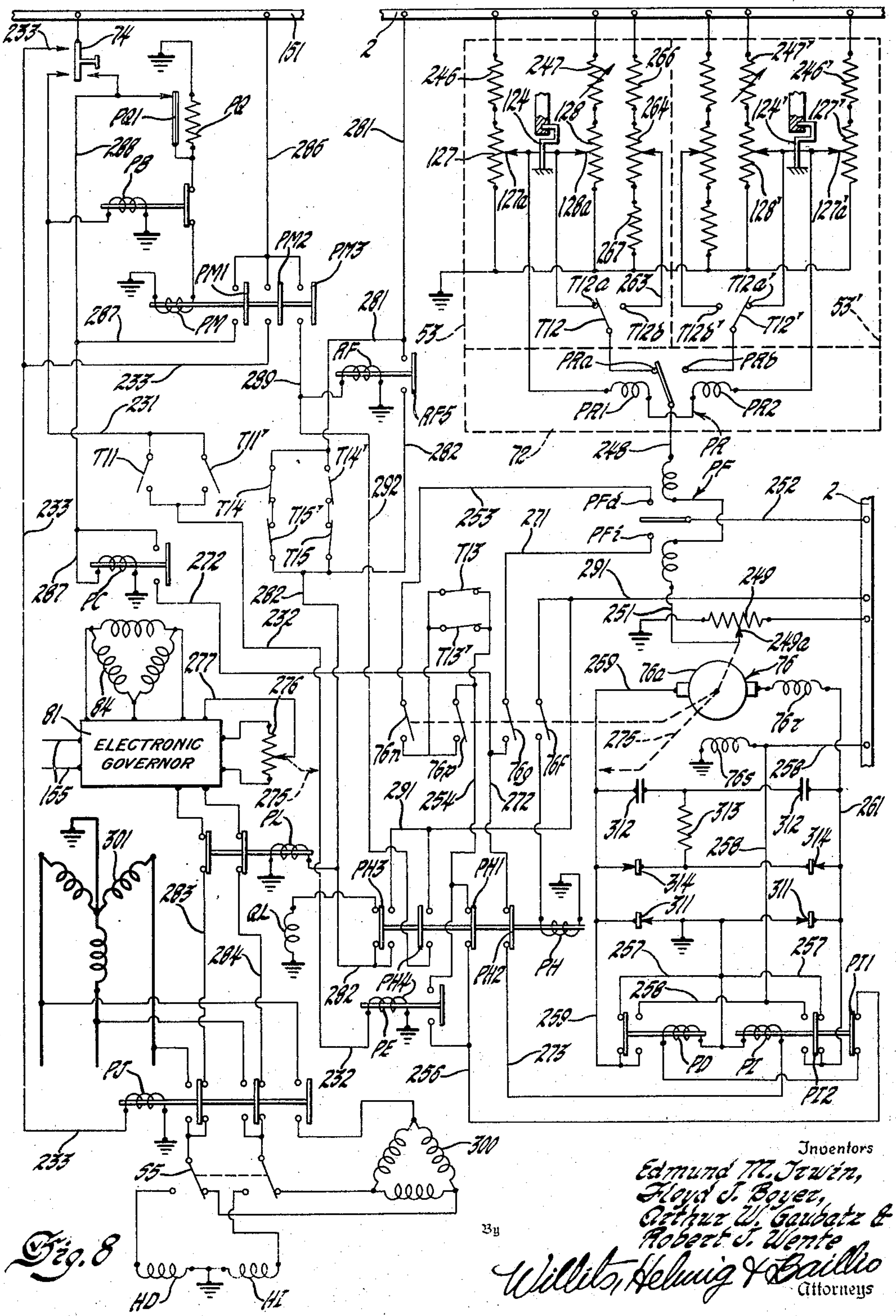

Fig. 8

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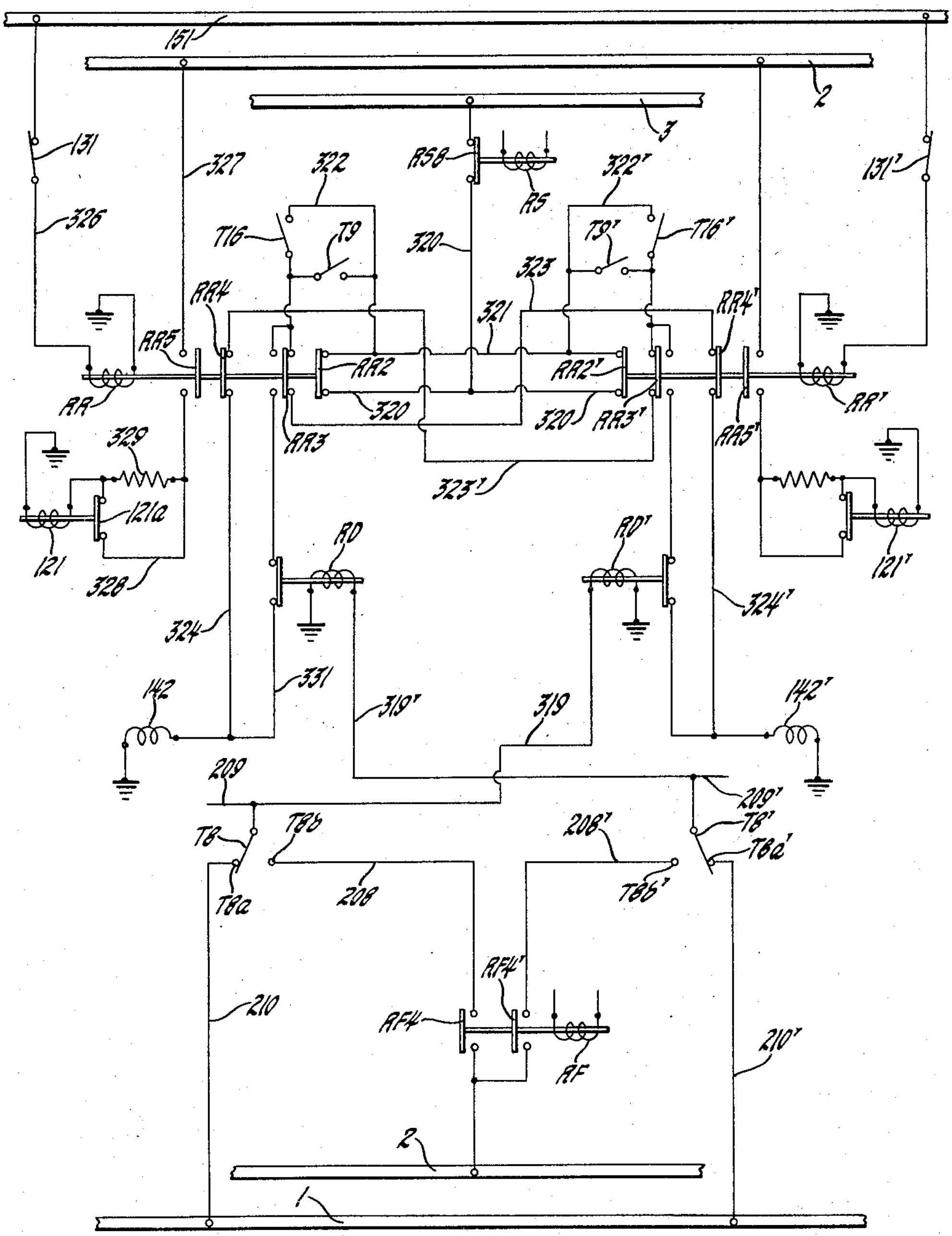

Fig. 9

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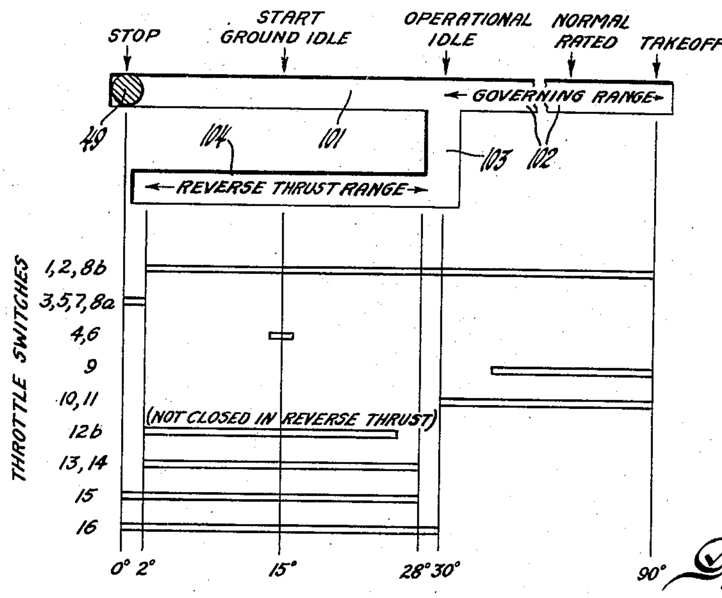

Fig. 10

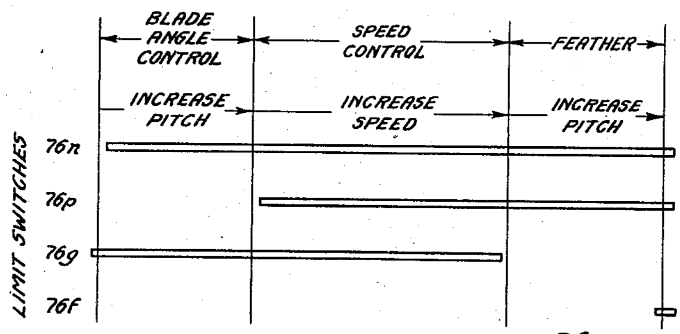

Fig. 12

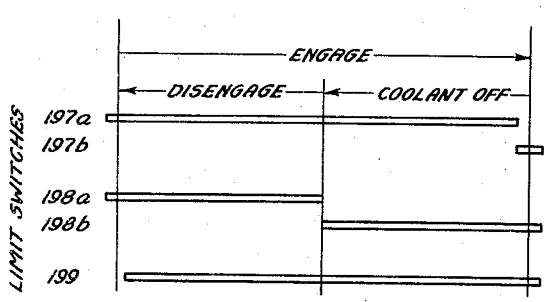

Fig. 11

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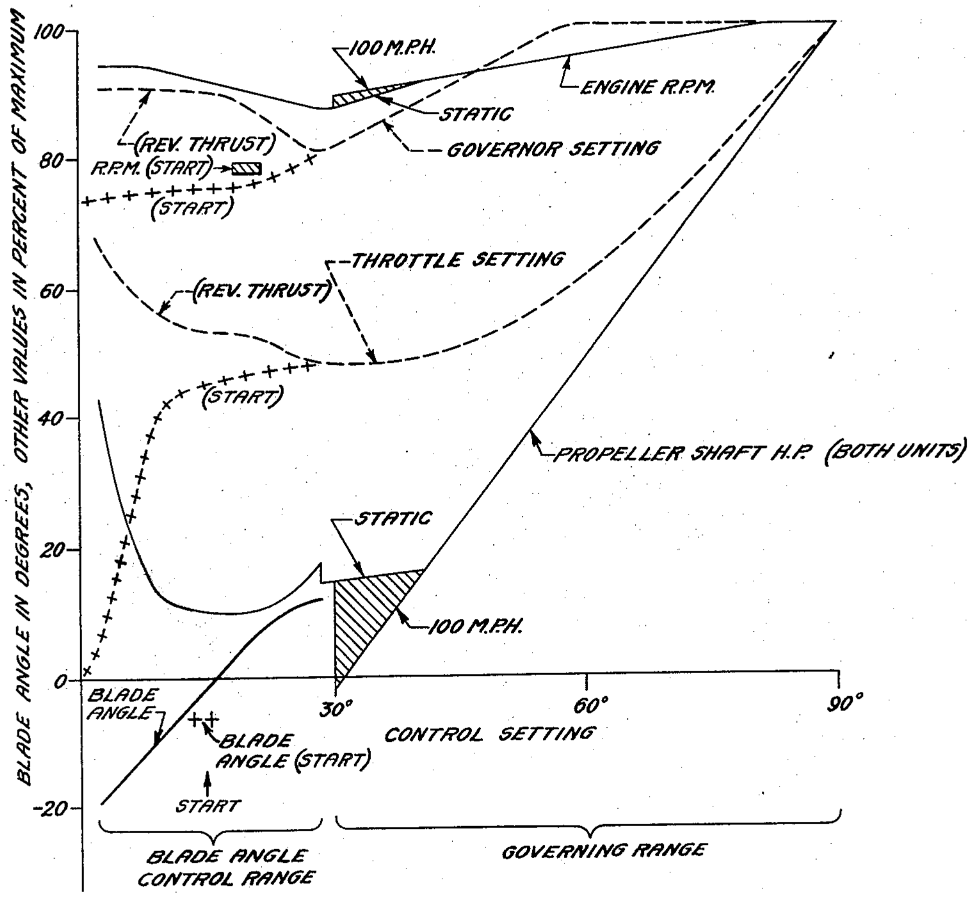

Fig. 13

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United States Patent Office

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2,851,113

CONTROL SYSTEM FOR A VARIABLE PITCH PROPELLER AND ITS DRIVING TURBINES

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Application November 8, 1950, Serial No. 194,716

66 Claims. (Cl. 170—135.72)

This invention relates to control systems for power plants and, more particularly, to a control system for an aircraft power plant in which a propeller is driven by two gas turbine engines.

The control system, in its preferred embodiment, is particularly adapted to the control of a particular propulsion unit embodying a variable pitch governing propeller which may be feathered and which may be operated in direct blade angle control in both forward and reverse pitch. The propulsion unit comprises clutches by which either or both power units may be utilized to drive the propeller. It comprises, moreover, a starting system, fuel supply apparatus, fuel feed controlling means, fuel ignition, and other engine auxiliaries.

A primary object of the invention is to assure and facilitate operation of the power plant most safely and efficiently, and with a wide choice of operating conditions. Another primary object of the invention is to provide a system by which the various components and accessories of the engine may be organized into a unitary system and the ultimate control by the pilot or flight engineer of an aircraft made as simple as possible. Another important purpose of the control system is to provide a maximum of flexibility of operation of the power plant with a minimum of controls requiring attention from the pilot. Another important object of the invention is to provide what may be termed a supervisory control to insure that conflicting and harmful control operations will not be possible; in other words, to provide proper scheduling and interlock of various functions relating to the power plant.

A further object of the invention is to provide for harmonious operation of the two power units of the engine and of one or both units with the propeller under various conditions.

Further and more specific objects of the invention are to provide a control which cuts out the power unit if the propeller is feathered; to provide a control adaptable to various propellers of the most advanced types; to facilitate starting of the units; to provide for safe, efficient, and automatic control of power clutches; to interlock the power control levers of the two units to prevent improper operation of each relative to the operation of the other and the operating condition of the power plant; and to coordinate the power control levers of the unit for joint control of both power units and the propeller to eliminate conflicts.

Many other objects and advantages of the invention will be apparent to those skilled in the art from the subsequent detailed description of the preferred embodiment of the invention. The importance of these will be apparent to those cognizant of the demands upon and responsibilities of aircraft flight personnel, which make it extremely important that the operation of the power plant of the aircraft provide for various procedures and contingencies, that it be accomplished by the simpliest possible controls, and that safeguards be provided against improper operation.

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Referring to the drawings, Figure 1 is a schematic diagram of a dual power unit gas turbine propeller aircraft propulsion plant incorporating the control system of the invention; Figure 2 is a somewhat schematic view of the mechanical structure of a power unit control and a pilot's control lever assembly; Figure 2*a* is a detail of the unit control; Figure 3 is a sectional view taken on the plane indicated in Figure 2, further illustrating a power control lever; Figures 4 to 9, inclusive, comprise a circuit diagram of the electrical system of the invention, which has been subdivided into separate figures according to function in view of the complexity of the system and to facilitate exposition thereof; Figure 10 is a diagram illustrating the operating sequence of the power control lever and throttle switches; Figures 11 and 12 are diagrams of the operating sequences of the limit switches of the actuators for the clutches and for the propeller, respectively; and Figure 13 is a chart of a preferred control schedule of an illustrative power plant.

More particularly, with reference to Figures 4 to 9, Figure 4 shows the power circuits, Figure 5 the starter circuits, Figure 6 the ignition, fuel control, and intake shutter circuits, Figure 7 the clutch circuits, Figure 8 the propeller control circuits, and Figure 9 the interlocking circuits of the power control levers. It will be understood that these circuits are interdependent. However, since the entire system cannot be shown properly on a single sheet, it is believed that clarity of exposition will best be served by dividing the control circuit between the various figures on a functional basis.

Introduction

In view of the complexity of the system, it is believed desirable to preface the detailed description by a general account of the nature of the system and of the power plant.

Referring to Figure 1, the power plant comprises two identical gas turbine engines A and B, which will be referred to as power units. Since these units may be of known type, and since the invention is not restricted in its application to a particular type of power unit, detailed description of these units is unnecessary. It may be pointed out, however, that each gas turbine power unit comprises a turbine driving a compressor. Atmospheric air taken in through intakes **11** is compressed by the compressor, the compressed air is heated by combustion therein of fuel, and the heated gases drive the turbine. The exhaust gases from the turbine leave the power units through exhaust cones **12** providing a rearwardly-directed exhaust which contributes to the propulsive effect. Each power unit drives a power output shaft **13** connected to a reduction gear assembly C. Reduction gearing of any suitable type, indicated schematically by the power unit pinions **16** and the gear **17**, drives a propeller shaft **18** on which is mounted the propeller D. The power shafts **13** drive the pinions **16** through clutches **19** which are illustrated schematically in the figure. It will be understood that the details of the reduction gear are, in general, immaterial to the invention. The reduction gearing C, and particularly the clutches **19**, are preferably of the type more fully disclosed in the copending application of Victor W. Peterson and Herbert H. Schnepel, Serial No. 174,052, filed July 15, 1950, now U. S. Patent No. 2,838,913.

An external source of power for starting the gas turbine engine is required. Preferably, this comprises a starter motor **21** energized from a source of compressed air indicated as **22** by an electrically-operated valve **23**. One starter serves both power units, being coupled by shaft **24** to a starter selector **26** illustrated more fully in the aforementioned Peterson et al. application by which the starter is clutched to either power unit. The shafts **27** and bevel gears **28** indicate schematically the power transmission from the starter selector to the power units.

