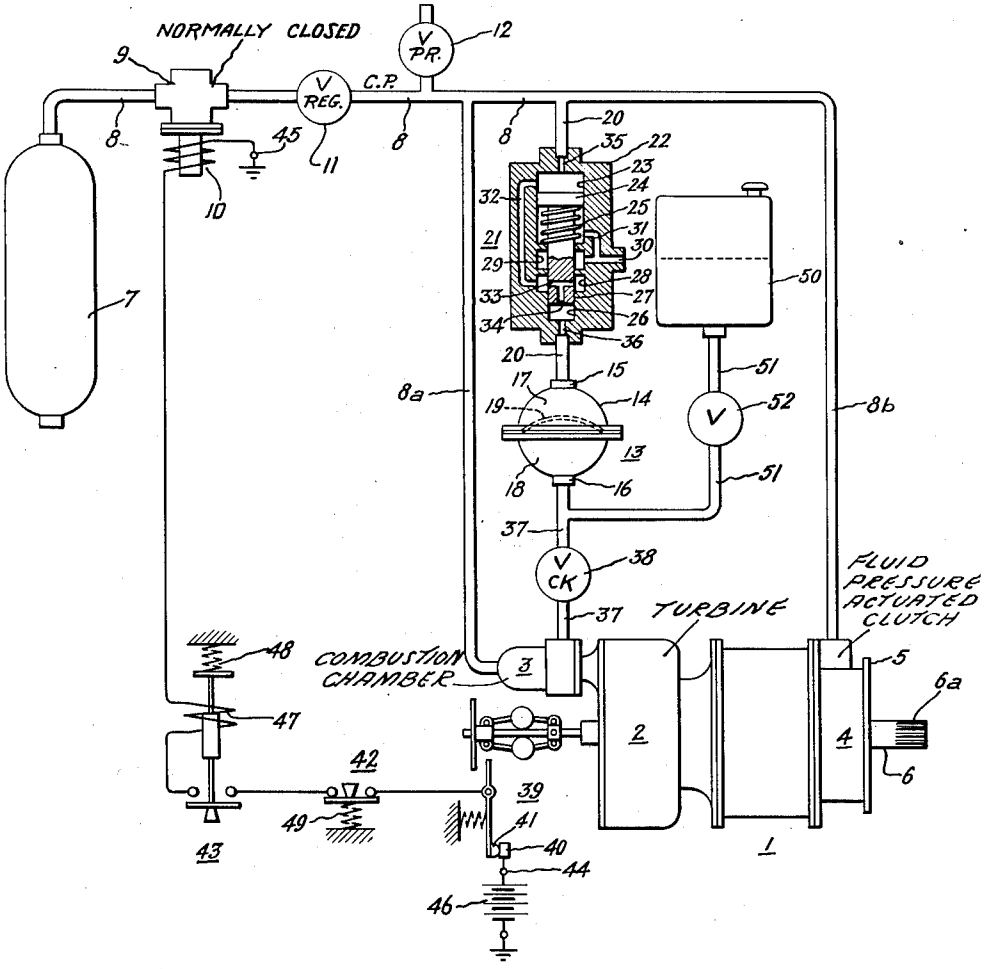
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SPEED LIMITING CONTROL FOR GAS TURBINES

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SPEED LIMITING CONTROL FOR GAS TURBINES

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This invention relates to fluid pressure turbines and particularly to speed limiting arrangements for turbine type starter motors for internal combustion power plants.

The invention may be used with turbine type starter motors for gas turbine power plants and also for starting reciprocating engines since either of these types of power plants have moving parts of considerable mass and thus require the expenditure of substantial amounts of energy in order to effect starting. If, during the starting operation, the starter becomes disconnected from its load, as for example, due to the power plant accelerating under its own power rather early in the starting cycle, or