Each power unit has associated with it a number of auxiliary and control instrumentalities which are shown in the figure only for the power unit A. Fuel for the unit is supplied through a line **31** from a source such as a fuel booster pump (not shown) and forced by a pump **32** driven by the unit through a fuel line **33**, fuel control **34**, line **35**, and solenoid- operated shutoff valve **36** to the fuel burners of the unit (not shown). Details of the fuel control are immaterial to the invention. In general, the functions of the fuel control are to meter the flow of fuel in proper relation to the desired power output from the engine and conditions such as temperature and pressure of the incoming air, the temperature of the heated gas, and engine speed to provide the desired power output without the necessity of detailed attention from the pilot; to promote efficient operation of the power unit; to safeguard the unit against overheating or overspeed; to insure the maintenance of combustion; to supervise acceleration and deceleration of the power unit; and to control the engine speed directly by a governor in the fuel control through a part of the operating range.

Such fuel controls are known to those skilled in the art. Basically, the fuel control operates by bypassing a portion of the pump output through a line **37** to the pump input, passing the remainder to the engine. The amount of fuel allowed to go to the engine is controlled by the factors and considerations mentioned above. Pressure and temperature of the air at the compressor inlet are transmitted to the fuel control from appropriative sensitive devices (not shown) through a pressure connection **38** and a temperature line **39**. Pressure may be sensed by at Pitot tube and temperature by a fluid-filled thermal bulb, in known manner. The utilization of these signals by the fuel control may be accomplished by mechanisms known to those skilled in the art, the details of which are irrelevant to the invention. The control requires a power unit speed input for the speed-responsive mechanism or governor therein, which may be derived in any suitable manner, as by the gearing indicated schematically by bevel gears **40**, shaft **41**, bevel gears **42**, and shaft **43**. The fuel control also receives an input indicative of temperatures in the turbine inlet of the unit from thermocouples **44** and amplifier **46**.

The fuel control receives two primary control input signals, lever **47** receiving an input indicative of the desired power output of the unit relative to the maximum power available under the existing conditions, and lever **48** receiving a speed signal to set the governor mechanism of the fuel control. These power and speed signals originate in a pilot's power control lever **49** which is coupled mechanically, as by link **51** and arm **52**, to a unit control **53**. The details of the internal mechanism of the fuel control are immaterial to this invention, which may be practiced with any fuel control having characteristics suited to the engine utilized. A fuel control having both power and speed inputs is shown in British Patent 729,201.

The unit control is an important part of the control system, having for its principal functions the transmission of power and speed signals to the fuel control and pitch or speed signals to the propeller mechanism. As will be explained more fully, the unit control schedules the signals to provide for efficient operation of the power unit without the necessity of calculation by the pilot or flight engineer. The transmission from the unit control to the fuel control may be of any suitable type, preferably a simple mechanical linkage such as push rods or links **57** and **58** coupled to the crank arms **47** and **48**, respectively.

The unit control also supervises other functions of the power unit. It controls the energization of an ignition generator **59** which, through a lead **61**, energizes spark plugs or other ignition devices by which combustion is initiated. The ignition apparatus is preferably of known type and need not be described. The amplifier **46** is coupled to the ignition apparatus to cut off the ignition when combustion is established and re-energize the ignition if the flame goes out.

The power unit air intake **11** is provided with shutters **62** which are ordinarily closed when the unit is out of operation. These shutters are opened and closed through any suitable connection such as the linkage illustrated at **63** by an electro-mechanical actuator **64**. This actuator is energized to open or to close the shutters by a shutter switch **66** by way of the unit control **53**, which prevents closing the shutters when the power unit is in operation.

The power unit clutch **19** is controlled by a clutch actuator **67** which is indicated for the purpose of illustration in the drawing as operating the clutch through a mechanical linkage **68**. Preferably, in practice, the clutch actuator is an electrical actuator operating a valve by which hydraulic fluid for engaging and disengaging the clutch is supplied to a double-acting hydraulic motor and a valve by which cooling fluid is supplied to the clutch during the period of engagement. The preferred clutch and the valve mechanism are disclosed in the abovementioned Peterson and Schnepel application, and the disclosure need not be duplicated here. The clutch actuator comprises an electric motor energized from the unit control **53**. The operation of the clutches is interlocked so that the clutches may not be brought into engagement simultaneously and so that control of clutch engagement and cooling is dependent upon the speed of the driving and driven shafts. The speed control is effected in part by speed switches **69**, preferably centrifugal switches, driven by the power unit, which transmit speed signals to the unit control.

Such speed switches are readily available articles of commerce. Examples of centrifugal switches are illustrated in U. S. Patents Nos. 2,452,298, 2,457,192 and 2,621,267. The specific structure of the speed switch is entirely immaterial to our invention.

The fuel pumping mechanism indicated schematically by the pump **32** is preferably in practice a system including a normal and an emergency fuel pump which may be, for example, of the type disclosed in an application of Floyd J. Boyer, Serial No. 139,216, filed January 18, 1950, for Fuel Systems (Patent 2,640,423). The system involves means for bypassing the main pump, to check the functioning of the auxiliary pump, by a check switch **71** operable by the pilot.

The auxiliary and control apparatus identified by the numerals **31** to **71**, inclusive, is duplicated for the power unit B.

Additional control instrumentalities common to both engines are a coordinating control **72**, a start switch **73**, and a feather switch **74**. As previously stated, the unit control serves to coordinate the various control operations for one power unit. The major function of the coordinating control is to coordinate the two power units of an engine with each other and with the propeller, as will be more fully explained.

The start switch **73** controls the starter air valve **23** by way of the coordinating control, which prevents operation of the starter under improper conditions.

As previously stated, the propeller D is of a feathering type. Feathering and unfeathering of the propeller are initiated by the pilot-operated feather switch **74** and the coordinating control which energize an electric motor in a propeller actuator **76**. This actuator is the primary control for the propeller and is coupled to the propeller through a mechanical linkage indicated at **77**. By means of the propeller actuator, the propeller may be feathered, may be operated as a speed-governing variable pitch propeller, may be operated in direct blade angle control through a range of positive and negative pitches for ground operation, and may be set at zero thrust when the propeller load is picked up by the power unit.

The coordinating control energizes the solenoids 88 to close the fuel shutoff valves 36 and also deenergizes certain of the unit control circuits when the propeller is feathered. The propeller actuator also receives a signal from the power control lever 49 of each unit by way of the unit controls 53 and the coordinating control, which coordinates these signals to transmit a single speed or pitch signal to the propeller actuator.

The control of the power plant also involves a speed switch device 78, driven from the propeller shaft 18 by suitable gearing, indicated schematically at 79, which transmits signals to the unit controls 53.

The operation of the propeller as a constant speed variable pitch propeller is directly controlled by an electrical propeller governor 81 which transmits signals to a hydraulic mechanism in the propeller, which increases and decreases pitch, through an electrical circuit indicated at 82. This propeller governor receives desired speed signals from the propeller actuator through an electrical circuit 83. It also receives an input indicative of the actual speed of the propeller from an alternator 84 driven by the propeller shaft through suitable gearing indicated at 86.

The power control lever 49 operates through a normal power control range and additionally through a reverse thrust range in which the power plant control is modified to secure both positive and negative thrust for ground operation. The reverse thrust control requires different coordination of the various elements of the mechanism. This also is achieved by the unit control, which is transferred to reverse thrust control by an electrical signal transmitted through a circuit 87 from the power control lever.

The unit control actuates a manual fuel shut-off valve located in the fuel regulator when the power control lever is moved to the stop position.

Power control levers and unit controls

A suitable structure of the unit controls 53 and the power control levers 49 is indicated in a general or schematic manner in Figures 2, 2*a*, and 3. It will be understood that structural details of these mechanisms are omitted from the drawings, since such details are unnecessary to an understanding of the principles and application of the invention, and may be varied widely. Figure 2 illustrates the arrangement of the two power control levers and one of the unit controls. The power control levers 49 operate in a quadrant 100, each lever operating through aligned slots 101 and 102 in the quadrant which constitute the normal operating path of the lever. Figure 10 shows the operating positions of the control lever more fully. It may be noted that slot 102 is shortened in Figure 10, the actual length being preferably about twice that of slot 101. When the lever is at the left hand or zero degree end of slot 101, the power unit is stopped. As the lever is moved through the slot 101, the engine is controlled in starting and idling conditions. At fifteen degrees, conditions are correct for starting and idling on the ground, and at thirty degrees for idling under operating conditions. Detent mechanism (not shown) may be provided to locate the lever in the Stop, Start, and Operational Idle positions. As the lever is progressed through the slot 102, the engine is operated in normal power operation with power increasing as the lever approaches the right hand end of the slot. Each lever may be moved through a gate 103 into a slot 104 in which the engine is operated in what is termed the reverse thrust control range, which is intended for ground operation, and in which both forward and reverse propeller thrust are available. When the lever is in the slot 101 or the slot 104, the propeller is under direct blade angle control, so that the operation in the slots 101 and 104 is referred to as the blade angle control range.

On the other hand, when the lever 49 is in the slot 102, which is referred to as the governing range, a speed signal is transmitted to the propeller governor so that the propeller pitch is varied to maintain the desired propeller R. P. M.

Each lever 49 may be mounted for rotation on an axis 106 fixed in a bracket 107 and for sliding movement along the axis (or otherwise) for passage through the gate 103. The lever 49 is coupled to the pull rod or link 51, the other end of which is coupled to the input arm 52 of the unit control 53 so that rotation of the power control lever rotates a shaft 108 journaled in the casing 109 of the unit control. The angles indicated in Figure 10 refer to rotation of shaft 108.

The power control levers are mounted side by side so that they may be operated together conveniently for normal aircraft operation or singly for starting or operation on one power unit.

The unit control 53 includes cam mechanism by which properly coordinated signals governing the operation of the power unit in both the normal and reverse thrust conditions of operation are transmitted. These signals, as previously indicated, are a power signal through rod 57 to the fuel control, a speed signal through rod 58 to the governor in the fuel control, and an electrical signal (via the coordinating control 72) to the propeller actuator controlling propeller pitch in the blade angle range and propeller speed in the governing range. Since the conditions of operation are entirely different in the reverse thrust range from those in the starting and idling portions of the normal control range, the system is set up for alternative operation so as to transmit properly coordinated signals in either type of control.

These signals are transmitted by cams 111, 112, and 113 rotated by the shaft 108. As illustrated, these are plate or disk cams with grooves in the faces of the cams engaged by cam followers. The cams are fixed to a sleeve 114 rotatively coupled to the shaft 108 as by conventional splines 116. The sleeve 114 is shiftable axially of the shaft 108 by a fork 117 pivoted on the casing 109 and engaging between flanges 118 on the sleeve. The sleeve 114 is biased into the axial position shown, which is that for the normal range, by a spring 119 acting on the lever 117, and is shifted axially for the reverse thrust range by a solenoid 121 which, as illustrated schematically, pulls on the lever 117 as an armature. The power control rod 57, which is slidable in the casing, is forked to provide cam followers 122 and 123 alternatively engageable in cam slots in both faces of power cam 111. The speed control rod 58 is similarly forked for engagement with the two cam slots of cam 112. One face provides for normal control, the other for control in the reverse thrust range. A third cam follower 124 actuated by the cam 113 is suitably guided for reciprocation in the casing 109, as by a guide member 126 fixed to the casing. The cam follower 124 transmits electrical signals to the propeller actuator by means of potentiometers 127 and 128, the movable contacts of which are shifted by the cam follower 124.

In the preferred control system, the movement of cam follower 124 is the same in both the starting and reverse thrust ranges. This cam has only one groove in which the follower engages in both ranges, as illustrated. Alternatively, this cam may be mounted directly on shaft 108 so as not to be shifted by solenoid 121.

The forms of the slots in the controlling cams are calculated to provide the desired operating characteristics, dependent upon the nature of the power units, the fuel control, and the propeller and its control mechanism.

The solenoid 121 is energized whenever the corresponding control lever 49 is moved through the gate 103 into the reverse thrust slot by a switch 131 which may be actuated by the power control lever in any suitable manner. As illustrated in Figure 3, the switch **131** is a normally open switch which may be closed by a bell-crank lever **132** pivoted on the fixed structure of the throttle quadrant assembly and urged into switch-closing position by a spring **133**. The lever **132** is normally held from engaging the switch by a bracket **134** extending from the throttle lever and of sufficient arcuate extent to remain in engagement with the lever **134** throughout the angular movement of the lever **49**. When the throttle lever is shifted through the gate, the lever **132** closes the switch, as indicated by the broken lines in Figure 3. With the solenoid **121** thus energized, the cams **111** to **113** are shifted downwardly, as viewed in Figure 2, so that the followers engage in the slots in the reverse thrust faces of the cams. This shift takes place as the throttle lever moves through the gate **103**; the radius of the cam slots is the same on both faces of the cams at the point corresponding to this angular position.

The supervisory control functions of the apparatus are regulated in accordance with the position of the power control levers under control of a number of switches closed through various ranges of angular position of the lever **49**. These switches, referred to as throttle switches, may be operated in any suitable manner by rotation of the shaft **108**. As indicated schematically in Figure 2, an appropriate number of switch-operating cams **136** fixed to the shaft **108** provide for actuation of throttle switches **137** fixed in any suitable manner to the housing **109**. These switches may be of a well-known type operated by reciprocation of a plunger which may be actuated by raised or depressed sectors of the peripheral portion of the disks **136**. The operating cycles of these switches are illustrated in Figure 10, the bars corresponding to the closed position of the contacts.

The unit control **53** also houses a throttle block mechanism which controls movement of the throttle lever out of the governing range in which it remains in normal flight conditions. This throttle block may comprise a disk or sector **138** (Figures 2 and 2*a*) formed with a dog engaged by a latch **141** normally retracted by a spring **139** or the like and urged into engagement with the disk **138** by a solenoid **142**. The solenoid **142** is energized in a manner to be described so that the power control may be moved into slots **101** or **104** under proper safeguards but may not be so moved improperly. The latch is formed to permit free advance of lever **49** into the governing range.

The switches **137** operate whether the control is in the normal or the reverse thrust range. A switch T12, operated only when the power control unit is in the normal range, is actuated by a cam **146** mounted on the cam disk **111**. As will be apparent, when cam **111** is shifted downwardly by the solenoid **121**, cam **146** will not engage the operating plunger of switch T12.

It does not seem practicable to discuss the structure and the details of operation of the control system more fully than has been done in advance of a detailed disclosure of the operating circuits. Details of the structure and operation will be considered in terms of the various circuits as they are described.

General scheduling of the power plant

It may be helpful in understanding the details of the system to examine, in a general way, the schedule or conditions of operation of the power plant for use with which the preferred embodiment of the control system is intended. Figure 13 is a scheduling diagram of a dual power unit gas turbine propeller engine employing the control of this invention. It will be understood that values given in this diagram are illustrative; they are to a certain extent a matter of choice for a given power plant, and may vary greatly from one power plant to another. The abscissa of the curves of Figure 13 is the control setting, which is the rotation of shaft **108** of the unit control. Scheduled engine R. P. M. and propeller shaft horsepower are indicated by solid lines in percent of the maximum value. The governor setting, by which is meant the setting of the governor in the fuel control, and the throttle setting, by which is meant the power control setting of the fuel control, are indicated by broken lines, likewise in percent of the maximum setting. Blade angle in the blade angle control range is plotted in degrees. As will be seen, the total travel is indicated as 90 degrees, zero degrees being the Stop position (see also Figure 10), the range from 2 degrees to 28 degrees being the blade angle control range, and that from 30 degrees to 90 degrees being the governing range in which the propeller pitch governor is in operation.

The curves for shaft horsepower and R. P. M. are for normal power operation through the reverse thrust and governing ranges, and do not include the starting range.

The curves for governor setting and throttle setting are two-valued in the blade angle control range, the broken lines indicating the setting in the reverse thrust range and the broken crossed lines indicating the values when the power control lever is in the slot **104** in which starting is effected.

Perhaps the most fundamental setting is the throttle setting which is advanced from zero or complete cutoff in the Stop position to about 45% for starting the engine, and then increases, first gradually and then more sharply, as the power control is moved to the 90 degree position for taking off. The Start and Ground Idle throttle settings are set in accordance with the operating characteristics of the engine to give sufficient power for consistent operation and to handle the propeller load. The throttle setting curve through the governing range is preferably such as to give a substantially straight line curve of shaft horsepower, as indicated. In the reverse thrust range, the throttle setting remains substantially constant through the positive thrust portion of the range but increases sharply toward the maximum negative thrust position of the control to provide sufficient power for braking. The shaft horsepower curve rises accordingly in the negative pitch range. The effect of the governor in the fuel control on operation in and near the blade angle control range will be discussed presently.

As will be noted from the blade angle curve, the blade angle decreases from about 12 degrees at the 28 degree control position to zero at about the 15 degree control position and increases negatively to minus 20 degrees pitch at the two-degree position. Throughout this range, blade angle is determined directly and solely by the position of the power control lever. No curve is given for blade angle in the governing range since, in this range, there is no fixed blade angle, the angle being adjusted by the propeller governor to maintain the desired engine speed.

The engine speed or R. P. M. curve shows only slight variation because of the characteristics of the gas turbine, which is essentially a constant speed power plant; that is, it does not admit of wide variation in speed like an internal combustion engine. Basically, engine R. P. M. is controlled in the blade angle control range by the governor in the fuel regulator and, throughout the governing range, which is Operational Idle and above, by the propeller governor.

In a limited range above Operational Idle, the control of engine R. P. M. and propeller shaft horsepower is effected by both governors, the actual operating points varying within the shaded areas bounded by the lines identified as "Static" and "100 M. P. H." Under static conditions the engine is governed to deliver about 15% rated power. However, assuming that the plane is landing at a speed of 100 M. P. H. with the control in Operational Idle for minimum operational power, the propeller governor can reduce the pitch only to a minimum value. The 100 M. P. H. relative wind acting on the propeller generates energy which is transmitted to the engine, so that at the Operational Idle point and 100

M. P. H. speed the propeller actually furnishes power to the engine amounting to about 2% of maximum engine rating. Above about a 40 degree control setting, the propeller governor takes over, the increased engine power at this setting being sufficient to require governing action by the propeller governor. The area between the engine R. P. M. curves for 100 M. P. H. and static conditions represents the deviation in engine speed from the scheduled speed which occurs at reduced throttle conditions. Maximum deviation occurs at static conditions, zero deviations at 100 M. P. H., and proportional deviation at speeds between these two values.

It will be noted that the fuel regulator governor setting is at about 90% rated engine speed through the negative pitch portion of the reverse thrust range, then decreases to approximately 80% rated speed at Operational Idle. The governor setting increases rapidly with further advance of the throttle so that, in normal operation in the governing range, the speed governor does not control the engine and does not conflict with the propeller governor. The governor setting at Start is in the neighborhood of 75%.

The blade angle at Start is the value corresponding to minimum torque requirements of the propeller which, in the particular installation chosen for discussion, is approximately minus 6 degrees as indicated on the figure. Operating conditions when the engine has started depend upon the throttle and governor settings, resulting in a speed for the engine when it is brought up to speed with the control in Start position of about 80% rated speed. The speed differs slightly with the clutch engaged due to the propeller load from that of the engine running unloaded, as indicated by the width of the shaded Speed (Start) area on the diagram.

It will be understood that Figure 13 is illustrative of the conditions with both power units in operation. The control is such that it is adapted to operation on a single power unit. With a single power unit in operation, the propeller governor, the fuel regulator governor, the throttle, and the blade angle are set to the same values as when two units are in operation. The horsepower available will, of course, be only one-half that for two units. Throughout the governing range, the principal effect of the reduced horsepower is simply to cause the propeller governor to reduce the propeller pitch so that the single unit can drive it at the scheduled speed. In the reverse thrust range, the scheduling is such that one power unit may handle the entire load. It will be noted that the maximum braking load is considerably under the full power of one unit. The power or throttle setting is sufficient throughout the blade angle control range for one unit to handle the propeller load. When both units are in operation, as is usually the case, an excess of power is available. In this case, however, the governors in the fuel regulators reduce the fuel supply to the individual units so that the speed and power of the two units follow the indicated schedule. Any variation between single and double-unit operation due to governor regulation characteristics is immaterial.

The principles of scheduling involved in the control will be clear to those skilled in the art from the above. The absolute values of the quantities indicated in Figure 13 and the relative values at different points through the range of the control will vary with the desired operating characteristics and with the type of power plant and load involved. The actual cam contours will also vary, of course, with the specific characteristics of the fuel regulator including the governor, the propeller governor, and the linkages or other connections between the cams and these controlling devices. Determination of the actual values for a particular installation is simply a matter of engineering design.

Power circuits

As a feature of the organization of the control system, several busses are provided to furnish power to the control devices, the energization of these busses being related to the operating setup at any given time. To avoid unnecessary duplication in the circuit diagrams, the organization of this bus system or power control circuit is illustrated in Figure 4.

Power for the operation of the control is derived from a D. C. power bus **150** in the aircraft. A nacelle bus **151** for each engine or dual power unit is energized from the power bus by a relay **152** energized by a manually-operable switch **153** under control of the pilot or flight engineer. This bus may energize fuel booster pumps, fuel tank shutoff valves, etc. (not shown). Alternating current for the thermocouple amplifiers and propeller governor is generated by an inverter **154** connected to the D. C. power bus **150**. The output of the inverter is fed to the 400 cycle bus **155** through front contacts of a relay **156** energized directly from the nacelle bus **151**.

The additional D. C. busses are identified as **1**, **2**, **3**, and **4**, bus **1** being energized from the nacelle bus **1951** through a fuse **157** so that this bus is constantly energized whenever the power plant is set up for operation by energization of the nacelle bus.

It may be noted here that, throughout this specification, the various switches, relays, and other electrical apparatus common to both power units and those individual to the A unit will be indicated by unprimed reference characters, and devices individual to the B power unit by corresponding primed reference characters. Throttle switches are indicated by T and speed switches by S. Relays in general are identified by R, relays in the clutch control circuits by C and relays in the propeller circuits by P.

Proceeding with the description of the power circuits, bus **2** is energized from bus **1** through the normally open contacts of a power relay RP energized by throttle switches T1 and T1′ in parallel which, as indicated in Figure 10, are closed except when the power control lever is in the Stop position. Thus, bus **2** is energized when either unit is in operation, but is cut out whenever the power controls for both units are moved to the Stop position.

Bus **3** is energized from bus **2** through back contacts RF1 of relay RF, the feather relay, which is energized whenever the controls are actuated to feather the propeller. The relay remains energized as long as the propeller remains feathered and bus **2** is energized.

Bus **4** is energized from bus **3** through the back contacts RR1 and RR1′, in series, of relays RR and RR′, the reverse thrust relays of each unit. Relays RR and RR′ are energized by the power control lever switch **131** of the corresponding unit when the lever is shifted through the gate **103** into the reverse thrust slot.

In summary, it may be pointed out that bus **2** is energized except when both power units are cut out; bus **3** is energized whenever bus **2** is energized unless the propeller is feathered or the feathering movement has been initiated; and bus **4** is energized whenever bus **3** is energized except when either control lever is shifted into the reverse thrust slot.

Starter circuits

The starter circuits shown in Figure 5 are solely those concerned with the operation of the starter selector to connect the starter to one or the other power unit and with the energization of the starter actuator to supply compressed air to the starter. The starter selector **26** comprises a coil **161** for engaging the clutch by which the starter is connected to power unit A and a coil **162** for clutching the starter to power unit B. The clutching mechanism is described in the above-mentioned Peterson et al. application; however, an understanding thereof is not necessary for the understanding of this invention. Coil **161** is energized by throttle switch **T2** and coil **162** by throttle switch **T2′**, these switches being closed except when the corresponding power lever is in Stop position.

The energizing circuits proceed from bus 4 through T2 or T2′, line 163 or 163′, front contacts RS1 or RS2 of the starter relay RS and coil 161 or 162 to ground. The starter relay RS, which may be in the coordinating control 72, is energized from bus 4 through throttle switches T3 and T3′ (in parallel), speed switches S1 and S1′, the pilot-operated start switch 73, and the RS relay coil to ground. The start button 73 is held closed by a solenoid 164 coupled to the movable contact and energized in parallel with relay RS.

Switches T3 and T3′ are closed only when the corresponding power lever 49 is in Stop position. Switches S1 and S1′ are closed below a low but self-sustaining running speed of the units A and B respectively, which speed may be taken as 5900 R. P. M. Thus, in order to energize the starter relay, the power control of the unit being started must be advanced from Stop, the other power control must be at Stop, the propeller must be unfeathered (to energize busses 3 and 4), both units must be below 5900 R. P. M., and the pilot must actuate the start switch 73. The starter relay closes contacts RS1 and RS2 in the circuits to the starter selector 26, energizing the coil 161 or 162 corresponding to the unit the control of which has been advanced.

Movement of the unit control to Start position closes its throttle switch T4 or T4′ to actuate the starter. These switches are connected in parallel in a circuit from bus 4 through front contacts RS3 of the starter relay lead 165, switches T4 and T4′, lead 166, and valve-opening field coil 23*b* and armature 23*a* of the motor of the air valve actuator 23, which opens the air valve and thus supplies power to the starter motor 21. The starter motor cranks the selected power unit, accelerating the unit until its speed reaches 5900 R. P. M., at which point the speed switch S1 opens, deenergizing the starter relay and the solenoid 164, releasing the start button 73. When the starter relay deenergizes, it closes back contacts RS4 which make a circuit from bus 2 through line 167 and the valve-closing field coil 23*c* and armature 23*a* of the air valve actuator, operating it in the reverse direction to shut off the air supply to the starter. The actuator motor 23 is a well-known type of reversible motor, and includes limit switches 168 and 169 which operate in the usual manner to open the circuit to the motor when the actuator has traveled through its full range, thus deenergizing the opening circuit when the valve is open and the closing circuit when the valve is closed.

Since all the starter selector and starter energizing circuits are supplied from bus 4, they are inoperative if the propeller is feathered or either unit control is in the reverse thrust range.

As will be apparent, the starter air valve circuit could easily be modified to provide a relay circuit for control of an electric starter motor if such were desired. The significance of the starter circuits will be more fully apparent after the description of related circuits. Lines 177, 177′, 206, and 206′, indicated on Figure 5, relate to other portions of the system, to be described. Switches T2 energize a number of circuits relating to the corresponding unit when the power control is moved from Stop. This common energizing circuit may be regarded as a unit bus.

Intake shutter circuits

Figure 6 illustrates the ignition, fuel, and shutter circuits. The circuits shown are for one power unit only, being duplicated for the other unit.

Shutters 62 (Fig. 1) are usually closed except when the power unit is in operation. Particularly when a power unit is shut down in flight, it is desirable to close the shutters so that ram air will not rotate the idle power unit. The shutters are opened and closed by the actuator 64, which is a standard reversing electric motor actuator with limit switches, under control of the shutter switch 66 and throttle switch T5, which is closed when the control is at Stop.

Switch 66, which is actuated by the pilot or flight engineer, is normally open and may be closed on one contact to energize the shutter opening field winding 64*b* and armature 64*a* of the actuator 64 from the nacelle bus 151, or on the other contact to energize the shutter closing field 64*c* and armature 64*a* through throttle switch T5. These circuits are made through the usual limit switches actuated by the motor, of the same nature as those previously described for the air valve actuator. Switch T5 is closed only when the power control of the unit is at Stop, thus providing an interlock to prevent closing of the shutter when the power unit is in operation.

Fuel system circuits

The elements in Figure 6 which are included in the fuel system are enclosed in a broken line. They include the solenoid 88 which closes the normally-open fuel shutoff valve 36 (Figure 1) when energized by a circuit from bus 2 through front contacts RF 2 of the feather relay, line 170, and solenoid 88 to ground. The fuel line is thus closed when the propeller is feathered, regardless of the position of the power control lever 49.

The pump checkout solenoid 171 in pump 32 is energized from the nacelle bus through the pilot-operated check switch 71 and line 172.

A pump failure warning light 173 indicates incipient failure of the main or primary fuel pump. This light is actuated by a change in pressure within the fuel system, which is all that need be known about it for the purpose of understanding the present invention; it is more fully disclosed in the abovementioned Boyer application. The light 173 is energized by a switch 174 actuated by a fluid pressure responsive device 176 in the fuel system. An energizing circuit for the switch 174 proceeds from bus 4 through throttle switch T2, which is closed except when the control lever is at Stop, and lead 177. Thus, the warning light is energized whenever bus 4 is energized, the power control lever is away from Stop, and the pressure switch is closed.

Switch T2 also energizes a circuit from bus 4 to the fuel shutoff solenoid 88 through lead 177, speed switch S2, lead 178, back contacts RF3 of the feather relay, and lead 170. Switch S2, which is one of the speed switches in the unit 69, is closed below a minimum suitable speed for initiation of combustion in the power unit, which may be 1700 R. P. M. Thus, when the propeller is unfeathered and the power control is moved away from Stop so that the unit can be started, the solenoid 88 is energized to keep the fuel shut off until the unit is accelerated to 1700 R. P. M., at which point the unit will provide sufficient air circulation for proper ignition of the fuel. This arrangement prevents possible flooding of the unit by supplying fuel at too low a speed, or improper combustion in the absence of sufficient air. At 1700 R. P. M. the power unit is capable of assisting the starter in bringing the unit up to a speed at which the unit is self-sustaining. Thus, the starter, aided by the turbine in the unit, continues to accelerate the unit until 5900 R. P. M. is reached, at which point the unit is more than self-sustaining and the starter is cut out by switch S1 or S1′ (Figure 5).

Ignition system control

The ignition system preferably includes spark plugs in the unit (not shown) and an ignition current generator which supplies a high potential to the spark plugs. Such systems are well known, and the control system of the invention is applicable to various ignition systems of this and other types. The invention is concerned only with control of the energization of the ignition generator, which is identified as 59 in Figures 1 and 6. The control system provides for energizing the ignition when the starting operation is initiated, de-energizing it when the flame has been established, and automatically reenergizing the ignition if a blowout of the flame occurs. The control includes the thermocouples 44 which respond to temperature in the turbine inlet, the output of which is amplified by amplifier 46 energized from the 400 cycle bus 155. The output circuit 181 of the amplifier is energized when the temperature to which the thermocouples respond reaches a value well below the operating range but sufficiently high to indicate the presence of combustion; such, for example, as 800 degrees F. This output energizes temperature relay RT, the front contacts of which close a circuit from line 177 through the coil of ignition relay RI to ground. The ignition generator 59 is energized from line 177 through the back contacts of the ignition relay RI and line 182.

When starting the unit, the unit is cold, relay RT is deenergized, and the circuit from line 177 to the ignition system is closed by relay RI. Therefore, when the power control lever is moved away from Stop, switch T2 is closed, providing ignition in the combustion chambers so that, when the fuel is injected at 1700 R. P. M., it is immediately ignited. The ignition circuit stays energized until the thermocouple amplifier responds at 800 degrees F., closing the contacts of relay RT and breaking the ignition circuit at relay RI. As will be apparent, if the flame goes out, the ignition circuit will be re-established by the thermocouple amplifier and relays RT and RI unless the power control has been returned to the Off position or bus 4 has been deenergized.

Clutch control circuits

The circuits previously described are interrelated with the circuits by which the clutch actuators 67 are controlled, illustrated in Figure 7. These clutch circuits are particularly adapted for use with the power plant and clutch system disclosed in the above-mentioned Peterson et al. application. However, they may, with appropriate modifications, be applied to other clutch arrangements, and it is believed that the principles of the invention are capable of wide application to various power plants and clutch arrangements therefor.

By way of introduction, it may be repeated that the clutches disclosed in the Peterson et al. application are engaged and disengaged by hydraulic motors controlled by valves operated by actuators. The actuator for each clutch also controls a valve to supply oil to the clutch for cooling during the period of slip after engagement. The actuator has three positions of rest: a clutch disengagement position, a clutch engagement position requiring full travel of the actuator from the disengagement position, and a coolant shutoff position involving movement part way back to the disengagement position. The supply of coolant is initiated by movement to the engagement position and terminated by movement to the coolant shutoff position. The clutch is disengaged by completing the return movement of the actuator.

The purposes and functions of the clutch control of the invention may be generally summarized as follows: The system provides for clutching the propeller automatically to an operating power unit, for clutching the second power unit to the power-driven propeller for starting thereof, and for clutching the idle units in sequence to a windmilling propeller for an air start of the units. The system insures that these operations can take place only under proper conditions of setting of the power control levers and speed of the power units and propellers. It also interlocks the clutches so that one clutch may not be engaged as long as the cooling oil is being supplied to a previously engaged clutch, because a clutch should not be required to pick up the load of the propeller and an idle engine at the same time, and because the supply of coolant is not adequate for two clutches.

These functions are assumed by circuits involving connections to the feather relay RF and starter relay RS, a number of throttle switches, speed switches responsive to the rotation of each power unit and of the propeller, and a number of relays in the operating circuit of each clutch.

Referring now to Figure 7, it may be pointed out that this figure illustrates the circuits involved in the control of the clutch of the A unit. Since the control of the clutches is interlocked, this includes certain of the control instrumentalities of the B unit clutch which are enclosed in a broken line rectangle in the figure. It will be understood that the control system for the B unit is identical to that shown for the A unit and involves the same cross-connections. It has, therefore, been omitted from the drawings to avoid unnecessary duplication and complication.

We may begin the description of the system by tracing the circuits involved in engagement of the A unit clutch with that unit in operation. Since the propeller is unfeathered before starting the unit, contacts RF4 of the feather relay RF will be open. In starting the power unit, the starter relay is energized, closing its front contacts RS5, RS6, and RS7. As previously explained (Figure 5), the starter relay is held in until the unit reaches 5900 R. P. M., when it is opened by speed switch S1. While closed, contacts RS5 energize a clutch transfer relay CT through lead 185. Relay CT completes a self-holding circuit from bus 4 through lead 186, propeller speed switch S4, line 187, and front contacts CT1. Switch S4, which is in the speed switch unit 78 driven by the propeller shaft, remains closed until the propeller shaft reaches a speed somewhat below the normal range for propulsion, which may be, for example, a speed corresponding to 11,200 R. P. M. of the engine, referred to hereinafter as 11,200 equivalent R. P. M.

Contacts RS6 of the starter relay close a circuit from bus 4 through line 188 to the coil of the ground start relay CG. Relay CG sets up a self-holding circuit through throttle switch T6, line 189, and its front contact CG1. Switch T6 is closed only in the Start position and thus holds relay CG energized until the power control is advanced from the Start setting. Lines 185′ and 188′ energize transfer relay CT′ and ground start relay CG′ respectively, of the B unit clutch control (not shown), and line 187′ from speed switch S4 provides the holding circuit for CT′.

Energization of relays CT and CG sets up a circuit for engaging the clutch through speed switch S3, which closes when the power unit reaches a speed slightly below that at which S4 opens, say 11,000 R. P. M. Thus, with the unit control in Start, as the unit becomes self-sustaining and accelerates to 11,000 R. P. M., at which point it is capable of taking on the propeller load, the clutch is engaged. The circuit is from bus 4 through T6, lead 191, front contacts CT2, switch S3, front contacts CT3, line 192, front contact CG2, line 193, throttle switch T7′ of the B unit (which is closed only when the B unit control is at Stop), line 194, back contacts CC1 of the coolant control relay CC, line 195, closed contacts 197*a*, and engaging field winding 67*e*, brake release coil 67*r*, and armature 67*a* of the clutch valve actuator motor 67 to ground. Switch 197 is one of three limit switches 197, 198, and 199 operated by the armature 67*a*. Figure 7 shows these switches in their condition when the actuator is in disengaging position. Figure 11 is a timing diagram of the switches. Switch 197 is closed on contact 197*a* until the actuator substantially completes its travel to the engaged position, when this switch is thrown to contact 197*b*. Movement of the switch 197 completes a circuit from the clutch-engaging line 195 through contact 197*b*, line 201, and the coil of pilot switch by-pass relay CB. This relay shunts throttle switch T7′ at its front contacts CB1. It also completes a self-holding circuit from the engagement line 195 through line 202 and front contacts CB2. Relay CB is provided to prevent deenergization of the clutch-engaging line by moving the power control of the other unit from Stop. It makes possible, if desired, the use of a solenoid-type actuator which must be held energized to continue the flow of cooling fluid to the clutch.

As stated, the energization of engagement line **195** occurs when the unit reaches 11,000 R. P. M. The inertia load and drag of the reduction gear and propeller decelerate the unit slightly, but the dropout point of switch S3 is low enough that this switch remains closed. As the propeller load is accelerated, the clutch synchronizes after an initial period of slip and the power unit regains speed until the propeller is turning at a speed equivalent to 11,200 unit R. P. M. At this point, switch **S4** opens, breaking the holding circuit of transfer relay CT. In deenergizing, this relay completes a circuit from bus **4** through lead **203**, back contacts CT2, switch S3, back contacts CT3, line **204**, and the coil of the coolant contral relay CC to ground. In energizing, relay CC opens back contacts CC1, deenergizing the clutch-engaging line **195** and thereby by-pass relay CB. Relay CC makes a circuit from bus **4** through throttle switch T2, which is closed except in Stop, line **206**, contacts CC2, line **207**, contact **198***b* of the limit switch **198**, and disengaging field winding **67***d*, brake release coil **67***r*, and armature **67***a* of the clutch valve actuator. This circuit energizes the actuator for reverse rotation to terminate the coolant supply. This coolant shutoff circuit is maintained energized through switch **T2** until the actuator **67***a* has closed the coolant valve, unless the unit is stopped. When the actuator has rotated in the reverse direction a sufficient distance to cut off the coolant, switch **198** closes on contact **198***a*, opening the circuit to the motor **67**.

The circuit just described provides for continuing the supply of coolant until the slip period of the clutch is terminated. The engine is now in normal operation with one power unit operating the propeller, and the power control may be advanced into the governing range or into the reverse thrust range for operation of the aircraft, although normally the second power unit would be started before any such operation is undertaken.

When the coolant flow is cut off, a circuit for energizing the B unit clutch is prepared. This circuit is from bus **4** through T2, line **206**, contacts CC2, line **207**, contact **198***a*, line **213**, and the coil of the B unit second clutch engagement relay CS' to ground. This circuit, the purpose of which will be explained, is not activated until the first clutch is engaged and the coolant supply has been terminated.

Having been engaged, the clutch may be disengaged either by actuating the controls to feather the propeller or by moving the unit control to Stop. If the propeller is feathered, the feather relay RF closes a circuit from bus **2** through front contact RF4, line **208**, contact T8*b* of throttle switch T8 (closed except in Stop), clutch-disengagement line **209**, limit switch **199**, disengage field **67***d*, and armature **67***a* to ground. The actuator is thus energized to complete its return movement, reversing the clutch engagement valve and disengaging the clutch. This movement is terminated by the limit switch **199**. It will be apparent that this control prevents any attempt to drive a feathered propeller. If the unit control is moved to Stop, switch **T8** closes on contact T8*a*, energizing the disengage line **209** from bus **1** through line **210** and contact T8*a*. Thus, either unit is automatically declutched by bringing the power control of the unit back to Stop.

A circuit is also provided to disengage the clutch when the power unit is started. When the starter relay is energized, contacts RS7 energize line **212** from bus 4, thus energizing contact T8*b*. When the unit power control is moved out of Stop position, contacts T8*b* close, energizing the clutch-disengaging line **209**.

The system also provides for engaging the clutch of one power unit to start that unit when the other power unit is already in operation. The manner in which the clutch is engaged when the unit is operating in the Start and Ground Idle power position has been explained for the A unit. Assuming that the A unit has not been started but that the B unit is operating in Ground Idle condition, we may now trace the operating circuit and procedure for starting the A unit. The feather relay RF and the starter relay RS will be deenergized. Coolant control relay CC is also deenergized.

When the B unit clutch has completed the engagement cycle, the B unit clutch actuator **67'** energizes the second clutch engagement relay CS of the A unit through lead **213'**, as previously described for relay CS'. For starting the A unit from the B unit, the power control of the B unit is left in the Start position. Ground start relay GG of the A unit, which was energized by the starter relay, is held energized from switch **T6'** of the B unit, since the holding circuits of relays CG and CG' are energized in parallel through leads **188** and **188'** and holding contacts CG1 and CG1'. Also, with the B unit in Start position, switch **T7'** will be open. As long as the A unit control is in Stop, the disengage circuit of the A unit clutch will be energized from bus **1** through lead **210**, contact **T8***a*, and lead **209**. This circuit will be broken at T8*a* when the A unit power control is moved away from the Stop position. The clutch transfer relay CT, the holding circuit of which is connected in parallel with that of relay CT' through lines **187** and **187'**, will have been deenergized by opening the holding circuit at speed switch S4 when the propeller reaches 11,200 equivalent R. P. M.

The second clutch engagement relay CS sets up the circuits by which the second clutch to be engaged is freed from control by the unit speed switch S3 and the throttle switch T7' of the other unit. Contacts CS1 bridge leads **191** and **192**, thereby shunting the front contacts CT2 and CT3 of the transfer relay. Contacts CS2 connect leads **193** and **194**, thus shunting the throttle switch T7'. When the power control of the A unit is brought to Start position, switch T6 is closed, completing a circuit from bus **4** through lead **191**, contacts CS1, lead **192**, front contacts CG2, lead **193**, contacts CS2, lead **194**, contacts CC1, and lead **195** to the clutch valve actuator **67**, which functions to engage the clutch as previously described. It may be noted that switch T6 also closes an additional holding circuit for relay CG through lead **189** and contacts CG1.

As the A unit is brought up to speed by the operating B unit, fuel is admitted at 1700 R. P. M. by switch S2 (Figure 6) and the ignition, which was energized by switch T2, is cut out by the ignition relay when the temperature reaches 800 degrees F., just as when the unit is cranked by the starter. When power unit A reaches a speed of 11,000 R. P. M., speed switch S3 closes, energizing a coolant shutoff relay circuit from bus **4** through lead **203**, back contacts CT2, switch S3, back contacts CT3, lead **204**, and relay coil CC to ground. Relay CC establishes the coolant shutoff circuit, as before, from bus 4 through switch T2, lead **206**, contacts CC2, and lead **207** to the actuator **67**, and breaks the clutch-engaging circuit at CC1.

With both units in operation, the power controls may be moved into the reverse thrust range or the governing range for taxiing, and may be advanced in the governing range for takeoff and flight. If it is desired to declutch one power unit in flight and drive the propeller by the remaining unit only, this may be accomplished by returning the power control on the unit which is to be cut out to Stop to energize the clutch disengagement circuit from bus **1** through wire **210**, contact T8*a*, and wire **209**.

The clutches may not be simultaneously engaged to start both the propeller and an idle unit from a running unit. With the unit control at Stop, the clutch engaging circuit of that unit is broken at T6. If it is moved from Stop, the engaging circuit of the other unit clutch is broken at speed switch S3 of that unit, which is open below 11,000 unit R. P. M. Switch S3 of the second unit is not bypassed until the coolant has been shut off in the first clutch engaged.

The system also provides for starting the power units one after the other from a windmilling propeller in flight, a feature which is principally for use in multi-engined aircraft. Wtih the power units out of operation, all relays will be deenergized and, ordinarily, the propeller will be feathered. If feathered, the propeller is unfeathered and allowed to gain speed. The feather relay when deenergized supplies busses **3** and **4**. Assuming that the A unit is to be started, the power control lever is moved into the governing range, closing throttle switch **T10**, establishing a circuit from bus **4** through **T10**, lead **216**, back contacts **CG2** of the ground start relay, lead **193**, B unit throttle switch **T7'**, lead **194**, and contacts **CC1** of the coolant shutoff relay to the engagement line **195**, causing engagement of the clutch in the manner previously described. The ignition and fuel circuits operate as previously described, and the A unit is thus brought into operation. The coolant control relay CC is energized to shut off the coolant when the unit reaches 11,000 R. P. M. under control of speed switch **S3** in a circuit from bus **4** through back contacts **CT2** and **CT3**. When the coolant is shut off, the second clutch engagement relay CS' of the B unit is energized as previously described.

If the B unit is started first, as soon as engagement is completed and the coolant is shut off, the clutch actuator **67'** energizes the second clutch engagement relay CS, contacts **CS2** of which bypass throttle switch **T7'** so that the A unit may be started. The clutch is engaged by a circuit from bus **4** through **T10**, line **216**, back contacts **CG2**, line **193**, contacts **CS2**, line **194**, contacts **CC1**, and line **195** to the clutch actuator. The coolant is cut off when switch **S3** energizes relay CC.

This sequence of operations provides an alternative method for starting the second power unit on the ground. In this method, the power control of the first unit started is advanced into the governing range. With the first power unit in the governing range, the second power unit may be started by advancing its control lever into the governing range, the clutching control sequence corresponding to that just described. Lead **319** branching from lead **209** relates to the throttle block circuits, to be described.

Propeller control circuits

The functions of the propeller control circuits are, in general, to establish the operating conditions of the propeller, to coordinate these conditions with the operation of the power units, and vice versa, and to establish a system of control eliminating conflicts between the unit controls. The invention is not concerned with the control elements of the propeller per se except as they are components of the overall control system. It is contemplated that the system may be used with propellers of various types as, for example, propellers with either hydraulic or electrical pitch control, and with various control arrangements, as long as the characteristics of the propeller control system are compatible with the overall control system of the invention. The principles of the invention also lend themselves to control with loads other than propellers. For this reason, and in the interest of conciseness, we will not concern ourselves with the details of the propeller governor and controls, and the general nature of these controls will be discussed only sufficiently to explain their relation to the power plant control which is the subject of this invention.

In general, to carry out the purposes and advantages of the invention as embodied in an aircraft power plant, the propeller should have three phases of operation: It should be capable of being feathered, that is, brought to a blade angle of approximately 90 degrees so that relative wind provides no substantial turning moment and the drag of the stationary propeller is a minimum.

Secondly, the propeller should have a variable pitch range for normal propulsive operation in which the pitch of the propeller is regulated by a speed governor. In this type of control, with the speed set at a desired value, the pitch of the propeller will depend principally upon the power input to the propeller, the air speed, and air density, in addition, of course, to the constants of the installation which depend upon the physical form and dimensions of the propeller.

Thirdly, the propeller should have a range of control in which the speed governor is inoperative and the blade angle is controlled directly through a range of positive and negative values. This control is desirable principally for ground operation. This range also provides for setting the propeller to a blade angle in which the propeller torque requirement is a minimum. Propellers of the characteristics stated are known and are available for aircraft installations.

A propeller having the three modes of operation referred to above and capable of external control to provide these modes of operation is shown in Blanchard et al. Patent 2,307,102. The preferred propeller for use in connection with this invention is a development of the Blanchard et al. patent propeller, generally as shown in Dinsmore et al. Patent 2,669,312, which discloses a propeller, including an electrical actuator and an electronic governor, of the type preferably employed with this invention.

The control system of the invention includes an arrangement by which no conflict arises when the power control levers of the units are at different positions, either through misalignment or because one unit is operating at reduced power or is cut out. The system further includes interlocks between the power control levers which, however, will be discussed in connection with Figure 9. The coordination of the power unit control with the propeller depends in large measure upon coordination of the slots in the controlling cams **111**, **112**, and **113** (Figure 2), and also upon certain interlocks in the controls. In this connection it will be remembered that the feather relay, which must be energized to feather the propeller, also controls the energization of busses **3** and **4** from which the starting, ignition, and clutch circuits are energized, as previously described; and, in addition, the feather relay controls the energization of the fuel shutoff valve solenoid and certain of the clutch circuits by means of contacts of the relay.

The preferred embodiment of this portion of the system is illustrated in Figure 8. The pilot's feather switch **74** controls feathering and unfeathering of the propeller, energizing the propeller actuator **76** through appropriate circuits. The actuator is coupled to limit switches ***76f***, ***76g***, ***76p***, and ***76n*** which provide limits for its operation over the various portions of the propeller actuating range. These switches are closed over the ranges indicated by the bars in Figure 12. In general, apart from the feather switch, actuator **76** is controlled by potentiometers **127** and **128** in the unit controls **53** and **53'** which transmit to the actuator signals establishing blade angle or propeller speed governor setting. The actuator is controlled by these potentiometers through a discriminator and follow-up circuit to be described.

The actuator also transmits electrical speed signals to the electronic governor **81** for the propeller which receives an input from the propeller-driven alternator **84** signalling actual propeller shaft speed. The propeller governor may be of the type disclosed in U. S. Patent 2,669,312. The propeller governor actuates hydraulic valve controlling solenoids HD and HI in the propeller which act to increase and decrease the pitch, respectively, when the propeller is under governor control. The propeller control solenoids HD and HI and the valve operated thereby may be of the type described in U. S. Patent No. 2,630,136, Brandes et al. (filed June 8, 1949). Normally, the governor controls the solenoids through lines **283** and **284**. Power for operating a pump to vary the propeller pitch is taken from the propeller shaft.

For feathering and unfeathering, an electric motor **300** drives a pump, which is thus operative when the propeller is not rotating. Motor **300** is energized from the aircraft A. C. power system, represented by a three-phase generator **301**, under control of a transfer relay PJ and a centrifugal switch S5, which is closed on the motor contacts below a low propeller speed. Switch S5 also breaks the circiut to solenoids HD and HI below the operating point of the switch. A governor disconnect relay PL also is provided to cut the circuits from the governor to coils HD and HI. The manner in which relays PJ and PL are energized will be made clear.

We may start by tracing the circuits by which the propeller is unfeathered, since this is a prerequisite to bringing the power plant into operation. First, the power control lever of one power unit must be advanced into the governing range to close throttle switch T11 or T11'. Then, by pushing feather switch **74** (that is, moving it to the left in Figure 8) and holding the switch in this position, a circuit is established from the nacelle bus **151** through the feather switch, line **231**, throttle switch T11 or T11', and line **232** to energize the unfeather relay PE. The pilot switch **74** also energizes transfer relay PJ through line **233**, connecting the feathering pump motor to the power line. The motor does not unfeather the propeller, however, until control is exerted by the propeller actuator **76**.

Unfeather relay PE sets up a circuit by which the actuator **76** is energized from the unit controls **53** and **53'**. Considering the unit control **53**, for example (the two being identical), cam follower **124** (see also Figure 2) adjusts the movable contacts of two potentiometers **127** and **128**. Potentiometer **127** is connected in a series circuit from bus **2** through a fixed resistance **246** and potentiometer resistor **127** to ground. Potentiometer **128** is connected between ground and bus **2** through a variable adjusting resistance **247**. The movable contact **128*a*** of potentiometer **128** transmits a position signal for the actuator **76**. The corresponding potentiometer **128'** of the B unit control transmits a signal in the same manner. Potentiometers **127** and **127'**, which are varied concurrently with potentiometers **128** and **128'**, respectively, transmit signals to a discriminator relay PR in the coordinating control **72** which selects for transmission to the actuator motor the signal from potentiometer **128** or **128'** which is of greater magnitude, thereby preventing conflicts and facilitating the cutting out of one power unit. The discriminator relay PR, which is of a polarized type, comprises coils PR1 and PR2 connected in series between the contacts of potentiometers **127** and **127'**. As will be apparent, if the contact **127*a*** is farther advanced from ground than contact **127*a*'**, current will flow from contact **127*a*** to contact **127*a*'**, and vice versa. When current thus flows from contact **127*a***, the relay contact is closed on fixed contact PR*a* which is connected to potentiometer contact **128*a***. The circuit from contact **128*a*** to contact PR*a* passes through throttle switch T12, which is closed on contact T12*a* except in the Start position. The discriminator relay movable contact is biased to remain closed on one or the other of contacts PR*a* and PR*b*, and will not remain open. The movable contact of relay PR is connected through line **248** to a follow-up control relay PF for the actuator motor **76**.

Since the propeller has been in feather or maximum pitch, the actuator is at the maximum pitch point of its range of movement. When the power lever **49** of the A unit is advanced, an electrical signal is transmitted by contact **128*a*** through switch T12 and contacts PR*a* to line **248** which calls for a movement of the actuator toward decreased pitch. The follow-up system by which the motor **76** is controlled includes a potentiometer **249** connected between bus **2** and ground, the movable contact **249*a*** of which is mechanically coupled to the armature **76*a*** of the actuator motor. Contact **249*a*** is connected through lead **251** and the coils of the polarized follow-up relay PF to signal line **248**. The potential tapped off by contact **249*a*** is thus balanced against the potential of contact **128*a*** or **128*a*'**. When the potential at **128*a*** is higher, current flows from line **248** to line **251**, engaging the movable contact of relay PF with the increase pitch contact PF*i*. If the current flows through the relay PF in the opposite direction, the movable contact engages the decrease pitch contact PF*d*. Relay PF is biased to open position, and leaves the motor-energizing circuits open unless the relay coils are energized. These contacts energize circuits to operate the armature **76*a*** in the appropriate direction to match the signal transmitted by the unit control. When the position of the actuator corresponds to that transmitted, the potentials at **249*a*** and **128*a*** balance, and the motor circuit is opened at the movable contact of follow-up relay PF.

The motor energizing circuit to unfeather may be traced from bus **2** through line **252**, contact PF*d*, line **253**, limit switches **76*n*** and **76*p*** in series, line **254**, the contacts of unfeather relay PE, line **256**, back contacts PI1 of the increase pitch relay PI, the coil of the decrease pitch relay PD, and line **257** to ground. Relays PI and PD are referred to as increase pitch and decrease pitch relays in terms of their function in blade angle control. The front contacts of relay PD close a circuit from bus **2** through line **258**, front contacts of relay PD, line **259**, armature **76*a*** and brake release coil **76*r*** of the actuator motor, line **261**, back contacts PI2 of the increase pitch relay, and line **257** to ground. Coil **76*r***, which is energized with the armature, releases a normally engaged brake which holds the motor shaft. The field **76*s*** of the actuator motor is energized directly from bus **2** through line **258**. When current flows as just described from line **259** through the armature to line **261**, the motor is rotated in a direction to operate the actuator to decrease the pitch of the propeller. The exact position at which the motor stops will depend upon the position of the power control lever, but is immaterial. The motor will bring the propeller actuator into the governing range, and therefore the propeller out of the feathered position into the range of pitch angles in which the governing control is effective, by a mechanical signal from the actuator to valves in the propeller which control the unfeathering operation, fluid being supplied to effect the operation by the feathering pump motor **300**. The function of relay PE is to bypass contacts PH1 of the feather limit relay which are open when the propeller is completely feathered. This arrangement prevents unfeathering unless the switch **74** is closed.

The feather limit relay PH is energized from bus **2** through line **291** and limit switch **76*f*** when the actuator is at the feather limit position (Figure 12). When the actuator leaves this position, relay PH is deenergized at switch **76*f***. Back contacts PH1 shunt the contacts of unfeather relay PE and maintain the "decrease" circuit to the motor energized.

It will be further understood that, by appropriate movement of the contact **128*a***, for example, the propeller may be taken out of the governing range into the blade angle control range in which blade angles preferably from about plus twelve degrees (just below the minimum pitch in the governing range) to about minus twenty degrees may be set by the power control and actuator without reference to propeller speed. The maximum negative pitch is obtained by movement of the control lever to the two degree position in the reverse thrust slot. As the lever is moved forward in this slot, the pitch increases to plus twelve degrees just below Operational Idle. At and above Operational Idle the propeller is in the governing range in which the pitch may vary, depending upon the operation of the governor, but is always greater than twelve degrees. In the governing range, the actuator operates through speed control rather than direct blade angle control. The feather position is beyond the governing range and is obtained by action of the actuator motor, the governor again being inactive.

As previously stated, the power control lever is brought back to the Start position to start the power unit. A feature of the invention is an arrangement to insure that the exact pitch setting for minimum torque is arrived at when the unit is started. This control is effected by the throttle switches T12 and T12′, which are closed in he Start position of the power control on contacts T12*b* and T12*b*′, respectively. As previously pointed out, switches T12, unlike the other throttle switches which respond only to the angular position of the shaft **108** (Figure 2), are actuated only when the control lever is in slot **101** and remain closed on contact T12*a* in the reverse thrust range. Thus, when the A unit control is in Start, contact PR*a* of the discriminator relay is connected through contact T12*b* and line **263** with an adjustable contact point of voltage dividing resistor **264**. Resistor **264** is connected in a circuit from bus **2** through fixed resistor **266**, tapped resistor **264**, and fixed resistor **267**. By adjusting the variable contact of the voltage divider **264**, it may be set up to transmit a potential signal to the actuator which will bring the propeller exactly to the minimum torque posion. The B unit control **53′** is identical in this respect with the A unit control, so that movement of either unit to the Start position with the other unit in Stop will energize the discriminator relay PR and shift the throttle switch T12 to transmit an exact minimum torque signal to the follow-up relay PF.

Actuator limit switch **76*p*** opens at the actuator position corresponding to minimum governed speed, just before the actuator enters the position corresponding to maximum positive pitch in blade angle control. However, throttle switches T13 and T13′ are closed in the blade angle control range (below Operational Idle and above Stop), and bypass switch **76*p***. Thus, when the control is shifted to Start, and the signal calling for decrease of blade angle to zero closes contacts PF*d*, the actuator motor is energized as previously described except that the circuit is maintained through switch T13 after limit switch **76*p*** opens. The actuator motor thus drives until the follow-up signal from potentiometer **249** opens the circuit at contact PF*d* with the propeller in starting condition.

A quadrant lock prevents the actuator from leaving the governing range at either end unless the lock is released by energizing a solenoid QL. When the power control levers are below Operational Idle and the propeller is unfeathered, a circuit is completed from bus **2** through line **281**, throttle switches T14 and T15′ or T14′ and T15, line **282**, and back contacts PH3 of the feather limit relay to energize a quadrant lock release solenoid QL. Switches T14 are closed in the blade angle control range and switches T15 are closed in this range and Stop. Thus, this circuit will be completed at the throttle switches if both power controls are in the blade angle control range, or if either is in this range and the other is at Stop.

When the quadrant lock is released, the governor circuit to the propeller through lines **283** and **284** is also broken at relay PL, which is energized from bus **2** through throttle switches T14 and T15 and line **282**.

Thus, when the power control is moved from the governing range into either the reverse thrust or the starting range, the quadrant lock is released and the governor circuit to coils HD and HI is opened.

When the propeller has been set at minimum torque blade angle, both power units may be brought into operation, as previously described. Assuming that the units have been started and one or both power controls is moved to Operational Idle, which is the lowest point of the governing range, or above, a signal is transmitted to the actuator **76** to drive into the governing range. The signal calling for rotation in the increase pitch direction operates the relay PF to complete a circuit from bus **2** through line **252**, contact PF*i*, line **271**, contact **76*g***, line **272**, contacts PH2 of the feather limit relay, line **273**, coil PI of the increase pitch relay, and line **257** to ground. Relay PI completes a circuit from bus **2** through line **258**, front contacts PI2, line **261**, coil **76*r***, armature **76*a***, line **259**, back contacts of relay PD, and line **257** to ground. This supplies current through the armature in the reverse direct to that previously described, driving the actuator in the increase pitch and increase speed direction. The armature **76*a*** stops when the follow-up relay is balanced.

When either power control is moved into the governing range, the governor disconnect relay PL and quadrant lock release solenoid QL are deenergized by throttle switches T14 and T15 or T14′ and T15′.

As the actuator enters the governing range, it ceases to set propeller blade angle and operates by way of the governor **81** to which it transmits a propeller speed signal. If the power control is advanced farther to call for higher power output and higher propeller speed, the actuator motor **76** will follow the signal up to the maximum propeller speed setting, at which point limit switch **76*g*** opens.

The operation of the propeller governing system may now be outlined, so far as it relates to the present invention. Although many arrangements by which the rotational position of the actuator motor may control a propeller governor, and many ways by which propeller speed may be transmitted to the governor, are available, a suitable one is illustrated diagrammatically. The actuator motor **76**, through a mechanical connection schematically indicated at **275**, moves the contact point of the potentiometer **276** energized from the electronic governor **81**, supplied by bus **155**. The potentiometer tap takes off a fraction of the potential across the potentiometer and feeds this potential into the electronic governor through line **277**. The ratio of the potential on line **277** to that across the resistor **276** constitutes a desired speed signal input to the governor **81**. The alternator **84**, which is driven by the propeller shaft, feeds an actual speed signal into the governor. By mechanisms in the governor, which are immaterial to the present invention, the desired speed and actual speed signals are compared and any discrepancy affects the output signal of the governor, which is transmitted through lines **283** and **284**, the contacts of relay PJ, and switch S5 to the solenoid coils HI and HD in the propeller. These coils actuate a hydraulic valve which, by mechanism immaterial to the invention, controls the transmission of fluid from a pump in the propeller, which is preferably driven by the propeller shaft, to hydraulic motors which vary the pitch of the propeller. If the propeller speed exceeds that signalled for, the coil HI acts to increase the propeller pitch and thus its resistance to rotation until the speed is reduced to the desired value. If the speed is too low, coil HD decreases the pitch so that the speed increases. As will be apparent, the coils HD and HI could be field coils of an electric motor to adjust the propeller pitch, or could be relay coils controlling an electrical system. They may be energized alternately during a cycle, with the resultant effect depending upon the relative time of energization of the two solenoids during the cycle. The structure of the propeller and the means by which the governor regulates the propeller are immaterial to the invention except that the characteristics of the propeller and its governor must accommodate themselves to the control system of the invention. The speed selected for the propeller is coordinated with the power control of the units by cams **111** and **113** in the unit controls, as previously described in connection with Figure 13.

We may now consider the circuits involved in blade angle control of the propeller in the reverse thrust range employed for ground operations. With the governor disabled and the quadrant block released by movement of the power control levers into the reverse thrust slot **104**, the potentiometer contact **128*a*** or **128*a*′** transmits a signal to the actuator to drive into the blade angle control range and set propeller pitch, which is accomplished in the same manner as previously described. The actual blade angle selected depends upon the position of the power control and varies over a range of from about twelve degrees positive to about twenty degrees negative, preferably. If the power control lever is pulled to the extreme two-degree position in the reverse thrust range for maximum reverse pitch, the propeller actuator continues to run until the decrease pitch circuit is opened at maximum negative pitch by the limit switch **76***n* coupled to the propeller actuator motor.

By moving either power control lever into the governing range, the governor disconnect relay PL and throttle block solenoid QL are deenergized at switches T14 and T15, an increase signal is transmitted to the actuator motor through contacts PF*i* and **76***g* to return it to the governing range, and the actuator resumes control of the electronic governor. When the actuator returns to the governing range, the quadrant block drops into the sector and again limits the travel of the actuator to the governing range.

If the engine is to be cut out of operation, the propeller is feathered. Feathering is accomplished by pulling feather switch **74** to the right as illustrated in Figure 8. This completes a circuit from the movable contact of switch **74** through the normally closed contact PQ1 and the heating coil of thermal delay relay PQ to ground. Relay PQ is of a well-known type in which the contact arm PQ1 is bimetallic and the contact remains closed until this bi-metal element is heated by the resistance PQ, the opening of the contact thus occurring after a predetermined time interval. The feather control relay PM is energized from the nacelle bus **151** through contact **74**, contact PQ1, back contacts of relay PB, and relay coil PM to ground. When relay PM is energized, it establishes a self-holding circuit from the nacelle bus through line **286**, front contacts PM1, line **287**, line **288**, and contacts of relays PQ and PB, thus holding relay PM energized until the thermal relay opens. The circuit through PM1 also maintains heating current in heater PQ. Relay PM also closes a circuit from line **286** through contacts PM2 and line **233** to energize a transfer relay PJ, which opens the governor circuit and prepares a power circuit to the feathering pump motor **300**. Relay PM additionally closes a circuit from line **286**, through contacts PM3 and line **289** to energize the feather relay RF.

The feather relay, in addition to the previously described contacts affecting other phases of the system, closes contacts RF5 completing a circuit from bus **2** through line **281**, contacts RF5 and line **282** to the governor disconnect relay PL, which opens the lines **283** and **284** leading from the governor to the propeller valve solenoids HD and HI. The quadrant block release solenoid QL is energized from line **282** through back contacts PH3 of the feather limit relay. Relay PM also energizes relay PC from the nacelle bus through line **286**, contacts PM1, line **287**, and relay coil PC to ground. The relay, when energized, completes a circuit from line **287** through the PC relay contacts, line **272**, back contacts PH2 of the feather limit relay, increase pitch coil PI, and line **257** to ground. Coil PI energizes the actuator motor, as previously described, to run in the increase pitch direction. It will be noted that the feather circuit is entirely independent of the unit controls, and since the quadrant block is released, the motor **76** continues to run until the actuator is brought to its maximum positive or feather position, at which point the feather limit switch **76***f* closes, completing a circuit from bus **2** through line **291**, limit switch **76***f*, and the coil of the feather limit relay PH. The feather limit relay breaks the increase pitch circuit at contacts PH2, thus stopping the actuator motor with the propeller in feathered position. It establishes a circuit from bus **2** through line **291** and front contacts PH3 to hold governor disconnect relay PL energized. It also establishes a holding circuit for the feather relay RF from bus **2** through line **291**, contacts PH4, and line **292**. It also opens contacts PH1, thus disabling the normal decrease pitch circuit to the actuator motor.

The actuator transmits a mechanical feathering signal to the propeller. With the preferred propeller, which is of a hydraulic type, the feathering is actually accomplished by a pump (not shown) in the propeller, driven by rotation of the propeller, which supplies fluid to the motors which increase the pitch of the feather position. Propeller rotation may cease before feathering has been completed. If so, speed switch S5 completes a circuit from the power supply **301**, through the contacts of the transfer relay PJ and speed switch S5 to the feathering pump motor **300**, which continues the operation. After time for full feathering, time delay contacts PQ1 open, deenergizing relay PM, relay PJ, and motor **300**. As will be apparent, this circuit relates to the particular type of propeller which is preferred. With other propellers, either hydraulic or electrically-actuated propellers, different feathering circuits of the propeller per se would be substituted. With the propeller feathered, the circuits are in condition for unfeathering, which may be accomplished as previously described.

If, after feathering has been initiated, the pilot changes his mind and wishes to reverse the feathering operation, the feather button **74** may be moved to the left. This actuates the unfeathering circuit as previously described and, in addition, energizes relay PB through contact **74** and line **231**. Relay PB breaks the holding circuit for relay PM which thus drops out, disabling the feather circuits. If both power control levers are returned to Stop, bus **2** is deenergized by relay RP (Figure 4) and all the propeller control circuits are deenergized, returning the relays to their deenergized condition.

An arc-suppression circuit is provided for the actuator motor **76** to prevent sparking at the contacts of relays PD and PI. This circuit comprises rectifiers **311** connected between the motor energizing lines **259** and **261** and ground, the rectifiers permitting flow of current from ground to the lines. It also comprises capacitors **312** connected in series between lines **259** and **261**, and a resistor **313** connected between the capacitors. The other end of resistor **313** is connected to lines **259** and **261** through rectifiers **314** which are directed to permit flow from the lines to the resistor. This circuit acts to dissipate surges due to breaking the circuits to the motor armature and brake release coil and thus protect the relay contacts from destructive arcing.

Throttle circuits

The operations of the parts of the system previously described are supervised by the throttle circuits shown in Figure 9. These circuits coordinate the operation of the two power control levers **49**. The circuits prevent the pilot from moving both control levers out of the governing range inadvertently and prevent moving one lever into the reverse thrust range unless the other lever is moved into this range at the same time, or unless the other power unit is cut out. They prevent cutting out one unit unless the other is operating on a reduced power setting. These circuits also actuate the solenoids by which the cams in the unit control are shifted when the control is moved into the reverse thrust range, and control the energization of bus **4**.

The throttle circuits for the two units are identical but, since the circuits are relatively simple and involve cross-connections between the controls of the two units, it is deemed advisable to show the throttle circuits of both power units in Figure 9. In general, the circuits pertaining to the A unit are shown at the left of the figure and those pertaining to the B unit at the right, distinguished by primes applied to the reference numerals. The starter relay RS and feather relay RF are common to both power units.

The circuits shown in the lower part of Figure 9 relate to the actuation of the clutches and have previously been described. These are the circuits by which the clutch disengagement lines **209** and **209'** are energized under control of the feather relay RF, starter relay RS, and throttle switches T8 of both power units. These clutch disengagement circuits also control the operation of the throttle blocks which, as previously mentioned, comprise solenoids **142** (see also Figures 2 and 2*a*) in each unit control. The solenoids, when energized, actuate throttle blocks in the control unit which prevent movement of the shafts **108** below 29 degrees, which is just below the Operational Idle position. Connected to the A unit clutch disengagement line **209** is a line **319** which energizes a declutch relay RD' of the B unit control. Similarly, a line **319'** connected to the B unit clutch disengagement line energizes declutch relay RD of the A unit control. These relays, when energized, disable the interlock circuits which normally prevent movement of only one of the power control levers into the reverse thrust range. The block for one unit is disabled when the other power unit is declutched, as will be further explained.

The circuits include the reverse thrust relays RR of each power unit which are energized from the nacelle bus by the reverse thrust switch **131** or **131'** (Figure 3) which is closed whenever the power control lever is shifted through gate **103** into the reverse thrust slot. In normal operation, relays RR, the feather relay RF, and the starter relay RS are deenergized.

Assuming first that both power units are in normal operation, the pilot may cut out either unit without any interference from the throttle by reducing power on the other unit and moving the control of the unit to be cut out to Stop, but may not cut out the second power unit inadvertently. With the starter relay deenergized, a circuit is completed from bus **3** through back contacts RS8, line **320**, to back contacts RR2 and RR2' of the reverse thrust relays, in parallel, and line **321** to branch lines **322** and **322'** leading to throttle switches T9, T16, T9', and T16'. These switches are thus energized unless the starter relay or both reverse thrust relays are energized. Switches T16 and T9 are in the throttle block circuit of the A unit, and switches T16' and T9' are in the throttle block circuit of the B unit. Switches T9 are closed when the unit is operating under substantial power rating in the governing range, opening at about the 35 degree position (slightly above Operational Idle). Switches **T16** are open in the governing range but are closed from immediately below Operational Idle to the Stop position. If either switch T16 or T9 is closed when line **322** is energized, as just described, the circuit is completed from line **322** through back contacts RR3 of the reverse thrust relay, line **323**, contacts RR4' of the B unit reverse thrust relay, and line **324'** to the B unit throttle block solenoid **142'**. With the solenoid energized, the B unit throttle cannot be moved out of the governing range.

Similarly, if either switch T16' or T9' is closed, the A unit throttle block solenoid **142** is energized.

As a result, neither power control may be moved out of the governing range unless the other is moved substantially to Operational Idle so that switch T9 or T9' is opened. If the B unit control is moved to Operational Idle, switch T9' is opened and switch T16' remains open. The throttle block solenoid **142** is thus deenergized, and the A unit power control may be moved to Stop which, as previously described, cuts out the A power unit and declutches it. As soon as the A unit power control is moved below Operational Idle it closes switch T16, maintaining the throttle block solenoid **142'** of the B unit energized so that this unit cannot be moved out of the governing range except by feathering the propeller. If the propeller is feathered, bus **3** is deenergized by the feather relay RF (Fig. 4), deenergizing the throttle block circuits and permitting the return of both controls to the Off position.

If an attempt is made to cut out both power units simultaneously without feathering the propeller, both throttle blocks are energized by switches T16 and T16' as the power levers reach a point immediately below Operational Idle, so that the levers are stopped at the 29 degree position.

If one unit, say the B unit, is in the normal control range and the A unit control is moved through gate **103** into the reverse thrust slot, switch **131** is closed, energizing the A unit reverse thrust relay RR from the nacelle bus through line **326**. Relay RR completes a circuit from bus **2** through line **327**, front contacts RR5, line **328**, and back contacts **121***a* to energize the shift solenoid **121**, which shifts the control cams **111** and **112** (Figure 2) to activate the reverse thrust cam slots. When the shift solenoid is energized, it breaks contacts **121***a*, but remains energized through a resistor **329** which reduces the solenoid current as it remains actuated. The reverse thrust relay also completes a circuit from bus **3** through contacts RS8, line **320**, back contacts RR2' of the other reverse thrust relay, lines **321** and **322**, throttle switch T16 (closed below Operational Idle), front contacts RR3, back contacts of the declutch relay RD, and line **331** to the A unit throttle block solenoid **142**, thus preventing movement of the throttle lever into the reverse thrust range. However, if the B unit has been cut out, this throttle block circuit is opened by relay RD so that reverse thrust operation of the one operating power unit is permitted. Relay RD is energized from bus **1** through line **210'**, contact T8*a'* of B unit throttle switch T8' (closed at Stop), and line **319'**.

If both power control levers are shifted through the gates **103**, both reverse thrust relays RR are energized. In this case, however, the throttle block circuits are not made, since the circuit is broken at both the back contacts RR2 and RR2'. Thus, the power units may be operated simultaneously in the reverse thrust range, if desired, by moving both power control levers through the gates **103** at the same time. If one unit is declutched, the other may be shifted freely into the reverse thrust range. If the B unit is declutched, for example, the declutch relay RD of the A unit is energized, opening the throttle block circuit through line **331**. The throttle block circuit through line **324** is opened by the reverse thrust relay RR when the reverse thrust switch **131** closes.

The starter, the ignition, and the clutch-engaging circuits may not be energized if either power control lever is in the reverse thrust range, as bus **4** is deenergized at contacts RR1 (Figure 4) if either reverse thrust relay RR is energized. This prevents starting in this range in which the scheduling is incorrect for starting, as illustrated in Figure 13. In starting the engine, a power control lever is moved into the governing range to energize the unfeathering circuit. To return the lever to Start, the start button **73** is closed. With one unit control at Stop, this energizes the starter relay RS, breaking the throttle block circuit at RS8 and permitting return of the control lever to slot **101** for starting.

Summary of operation of the system

The principles of the control system may be made clearer by a summary of the operation of the system. In the interest of brevity, circuits involved in the various operations will not be traced, as these have been described.

Starting.—Assuming all circuits are dead and the units at rest with the power control levers at Stop and the propeller feathered, the starting sequence on the ground is as follows:

(1) Close power switch **153**, energizing the nacelle bus **151**, bus **1**, the clutch actuator "disengage" lines, the thermocouple amplifiers, and the propeller governor, as well as any auxiliary apparatus supplied from the nacelle bus.

(2) Operate switches **66** to open the intake shutters.

(3) Advance one power control to the governing range. This energizes bus **2**, supplying the coordinating control circuits by which the propeller actuator is energized, energizes the feather limit relay, the feather relay, and the propeller governor disconnect relay. The feather relay closes the solenoid fuel shutoff valve. The power control lever actuates the cams in the unit control, but without

any affect, as the unit is not started. The clutch disengage line is held energized through RF4 and T8. The unfeather circuit interlock switch T11 is closed.

(4) Operate the feather switch **74** to unfeather the propeller. The actuator runs into the governing range, deenergizing the feather limit, feather, and governor disconnect relays. Busses **3** and **4** are energized by the feather relay. Bus **3** energizes the starter air valve closing circuit and the power lever interlock or throttle block circuits. Bus **4**, through T2, energizes the ignition and the fuel shutoff solenoid of the unit, the control lever of which has been advanced. Energization of bus **4** is necessary to operation of the starter and engagement of the clutches.

(5) Close the start button **73** to release the power lever block and energize the appropriate starter selector solenoid **161** or **162**.

(6) Return the power control to Start. This transmits appropriate signals to the fuel control for starting, releases the quadrant lock, energizes the propeller actuator to set zero propeller pitch, and completes the circuit to the starter actuator to energize the starter.

The unit starts automatically; fuel is admitted at 1700 R. P. M., the starter is cut out at 5900 R. P. M., and the ignition is cut out when temperature reaches 800 degrees F.

The clutch engages automatically at 11,000 R. P. M., and the clutch coolant is shut off automatically when the load is synchronized.

The propeller is maintained at zero pitch, and overspeeding of the unti is prevented by the governor in the fuel control, set to about 11,500 R. P. M.

It may be noted that the second unit power control must be left at Stop during the starting procedure, as otherwise the starter relay would be deenergized at T3 and T3', and the clutch engagement line would be broken at T7 or T7'.

(7) Move the power control of the second unit to Start, automatically engaging the second unit clutch (after coolant in the first clutch is shut off) to accelerate the second unit. The fuel supply and ignition of the second unit operate automatically. Both units are now operating in Ground Idle condition under speed governor control with the propeller at zero pitch.

Normal control.—The aircraft may be maneuvered on the ground in either the normal governing range or the reverse thrust range. Reverse propeller pitch is obtainable only in the latter. We may consider governing control first:

(1) Move both power controls to Operational Idle. The fuel control setting is advanced for additional power. The propeller actuator drives into the governing range and transmits a minimum speed signal to the propeller governor. The governor disconnect relay and quadrant lock solenoid are deenergized. The governor in the fuel control is set to prevent overspeeding and the engine operates at about 15% rated shaft horsepower.

(2) Advance both power controls, if desired. As these levers are advanced, both propeller governor speed setting and the power setting of the fuel control are advanced, to provide increased power and thrust progressively as the levers are advanced, and thus provide power for taxiing.

(3) For takeoff, both control levers are moved to the maximum or Takeoff position, providing (by cams **111**—**113**) maximum power and speed settings for takeoff.

(4) After takeoff, the control levers should be returned to the Normal Rated position at which the fuel control delivers a slightly reduced quantity of fuel for a more conservative operational rating.

(5) For reduced power for cruising, either or both power control levers may be moved farther back.

(6) By returning the one power control to Operational Idle and the other to Stop, one unit is stopped and declutched.

(7) The power control of the operating unit may then be advanced for economical cruising on one power unit.

(8) If additional power is required, the second unit is automatically started and clutched in by moving its power control lever into the governing range.

(9) The engine may be cut out completely by actuating the feather switch to feather the propeller.

(10) Either unit may be restarted in flight by moving the power control into the governing range and unfeathering the propeller.

(11) The other unit may then be started by moving its power control into the governing range.

Reverse thrust range.—Reverse thrust control may be employed at will through a graduated range from low positive thrust through zero thrust to a considerable negative thrust. The engine (one or both units) must first be in operation in the governing range.

(1) Move both power control levers simultaneously into the reverse thrust slot (or the lever of the operating unit if the other is at Stop). This inactivates the propeller governor and sets the propeller at about 10 degrees blade angle. The power units are controlled by the speed governors in the fuel controls. Low positive propeller thrust is obtained.

(2) For decreased thrust, move the levers back, zero propeller thrust being obtainable.

(3) For reverse thrust, move the levers farther back toward or to the two degree position, increasing engine power and speed and negative propeller pitch, these changes being graduated according to position of the power controls.

(4) To return to normal operation, it is sufficient to return one power control lever to the governing range, although both are normally moved together if both units are in operation. In any event, the discriminator circuits prevent conflicting signals to the propeller, and if one unit control is left in the reverse thrust range no harm is done.

Conclusion

It is believed that the principles of the invention, its advantages, and the manner in which the objects thereof are realized, will be apparent to those skilled in the art from the foregoing description. It will be apparent, also, that the control system of the invention provides a remarkably complete and well integrated system providing for the greatest simplicity of control by the pilot to handle an inherently complex situation.

Obviously, certain features of the invention may be omitted while retaining the advantages of other features; and modifications may be made to suit the system to power plants and driven devices of various sorts. Certain features of the system are provided particularly for the dual power unit arrangement. Many of the advantages of the system could be retained in a control system for the combination of a single power unit and a driven device.

No previous mention has been made of installations in which a plurality of power plants, such as that described herein, are installed in a single aircraft. It should be noted, however, that the system is particularly desirable for such installations, wherein each propulsion unit may be controlled in the most simple manner, thereby rendering the control of two or four such propulsion units, for example, easy to accomplish. The control system is readily adaptable to various types of propellers and is such that synchronization of two or more power units may be readily accomplished.

It may also be noted that reference to ground operation of the aircraft is intended to cover similar operations on water, as in the case of flying boats. The provision for reverse thrust is particularly desirable for maneuvering an aircaft on water.

Many modifications of the described apparatus within the scope of the invention will occur to those skilled in the art, and the invention is not to be considered as limited by the description herein of the presently preferred embodiment thereof.

We claim:

1. An aircraft propulsion power plant comprising, in combination, two engines, a propeller coupled thereto, a power control for each engine movable through a power range and to an engine starting position, means normally coupling each power control to the corresponding engine and means coupling both power controls to the propeller for control of the operation of the engine and propeller by movement of the power controls through the power range, control means for setting the propeller to a low blade angle condition suitable for initiation of rotation thereof, and means actuated by movement of either power control into the starting position to actuate the said control means.

2. A system comprising, in combination, two independently operable primary control devices, a respective control signal transmitting means traversed from a datum point through a control range by each primary control device, an output signal transmitting means, discriminator means for coupling the output signal transmitting means to either of the control signal transmitting means, discriminator control means responsive to the primary control devices for actuating the discriminator means to couple the output signal transmitting means to the power signal transmitting means farthest removed from its datum point, a fixed signal transmitting means associated with each primary control device, and means actuated by the primary control device for disabling the corresponding control signal transmitting means and concurrently connecting the fixed signal transmitting means to the output signal transmitting means to transmit the control signal.

3. A system comprising, in combination, two independently operable primary control devices, a control signal transmitting means coupled to each primary control device and traversed from a datum point through a control range by the corresponding primary control device, a discriminator signal transmitting means traversed by each primary control device concurrently with the control signal transmitting means, an output signal transmitting means, discriminator means for coupling the output signal transmitting means to either of the control signal transmitting means, and discriminator control means actuated by the discriminator signal transmitting means for actuating the discriminator means to couple the output signal means to the power signal transmitting means farthest removed from its datum point.

4. A system comprising, in combination, two independently operable primary control devices, a control signal transmitting potentiometer means coupled to each primary control device and traversed from a datum point through a control range by the corresponding primary control device, a discriminator signal transmitting potentiometer means traversed by each primary control device concurrently with the control signal transmitting means, an output signal circuit, discriminator relay means for coupling the output signal circuit to either of the control signal transmitting means, and discriminator control means actuated by the discriminator signal transmitting means for actuating the discriminator relay means to couple the output signal circuit to the power signal transmitting means farthest removed from its datum point.

5. A power control system for a plurality of power units driving a common feathering propeller comprising, in combination, a power control for each unit movable from a stop position into a first operating range and a second operating range, a first bus, a second bus, means responsive to movement of any power control from stop position into an operating range to energize the second bus from the first bus, a third bus, means responsive to an unfeathered condition of the propeller for energizing the third bus from the second bus, a fourth bus, means for connecting the fourth bus to the third bus, means responsive to movement of any power control into the second operating range for operating the connecting means to deenergize the fourth bus, a unit bus for each unit, means responsive to movement of the power control of each unit from stop position into an operating range to energize the unit bus of that unit from the fourth bus, and means for starting each power unit energized from the unit bus of that unit.

6. An aircraft propulsion power plant comprising, in combination, two power units, a propeller, a clutch between each power unit and the propeller, a power control for each unit movable through a normal range and an abnormal range, means to block movement of either power control into the abnormal range, means actuated by each power control in the stop position to release the blocking means of the other unit power control, and means actuated by concurrent entry of both power controls into the abnormal range to release both blocking means.

7. An aircraft propulsion power plant comprising, in combination, two power units, a propeller driven thereby, a power control for each unit movable through a normal operating range and through an abnormal range in which stop and start signals are transmitted to the unit, means actuated by movement of either power control beyond a predetermined point in the normal range to block movement of the other power control into the abnormal range, means actuated by stopping either unit to release the blocking means of the other unit power control, means actuated by concurrent entry of both power controls into the abnormal range to release both blocking means, manual means for disabling both blocking means, and means responsive to operation of either power unit to disable the said manual means.

8. An aircraft propulsion power plant comprising, in combination, two power units, a propeller driven thereby, a power control for each unit including signal transmitting means connected to that unit and to the propeller and movable through a normal range in which a varying power signal is transmitted to the unit and a speed-governing signal is transmitted to the propeller, a first abnormal range in which varying power and speed signals are transmitted to the unit and a varying blade angle signal is transmitted to the propeller, and a second abnormal range in which stop and start signals are transmitted to the unit and a substantially flat blade angle signal is transmitted to the propeller, means actuated by movement of either power control beyond a predetermined point in the normal range to block movement of the other power control into the second abnormal range, means to block movement of either power control into the first abnormal range, means actuated by each power control in the stop position of the second abnormal range to release the blocking means of the other power control, means actuated by concurrent entry of both power controls into the first abnormal range to release both blocking means, manual means for disabling both blocking means, and means responsive to operation of either power unit to disable the said manual means.

9. An aircraft propulsion power plant comprising, in combination, two power units, a propeller, a clutch between each power unit and the propeller, a power control for each unit including signal transmitting means connected to that unit and to the propeller and movable through a normal range in which a varying power signal is transmitted to the unit and a speed-governing signal is transmitted to the propeller, a first abnormal range in which varying power and speed signals are transmitted to the unit and a varying blade angle signal is transmitted to the propeller, and a second abnormal range in which stop and start signals are transmitted to the unit and a substantially flat blade angle signal is transmitted to the propeller, means actuated by movement of either power control beyond a predetermined point in the normal range

to block movement of the other power control into the second abnormal range, means to block movement of either power control into the first abnormal range, means actuated in response to declutching either power unit for releasing the blocking means of the other unit power control, mean actuated by concurrent entry of both power controls into the first abnormal range to release both blocking means, manual means for disabling both blocking means, and means responsive to operation of either power unit to disable the said manual means.

10. An aircraft propulsion power plant comprising, in combination, two power units, an output shaft driven thereby, a clutch between each unit and the shaft, a power control for each unit movable from a stop position in which the unit is cut out through a low power position into a higher power range, means responsive to movement of either power control to stop position to disengage the clutch of the corresponding unit, and interlocking means coupling the power controls operative to block movement of either power control to the stop position when the other power control is not in the low power position.

11. An aircraft propulsion power plant comprising, in combination, two power units, a propeller driven thereby, a clutch between each unit and the propeller, a power control for each unit movable from a stop position in which the unit is cut out through a low power position into a high power range, means responsive to movement of either power control to stop position to disengage the clutch of the corresponding unit, interlocking means coupling the power controls operative to block movement of either power control to the stop position when the other power control is not in the low power position, means for feathering the propeller, and means actuated by the said feathering means for disabling the interlocking means.

12. An aircraft propulsion power plant comprising, in combination, two power units, a propeller driven thereby, a clutch between each unit and the propeller, a power control for each unit movable from a stop position in which the unit is cut out to a start position and through a low power position into a high power range, means responsive to movement of either power control to stop position to disengage the clutch of the corresponding unit, means responsive to movement of either power control to start position to start the corresponding unit and engage the clutch thereof, and interlocking means coupling the power controls operative to block movement of either power control to the stop position when the other power control is not in the low power position.

13. A power plant comprising, in combination, a power unit, a power output shaft, a clutch including driving and driven clutch elements coupling the unit to the output shaft, the clutch including cooling means, a control for the unit movable from a stop position to a start position, a clutch actuator movable from a first position in which the clutch is disengaged thereby to a second position in which the clutch is engaged and the cooling means is activated thereby and then to a third position in which the clutch is engaged and the cooling means is deactivated thereby, a power unit speed-responsive device, means responsive to movement of the control to start position and actuation of the unit speed-responsive device to operate the actuator from the first position to the second position, and means responsive to substantial synchronization of the clutch elements to operate the actuator from the second to the third position.

14. A power plant comprising, in combination, a power unit, a power output shaft, a clutch including driving and driven clutch element coupling the unit to the output shaft, the clutch including cooling means, a control for the unit movable from a stop position to a start position, a clutch actuator movable from a first position in which the clutch is disengaged thereby to a second position in which the clutch is engaged and the cooling means is activated thereby, then to a third position in which the clutch is engaged and the cooling means is deactivated thereby, and then back to the first position, a power unit speed-responsive devices, means responsive to movement of the control to start position and actuation of the unit speed-responsive device to operate the actuator from the first position to the second position, means responsive to substantial synchronization of the clutch elements to operate the actuator from the second to the third position, and means responsive to movement of the control to stop position to operate the actuator from the third to the first position.

15. A power plant comprising, in combination, a power unit, a power output shaft, a clutch coupling the unit to the output shaft, the clutch including cooling means, a control for the unit movable from a stop position to a start position, a clutch actuator movable from a first position in which the clutch is disengaged thereby to a second position in which the clutch is engaged and the cooling means is activated thereby, and then to a third position in which the clutch is engaged and the cooling means is deactivated thereby, a power unit speed-responsive device, an output shaft speed-responsive device, means responsive to movement of the control to start position and actuation of the unit speed-responsive device to operate the actuator from the first position to the second position, and means responsive to actuation of the shaft speed-responsive device to operate the actuator from the second to the third position.

16. A power plant comprising, in combination, a power unit, a power output shaft, a clutch coupling the unit to the output shaft, the clutch including cooling means, a control for the unit movable from a stop position to a start position, a clutch actuator movable from a first position in which the clutch is disengaged thereby to a second position in which the clutch is engaged and the cooling means is activated thereby, then to a third position in which the clutch is engaged and the cooling means is deactivated thereby, and then back to the first position, a power unit speed-responsive device, an output shaft speed-responsive device, means responsive to movement of the control to start position and actuation of the unit speed-responsive device to operate the actuator from the first position to the second position, means responsive to actuation of the shaft speed-responsive device to operate the actuator from the second to the third position, and means responsive to movement of the control to stop position to operate the actuator from the third to the first position.

17. A power plant comprising, in combination, first and second power units, a power output shaft, a clutch including driving and driven clutch elements coupling each unit to the output shaft, means for cooling each clutch, a control for each unit movable from a stop position to a start position, a power unit speed-responsive device for each unit, means responsive to movement of the first unit control to start position and actuation of the first unit speed-responsive device to engage the first unit clutch and activate the cooling means therefor, means responsive to substantial synchronism of the first unit clutch elements to deactivate the first unit clutch cooling means, means responsive to substantial synchronism of the first unit clutch elements and movement of the second unit control to start position to engage the second unit clutch and activate the cooling means therefor, and means responsive to actuation of the second unit speed-responsive device to deactivate the second unit clutch cooling means.

18. A power plant comprising, in combination, first and second gas turbine power units, a propeller, a clutch coupling each unit to the propeller, means for cooling each clutch, a control for each unit movable from a stop position to a start position, a power unit speed-responsive device for each unit, a propeller speed-responsive device, means responsive to movement of the first unit control to start position and actuation of the first

unit speed-responsive device to engage th first unit clutch and activate the cooling means therefor, means responsive to actuation of the propeller speed-responsive device to deactivate the first unit clutch cooling means, means responsive to actuation of the propeller speed-responsive device and movement of the second unit control to start position to engage the second unit clutch and activate the cooling means therefor, and means responsive to actuation of the second unit speed-responsive device to deactivate the second unit clutch cooling means.

19. A power plant comprising, in combination, first and second power units, a power output shaft, a clutch coupling each unit to the output shaft, means for cooling each clutch, a power control for each unit movable from a stop position to a start position, a power unit speed-responsive device for each unit, an output shaft speed-responsive device, means responsive to movement of the first unit power control to start position and actuation of the first unit speed-responsive device to engage the first unit clutch and activate the cooling means therefor, means responsive to actuation of the shaft speed-responsive device to deactivate the first unit clutch cooling means, means responsive to actuation of the shaft speed-responsive device and movement of the second power control to start position to engage the second unit clutch and activate the cooling means therefor, means responsive to actuation of the second unit speed-responsive device to deactivate the second unit clutch cooling means, and means responsive to movement of either power control to stop position to disengage the corresponding clutch.

20. A power plant comprising, in combination, first and second power units, a power output shaft, a clutch coupling each unit to the output shaft, a control for each unit movable from a stop position to a start position, a clutch actuator for each clutch movable from a first position in which the clutch is disengaged to a second position in which the clutch is engaged, a power unit speed-responsive device for each unit, an output shaft speed-responsive device, means responsive to movement of the first control to start position and actuation of the first unit speed-responsive device to operate the first actuator from the first position to the second position, means responsive to actuation of the shaft speed-responsive device and movement of the second control to start position to operate the second actuator from the first to the second position, and means responsive to movement of either control to stop position to operate the corresponding actuator to the first position.

21. A power plant comprising, in combination, first and second power units, a power output shaft, a clutch including driving and driven clutch elements coupling each unit to the output shaft, each clutch including cooling means, a power control for each unit movable from a stop position to a start position, a clutch actuator for each clutch movable from a first position in which the clutch is disengaged thereby to a second position in which the clutch is engaged and the cooling means is activated thereby and then to a third position in which the clutch is engaged and the cooling means is deactivated thereby, means responsive to movement of the first power control to start position and operation of the first unit to operate the first actuator from the first position to the second position, means responsive to substantial synchronism of the first unit clutch elements to operate the first actuator from the second to the third position, means responsive to movement of the first actuator to the third position and movement of the second power control to start position to operate the second actuator from the first to the second position, and means responsive to substantial synchronism of the second unit clutch elements to operate the second actuator from the second to the third position.

22. A power plant comprising, in combination, first and second power units, a power output shaft, a clutch coupling each unit to the output shaft, each clutch including cooling means, a power control for each unit movable from a stop position to a start position, a clutch actuator for each clutch movable from a first position in which the clutch is disengaged thereby to a second position in which the clutch is engaged and the cooling means is activated thereby, and then to a third position in which the clutch is engaged and the cooling means is deactivated thereby, a power unit speed-responsive device for each unit, an output shaft speed-responsive device, means responsive to movement of the first power control to start position and actuation of the first unit speed-responsive device to operate the first actuator from the first position to the second position, means responsive to actuation of the shaft speed-responsive device to operate the first actuator from the second to the third position, means responsive to movement of the first actuator to the third position and movement of the second power control to start position to operate the second actuator from the first to the second position, and means responsive to actuation of the second unit speed-responsive device to operate the second actuator from the second to the third position.

23. A power plant comprising, in combination, first and second gas turbine power units, a power output shaft, a clutch coupling each unit to the output shaft, each clutch including cooling means, a power control for each unit movable from a stop position to a start position, a clutch actuator for each clutch movable from a first position in which the clutch is disengaged thereby to a second position in which the clutch is engaged and the cooling means is activated thereby, then to a third position in which the clutch is engaged and the cooling means is deactivated thereby, and then back to the first position, a power unit speed-responsive device for each unit, an output shaft speed-responsive device, means responsive to movement of the first power control to start position and actuation of the first unit speed-responsive device to operate the first actuator from the first position to the second position, means responsive to actuation of the shaft speed-responsive device to operate the first actuator from the second to the third position, means responsive to movement of the first actuator to the third position and movement of the second power control to start position to operate the second actuator from the first to the second position, means responsive to actuation of the second unit speed-responsive device to operate the second actuator from the second to the third position, and means responsive to movement of either power control to stop position to operate the corresponding actuator from the third to the first position.

24. A power system comprising, in combination, two power units, a power shaft, a clutch coupling each unit to the shaft, a power control for each unit settable to stop and start positions, an actuator for each clutch operable to engage and disengage the clutch, a device for each unit responsive to a condition indicative of operation of the unit, a device sensitive to a condition indicative of operation of the shaft, means actuated by movement of one unit power control to start and actuation of the said one unit operation responsive device to energize the actuator to engage the clutch of the said one unit, interlock means actuated by movement of the other unit power control from stop to prevent engagement of the clutch of the said one unit, means actuated by the shaft operation sensitive device upon operation of the shaft to disable the said interlock means, and means actuated by movement of the other unit control to start to energize the other unit clutch actuator to engage the other unit clutch.

25. A power system comprising, in combination, two power units, a power shaft, a clutch coupling each unit to the shaft, a power control for each unit settable to stop and start positions, an actuator for each clutch operable to engage and disengage the clutch, a device for each unit responsive to the speed of the unit, a de-

vice sensitive to the speed of the shaft, means responsive to movement of either power control to stop position to operate the actuator to disengage the clutch, means actuated by movement of one unit power control to start and actuation of the said one unit speed responsive device to energize the actuator to engage the clutch of the said one unit, interlock means actuated by movement of the other unit power control from stop to prevent engagement of the clutch of the said one unit, means actuated by the shaft speed sensitive device to disable the said interlock means, and means actuated by movement of the other unit control to start to energize the other unit clutch actuator to engage the other unit clutch.

26. A power system comprising, in combination, two gas turbine power units, a power shaft, a feathering propeller driven by the shaft, a clutch coupling each unit to the shaft, a power control for each unit settable to stop and start positions, an actuator for each clutch operable to engage and disengage the clutch, a device for each unit reponsive to a condition indicative of operation of the unit, a device sensitive to a condition indicative of operation the shaft, means responsive to movement of either power control to stop position to operate the actuator to disengage the corresponding clutch, means actuated by feathering the propeller to disengage both clutches, means actuated by movement of one unit power control to start to set the propeller to a low pitch value and start the corresponding unit, means responsive to actuation of the said one unit operation responsive device to energize the actuator to engage the clutch of the said one unit, interlock means actuated by movement of the other unit power control from stop to prevent engagement of the clutch of the said one unit, means actuated by the shaft operation sensitive device upon operation of the shaft to disable the said interlock means, and means actuated by movement of the other unit control to start to energize the other unit clutch actuator to engage the other unit clutch.

27. An aircraft propulsion plant comprising, in combination, two power units, a propeller, a clutch coupling each unit to the propeller, starting means for the units, a power control for each unit settable to stop and start positions, a ground start control device for each clutch activated by actuation of the starting means, means under control of the ground start control device when activated to effect engagement of the clutch of one unit by movement of the power control thereof to start, interlock means for each unit actuated by movement of the unit control from stop to block engagement of the clutch of the other unit, and means responsive to engagement of each unit clutch to disable the interlock means of that unit.

28. An aircraft propulsion plant comprising, in combination, two power units, a propeller, a clutch coupling each unit to the propeller, starting means for the units, a power control for each unit settable to stop, start, and operating positions, a ground start control device for each clutch activated by actuation of the starting means, means under control of the ground start control device when activated to effect engagement of the clutch of one unit by movement of the power control thereof to start, interlock means for each unit actuated by movement of the unit control from stop to block engagement of the clutch of the other unit, means responsive to engagement of each unit clutch to disable the interlock means of that unit, and means under control of the interlock means for engaging each clutch energized by concurrent deactivation of the ground start control device and movement of the power control of the corresponding unit to operating position.

29. An aircraft propulsion plant comprising, in combination, two gas turbine power units, a feathering propeller, a clutch coupling each unit to the propeller, starting means for the units, a power control for each unit settable to stop and start positions, means responsive to feathering the propeller to disengage both clutches, means responsive to movement of either power control to stop to disengage the corresponding clutch, a ground start control device for each clutch activated by energization of the starting means, means under control of the ground start control device when activated to effect engagement of the clutch of one unit by movement of the power control thereof to start, interlock means for each unit actuated by movement of the unit control from stop to block engagement of the clutch of the other unit, and means responsive to engagement of each unit clutch to disable the interlock means of that unit.

30. An aircraft propulsion plant comprising, in combination, two gas turbine power units, a feathering propeller, a clutch coupling each unit to the propeller, starting means for the units, a power control for each unit settable to stop, start, and operating positions, means responsive to feathering the propeller to disengage both clutches, means responsive to movement of either power control to stop to disengage the corresponding clutch, a ground start control device for each clutch activated by energization of the starting means, means under control of the ground start control device when activated to effect engagement of the clutch of one unit by movement of the power control thereof to start, interlock means for each unit actuated by movement of the unit control from stop to block engagement of the clutch of the other unit, means responsive to engagement of each unit clutch to disable the interlock means of that unit, and means under control of the interlock means for engaging each clutch energized by the ground start control device and movement of the power control of the corresponding unit to operating position.

31. An aircraft propulsion plant comprising, in combination, two power units, an output shaft, a clutch coupling each unit to the shaft, a power control for each unit settable to stop, start, and operating positions, means responsive to movement of either power control to stop to disengage the corresponding clutch, a ground start control device for each clutch, means under control of the ground start control device when activated to effect engagement of the clutch of one unit by movement of the power control thereof to start, interlock means for each unit actuated by movement of the unit control from stop to block engagement of the clutch of the other unit, means responsive to engagement of each unit clutch to disable the interlock means of that unit, and means under control of the interlock means for engaging each clutch energized by concurrent deactivation of the ground start control device and movement of the power control of the corresponding unit to operating position.

32. An aircraft propulsion power plant comprising, in combination, two power units, a propeller driven thereby, settable pitch regulating means operable to vary the pitch of the propeller to maintain propeller speed constant, means for setting the propeller to desired pitch angles, a fuel-metering device for each unit, a master control for each unit operable from a stop position to a start position, a normal operating range and an auxiliary operating range, means actuated by the master control of each unit for controlling the fuel-metering device of that unit, a coordinating control device, means for transmitting signals from each master control to the coordinating control device indicative of the setting of the master control, means in the coordinating control for rejecting the signal from the master control device least advanced from a datum point, means in the coordinating control for transmitting signals from the other master control to the propeller regulating device in the normal range and to the propeller pitch setting device in the auxiliary range, means for setting the propeller to substantially zero pitch by movement of a master control to the start position, feathering means for feathering and unfeathering the propeller,

a starter for the power units, means for coupling the starter to either power unit actuated by movement of the corresponding unit master control to the start position, a first power bus energized by movement of either master control from stop position, a second power bus energized from the first bus under control of the feathering means when the propeller is unfeathered, a third power bus energized from the second power bus and deenergized by either master control device when it is moved into the auxiliary range, means actuated by each master control for energizing the starter from the third bus when the master control is moved to start position, first interlock means between the master controls operable when either control is advanced beyond a given point in the normal range to block movement of the other power control from the normal range, and a second interlock means between the master controls operable to block movement of either power control into the auxiliary range when the other power control is in the normal range.

33. An aircraft propulsion power plant comprising, in combination, two power units, a propeller driven thereby, a clutch coupling each power unit to the propeller, a speed governor for each unit, a fuel-metering device for each unit, a master control for each unit operable from a stop position to a start position, a normal operating range, and an auxiliary operating range, means actuated by the master control of each unit for controlling the speed governor and the fuel-metering device of that unit, means for setting the propeller to substantially zero pitch by movement of a master control to the start position, feathering means for feathering and unfeathering the propeller, a starter for the power units, means for coupling the starter to either power unit actuated by movement of the corresponding unit master control to the start position, a first power bus energized by movement of either master control from stop position, a second power bus energized from the first bus under control of the feathering means when the propeller is unfeathered, a third power bus energized from the second power bus and deenergized by either master control device when it is moved into the auxiliary range, means actuated by each master control for energizing the starter from the third bus when the master control is moved to start position, means responsive to operation of each power unit, clutch engaging means responsive to movement of the master control to start position and actuation of the power unit responsive means to energize the clutch of the corresponding unit, the said clutch engaging means being energized from the said third bus, means actuated by the feathering means when the propeller is feathered to disengage both clutches, means responsive to rotation of the propeller, means responsive to the last-named means and to actuation of the power control of either unit from stop position to engage the clutch of the corresponding unit, first interlock means between the master controls operable when either control is advanced beyond a given point in the normal range to block movement of the other power control from the normal range, and a second interlock means between the master controls operable to block movement of either power control into the auxiliary range when the other power control is in the normal range.

34. An aircraft propulsion power plant comprising, in combination, two power units, a propeller driven thereby, a clutch coupling each power unit to the propeller, settable pitch regulating means operable to vary the pitch of the propeller to maintain propeller speed constant, means for setting the propeller to desired pitch angles, a speed governor for each unit, a fuel-metering device for each unit, a master control for each unit operable from a stop position to a start position, a normal operating range, and an auxiliary operating range, means actuated by the master control of each unit for controlling the speed governor and the fuel-metering device of that unit, a coordinating control device, means for transmitting signals from each master control to the coordinating control device indicative of the setting of the master control, means in the coordinating control for rejecting the signal from the master control device least advanced from a datum point, means in the coordinating control for transmitting signals from the other master control to the propeller regulating device in the normal range and to the propeller pitch setting device in the auxiliary range, means for setting the propeller to substantially zero pitch by movement of a master control to the start position, feathering means for feathering and unfeathering the propeller, means responsive to operation of each power unit, clutch engaging means responsive to movement of the master control to start position and actuation of the power unit responsive means to energize the clutch of the corresponding unit, means actuated by the feathering means when the propeller is feathered to disengage both clutches, means responsive to rotation of the propeller, means responsive to the last-named means and to actuation of the power control of either unit from stop position to engage the clutch of the corresponding unit, first interlock means between the master controls operable when either control is advanced beyond a given point in the normal range to block movement of the other power control from the normal range, and a second interlock means between the master controls operable to block movement of either power control into the auxiliary range when the other power control is in the normal range.

35. An aircraft propulsion power plant comprising, in combination, two power units, a propeller driven thereby, a clutch coupling each power unit to the propeller, settable pitch regulating means operable to vary the pitch of the propeller to maintain propeller speed constant, means for setting the propeller to desired pitch angles, a speed governor for each unit, a fuel-metering device for each unit, a master control for each unit operable from a stop position to a start position, a normal operating range, and an auxiliary operating range, means actuated by the master control of each unit for controlling the speed governor and the fuel-metering device of that unit, a coordinating control device, means for transmitting signals from each master control to the coordinating control device indicative of the setting of the master control, means in the coordinating control for rejecting the signal from the master control device least advanced from a datum point, means in the coordinating control for transmitting signals from the other master control to the propeller regulating device in the normal range and to the propeller pitch setting device in the auxiliary range, means for setting the propeller to substantially zero pitch by movement of a master control to the start position, feathering means for feathering and unfeathering the propeller, a starter for the power units, means for coupling the starter to either power unit actuated by movement of the corresponding unit master control to the start position, a first power bus energized by movement of either master control from stop position, a second power bus energized from the first bus under control of the feathering means when the propeller is unfeathered, a third power bus energized from the second power bus and deenergized by either master control device when it is moved into the auxiliary range, means actuated by each master control for energizing the starter from the third bus when the master control is moved to start position, means responsive to operation of each power unit, clutch engaging means responsive to movement of the master control to start position and actuation of the power unit responsive means to energize the clutch of the corresponding unit, the said clutch engaging means being energized from the said third bus, means actuated by the feathering means when the propeller is feathered to disengage both clutches, means responsive to rotation of the propeller, and means responsive to the last-named means and to actuation of

the power control of either unit from stop position to engage the clutch of the corresponding unit

36. An aircraft propulsion power plant comprising, in combination, two power units, a propeller driven thereby, a clutch coupling each power unit to the propeller, settable pitch regulating means operable to vary the pitch of the propeller to maintain propeller speed constant, means for setting the propeller to desired pitch angles, a speed governor for each unit, a fuel-metering device for each unit, a master control for each unit operable from a stop position to a start position, a normal operating range, and an auxiliary operating range, means actuated by the master control of each unit for controlling the speed governor and the fuel-metering device of that unit, a coordinating control device, means for transmitting signals from each master control to the coordinating control device indicative of the setting of the master control, means in the coordinating control for rejecting the signal from the master control device least advanced from a datum point, means in the coordinating control for transmitting signals from the other master control to the propeller regulating device in the normal range and to the propeller pitch setting device in the auxiliary range, means for setting the propeller to substantially zero pitch by movement of a master control to the start position, feathering means for feathering and unfeathering the propeller, a starter for the power units, means for coupling the starter to either power unit actuated by movement of the corresponding unit master control to the start position, a first power bus energized by movement of either master control from stop position, a second power bus energized from the first bus under control of the feathering means when the propeller is unfeathered, a third power bus energized from the second power bus and deenergized by either master control device when it is moved into the auxiliary range, means actuated by each master control for energizing the starter from the third bus when the master control is moved to start position, means responsive to operation of each power unit, clutch engaging means responsive to movement of the master control to start position and actuation of the power unit responsive means to energize the clutch of the corresponding unit, the said clutch engaging means being energized from the said third bus, means actuated by the feathering means when the propeller is feathered to disengage both clutches, means responsive to rotation of the propeller, means responsive to the last-named means and to actuation of the power control of either unit from stop position to engage the clutch of the corresponding unit, first interlock means between the master controls operable when either control is advanced beyond a given point in the normal range to block movement of the other power control from the normal range, and a second interlock means between the master controls operable to block movement of either power control into the auxiliary range when the other power control is in the normal range.

37. An aircraft propulsion power plant comprising, in combination, a gas turbine power unit, a variable pitch propeller driven thereby including means whereby the propeller is operable in blade angle control and in speed governing control, the propeller including a speed governor, a master control for the unit, a fuel regulator for the unit conrtolling the fuel supply to the unit, the fuel regulator including a power regulating fuel control and a speed governing fuel control, means in the master control coupled to the fuel regulator for variably setting the said fuel controls of the unit, means in the master control coupled to the propeller for transmitting variable pitch signals to the propeller in a first range of operation, and means in the master control coupled to the propeller speed governor for transmitting speed signals to the propeller speed governor in a second range of operation.

38. An aircraft propulsion power plant comprising, in combination, a power unit, a variable pitch propeller driven thereby including means whereby the propeller is operable in blade angle control and in speed governing control, the propeller including a speed governor, a master control for the unit, a speed governing control device coupled to the unit to govern the speed thereof, means in the master control coupled to the speed governing control device for transmitting speed signals to the speed governing control device, means in the master control coupled to the propeller for transmitting variable pitch signals to the propeller in a first range of operation, and means in the master conrtol to the propeller speed governor for transmitting speed signals to the propeller in a second range of operation, the several transmitting means of the master control being so scheduled that the signals therefrom are coordinated in the first range of operation to provide varying pitch angles through the range and to regulate the speed governing control device to provide suitable limitation of unit speed for each value of pitch; and being so scheduled that the signals therefrom are coordinated in the second range so that the propeller speed setting is suited to the unit characteristics at each point in the range and the speed governing control device of the unit is set to a higher speed than the propeller through the major part of the range.

39. An aircraft propulsion power plant comprising, in combination, a power unit, a variable pitch propeller driven thereby including means whereby the propeller is operable in blade angle control and in speed governing control, the propeller including a speed governor, a master control for the unit, a regulator for the unit including a unit power regulating control, means in the master control coupled to the regulator for transmitting power signals to the regulator, means in the master control coupled to the propeller for transmitting variable pitch signals to the propeller in a first range of operation, and means in the master control coupled to the propeller speed governor for transmitting speed signals to the propeller speed governor in a second range of operation, the several transmitting means of the master control being so scheduled that the signals therefrom are coordinated in the first range of operation to provide varying pitch angles through the range and to provide sufficient available power from the unit at each value of pitch that the unit is capable of driving the propeller; and being so scheduled that the signals therefrom are coordinated in the second range so that available power from the unit varies smoothly from a minimum value to a maximum value and the propeller speed setting is suited to the unit characteristics at each point in the range.

40. An aircraft propulsion power plant comprising, in combination, a power unit, a variable pitch propeller driven thereby including means whereby the propeller is operable in blade angle control and in speed governing control, the propeller including a speed governor, a master control for the unit, a fuel regulator for the unit including a unit power regulating control and a unit speed governing control, means in the master control coupled to the power regulating control and the speed governing control, respectively, for transmitting power signals and speed signals to the regulating control and governing control, respectively, of the unit fuel regulator, means in the master control coupled to the propeller for transmitting pitch signals to the propeller in a first range of operation, and means in the master control coupled to the propeller speed governor for transmitting speed signals to the propeller speed governor in a second range of operation, the several transmitting means of the master control being so scheduled that the signals therefrom are coordinated in the first range of operation to provide varying pitch angles through the range, to provide sufficient available power from the unit at each value of pitch that the unit is capable of driving the propeller, and to regulate the unit speed governing control to provide suitable limitation of

unit speed; and being so scheduled that the signals therefrom are coordinated in the second range so that available power from the unit varies smoothly from a minimum value to a maximum value, the propeller speed setting is suited to the unit speed characteristics at each point in the range, and the unit governing control is set to a higher speed than the propeller through the major part of the range.

41. An aircraft propulsion power plant comprising, in combination, two gas turbine power units, a variable pitch propeller driven thereby including means whereby the propeller is operable in blade angle control and in speed governing control, the propeller including a speed governor, a master control for each unit, a fuel regulator for each unit controlling the fuel supply thereto and including a unit power regulating fuel control and a unit speed governing fuel control, means in each master control coupled to the unit power regulating control for transmitting power signals to the power regulating control of the corresponding unit, means in each master control coupled to the unit speed governing control for transmitting speed signals to the governing control of the corresponding unit, means in each master control coupled to the propeller for transmitting pitch signals to the propeller in a first range of operation, and means in each master control coupled to the propeller speed governor for transmitting speed signals to the propeller speed governor in a second range of operation.

42. An aircraft propulsion power plant comprising, in combination, two power units, a variable pitch propeller including means whereby the propeller is operable in blade angle control and in speed governing control driven by the power units, the propeller including a speed governor, a master control for each unit, a speed governing control for each unit, means in each master control coupled to the unit speed governing control for transmitting speed signals to the speed governing control of the corresponding unit, means in each master control coupled to the propeller for transmitting pitch signals to the propeller in a first range of operation, and means in each master control coupled to the propeller speed governor for transmitting speed signals to the propeller speed governor in a second range of operation, the several transmitting means of each master control being scheduled so that the signals therefrom are coordinated in the first range of operation to provide varying pitch angles through the range and to regulate each governing control to provide suitable limitation of unit speed when either unit and when both units are in operation; and so that the signals therefrom are coordinated in the second range so that the propeller speed setting is suited to the unit characteristics at each point in the range and the unit governing control is set to a higher speed than the propeller through the major part of the range.

43. A power plant comprising, in combination, two power units, a variable pitch propeller including means whereby the propeller is operable in blade angle control and in speed governing control driven by the power units, the propeller including a speed governor, a master control for each unit, a power control for each unit, means in each master control coupled to the unit power control for transmitting power signals to the power control of the corresponding unit, means in each master control coupled to the propeller for transmitting pitch signals to the propeller in a first range of operation, and means in each master control coupled to the propeller speed governor for transmitting speed signals to the propeller speed governor in a second range of operation, the several transmitting means of each master control being scheduled so that the signals therefrom are coordinated in the first range of operation to provide varying pitch angles through the range and to provide sufficient available power from each unit at each value of pitch that either unit is capable of driving the propeller; and so that the signals therefrom are coordinated in the second range so that available power from each unit varies smoothly from a minimum value to a maximum value and the propeller speed setting is suited to the unit characteristics at each point in the range.

44. An aircraft propulsion power plant comprising, in combination, two power units, a variable pitch propeller including means whereby the propeller is operable in blade angle control and in speed governing control, the propeller including a speed governor, a clutch coupling each power unit to the propeller, a master control for each unit, a regulator for each unit including a power regulating control, means in each master control coupled to the unit regulator for transmitting power signals to the regulator of the corresponding unit, means in each master control coupled to the propeller for transmitting pitch signals to the propeller in a first range of operation, and means in each master control coupled to the propeller speed governor for transmitting speed signals to the propeller speed governor in a second range of operation, the several transmitting means of each master control being scheduled so that the signals therefrom are coordinated in the first range of operation to provide varying pitch angles through the range and to provide sufficient available power from each unit at each value of pitch that either unit is capable of driving the propeller; and so that the signals therefrom are coordinated in the second range so that available power from each unit varies smoothly from a minimum value to a maximum value and the propeller speed setting is suited to the unit characteristics at each point in the range.

45. An aircraft propulsion power plant comprising, in combination, two gas turbine power units, a variable pitch propeller including means whereby the propeller is operable in blade angle control and in speed governing control driven by the power units, the propeller including a speed governor, a clutch coupling each power unit to the propeller, a master control for each unit, a fuel regulator for each unit including a power regulating fuel control and a speed governing fuel control, means in each master control coupled to the unit regulating control for transmitting power signals to the regulating control of the corresponding unit, means in each master control coupled to the unit governing control for transmitting speed signals to the governing control of the corresponding unit, means in each master control coupled to the propeller for transmitting pitch signals to the propeller in a first range of operation, and means in each master control coupled to the propeller speed governor for transmitting speed signals to the propeller speed governor in a second range of operation, the several transmitting means of each master control being scheduled so that the signals therefrom are coordinated in the first range of operation to provide varying pitch angles through the range, to provide sufficient available power from each unit at each value of pitch that either unit is capable of driving the propeller, and to regulate each governing control to provide suitable limitation of unit speed when either unit and when both units are in operation; and so that the signals therefrom are coordinated in the second range so that available power from each unit varies smoothly from a minimum value to a maximum value, the propeller speed setting is suited to the unit characteristics at each point in range, and the unit governing control is set to a higher speed than the propeller through the major part of the range.

46. An aircraft propulsion power plant comprising, in combination, two power units, a variable pitch propeller including means whereby the propeller is operable in speed governing control driven by the power units, the propeller including a speed governor, a master control for each unit, a regulator for each unit including a power regulating control and a speed governing control, means in each master control coupled to the unit regulator for transmitting power signals and speed signals to the respective controls of the regulator of the unit and means in each

master control coupled to the propeller speed governor for transmitting speed signals to the propeller speed governor, each master control being scheduled so that the signals therefrom are coordinated so that available power from each unit varies smoothly from a minimum value to a maximum value, the propeller speed setting is suited to the unit characteristics at each point in the range, and the unit governing control is set to a higher speed than the propeller through the major part of the range.

47. An aircraft propulsion power plant comprising, in combination, two power units, a variable pitch propeller including means whereby the propeller is operable in blade angle control driven by the power units, a master control for each unit, a regulator for each unit including a power regulating control and a speed governing control, means in each master control coupled to the unit regulator for transmitting power signals and speed signals to the respective controls of the regulator of the unit and means in each master control coupled to the propeller for transmitting pitch signals to the propeller, each master control being scheduled so that the signals therefrom are coordinated to provide varying pitch angles through a range, to provide sufficient available power from each unit at each value of pitch that either unit is capable of driving the propeller, and to regulate each governing control to provide suitable limitation of unit speed when either unit and when both units are in operation.

48. An aircraft propulsion plant comprising, in combination, an engine, a propeller driven thereby, means for feathering the propeller, engine starting means coupled to the engine, means for disabling the starting means connected thereto, and means actuated by the feathering means for actuating the disabling means.

49. An aircraft propulsion plant comprising, in combination, an engine, a propeller driven thereby, means for feathering the propeller, means for supplying fuel to the engine, means for disabling the fuel supplying means, means for starting the engine, means for disabling the starting means, and means actuated by the feathering means for actuating both the said disabling means.

50. An aircraft propulsion plant comprising, in combination, an engine, a propeller driven thereby, means for feathering the propeller, means for supplying fuel to the engine, means for starting the engine, means for clutching the engine to the propeller, and means connecting the feathering means to the said fuel-supplying, starting, and clutching means and operable upon feathering the propeller to disable the said fuel-supplying, starting, and clutching means.

51. An aircraft propulsion power plant comprising, in combination, a power unit, a propeller, a clutch coupling the power unit to the propeller, means for feathering the propeller, means for initiating the feathering operation, means operative to disengage the clutch, and means actuated by the said iniitating means to operate the said means to disengage the clutch.

52. An aircraft propulsion power plant comprising, in combination, two power units, a propeller, a clutch coupling each power unit to the propeller, means for feathering the propeller, means for disengaging each clutch, and means actuated by the said feathering means for operating both disengaging means to disengage the clutches.

53. An aircraft propulsion power plant comprising, in combination, two power units, a propeller, a clutch coupling each power unit to the propeller, means for engaging the clutches, means operable to disable the clutch-engaging means coupled thereto, means for feathering the propeller, and means coupling the feathering means to the disabling means and actuated by the said feathering means for disabling the means for engaging the clutches.

54. An aircraft propulsion power plant comprising, in combination, two power units, a propeller, a clutch coupling each power unit to the propeller, means for feathering the propeller, means for initiating the feathering operation, means in each clutch to disengage the clutch, and means actuated by the said initiating means to operate the said disengaging means of both clutches.

55. A power plant comprising, in combination, two power units, a common starter for the units, means for coupling the starter to the units, a power control for each unit movable from a stop position to a start position, means for energizing the starter coupled to both power controls so as to be actuated by movement of either power control to start position, means actuated by movement of both power controls from stop position for disabling the starter-energizing means and deenergizing the starter, and means coupled to both units and actuated by operation of either unit above a predetermined speed for deenergizing the starter.

56. A power plant comprising, in combination, two power units, a common starter for the units, selector means for coupling the starter to either unit, a power control for each unit movable from a stop position to a start position, means coupled to both power controls so as to be responsive to movement of either control to start position to actuate the starter selector to couple the starter to the corresponding unit, means for energizing the starter coupled to both power controls so as to be actuated by movement of either power control to start position, means actuated by movement of both power controls from stop position for disabling the starter-energizing means, and means coupled to both units and actuated by operation of a unit above a predetermined speed for deenergizing the starter.

57. A power plant comprising, in combination, two power units, a common starter for the units, selector means for coupling the starter to either unit, a power control for each uit movable from a stop position to a start position, means coupled to both power controls so as to be responsive to movement of either control to start position to actuate the starter selector to couple the starter to the corresponding unit, means for energizing the starter coupled to both power controls so as to be actuated by movement of either power control to start position, and means actuated by movement of both power controls from stop position for disabling the starter-energizing means and deenergizing the starter.

58. An aircraft propulsion power plant comprising, in combination, two power units, a power output shaft, a clutch coupling each power unit to the shaft, a power control for each power unit movable from a stop position to a start position, means responsive to movement of one power control to start position to start the corresponding unit, means responsive to operation of the unit to operate the unit clutch to clutch it to the shaft, means responsive to completion of the said clutching operation, means responsive to movement of the other unit power control to start position, and means responsive to the two last-recited means effective to operate the other unit clutch to clutch the other power unit to the shaft.

59. An aircraft propulsion power plant comprising, in combination, two power units, a feathering propeller, a clutch coupling each power unit to the propeller, a power control for each power unit movable from a stop position to a start position, means actuated by unfeathering of the propeller and movement of one power control to start position to start the corresponding unit, means responsive to operation of the unit to operate the unit clutch to clutch it to the propeller, means responsive to completion of the said clutching operation, means responsive to movement of the other unit power control to start position, and means responsive to the two last-recited means effective to operate the other unit clutch to clutch the other power unit to the propeller.

60. An aircraft propulsion power plant comprising, in combination, two power units, a feathering propeller, a clutch coupling each power unit to the propeller, a power control for each power unit movable from a stop posi-

tion to a start position, means responsive to movement of one power control to start position to start the corresponding unit, means responsive to operation of the unit to operate the unit clutch to clutch it to the propeller, means responsive to completion of the said clutching operation, means responsive to movement of the other unit power control to start position, and means responsive to the two last-recited means effective to operate the other unit clutch to clutch the other power unit to the propeller, means responsive to movement of either power control to stop position to disengage the clutch of the corresponding unit, and means actuated by feathering the propeller to disengage both clutches.

61. An aircraft propulsion power plant comprising, in combination, two power units, a propeller driven thereby, a movable power control for each power unit, means actuated by each power control through a first range of movement for transmitting speed governing signals to the propeller, means actuated by each power control through a second range of movement for transmitting blade angle signals to the propeller, and means responsive to the position of either power control in the first range to block movement of the other power control into the second range.

62. An aircraft propulsion power plant comprising, in combination, two power units, a propeller driven thereby, a clutch between each power unit and the propeller, a movable power control for each power unit, means actuated by each power control through a first range of movement for transmitting speed governing signals to the propeller, means actuated by each power control through a second range of movement for transmitting blade angle signals to the propeller, means responsive to the position of either power control in the first range to block movement of the other power control into the second range, and means actuated by releasing the clutch of one unit to disable the blocking means of the other unit.

63. An aircraft propulsion power plant comprising, in combination, two power units, a feathering propeller driven thereby, a movable power control for each power unit, means actuated by each power control through a first range of movement for transmitting speed governing signals to the propeller, means actuated by each power control through a second range of movement for transmitting blade angle signals to the propeller, means responsive to the position of either power control beyond a predetermined point in the first range to block movement of the other power control into the second range, and means actuated by feathering the propeller to disable the blocking means.

64. An aircraft propulsion power plant comprising, in combination, two power units, a propeller driven thereby, a movable power control for each power unit, means actuated by each power control through a first range of movement for transmitting speed governing signals to the propeller, means actuated by each power control through a second range of movement for transmitting blade angle signals to the propeller, means responsive to the position of either power control in the first range to block movement of the other power control into the second range, a starter for the power units, and means responsive to actuation of the starter to disable the blocking means.

65. An aircraft propulsion power plant comprising, in combination, two power units, a propeller driven thereby, a power control for each unit movable through a normal range and an abnormal range, a blocking means for each power control actuated by movement of the other power control beyond a predetermined point in the normal range to block movement of the power control into the abnormal range, means for concurrently stopping either unit and releasing the blocking means of the other unit power control, and means actuated by concurrent entry of both power controls into the abnormal range to release both blocking means.

66. An aircraft propulsion power plant comprising, in combination, two gas turbine power units, a variable pitch propeller driven thereby, a clutch coupling each unit to the propeller, means for regulating the supply of fuel to each unit, a master control for each unit controlling the said regulating means of that unit, a coordinating control for the power plant controlled by the two unit controls, means for controlling the propeller actuated by the coordinating control, a starter for the power units, means for energizing the starter governed by the coordinating control, and means for releasing the clutches actuated by the coordinating control.

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CERTIFICATE OF CORRECTION

Patent No. 2,851,113 September 9, 1958

Edmund M. Irwin et al.

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 3, line 33, for "appropriative" read -- appropriate --; column 10, line 19, for "1951" read -- 151 --; column 16, line 11, for "GG" read -- CG --; column 17, line 4, for "Wtih" read -- With --; column 19, line 8, for "circiut" read -- circuit --; column 21, line 8, for "he" read -- the --; line 24, for "posion" read -- position --; column 24, line 8, for "pitch of" read -- pitch to --; column 27, line 31, for "unti" read -- unit --; column 31, line 16, for "higher" read -- high --; line 70, for "element" read -- elements --; column 32, line 4, for "devices" read -- device --; column 33, line 1, for "th" read -- the --; column 43, line 55, for "iniitating" read -- initiating --; column 44, line 34, for "uit" read -- unit --.

Signed and sealed this 5th day of May 1959.

(SEAL)
Attest:

KARL H. AXLINE
Attesting Officer

ROBERT C. WATSON
Commissioner of Patents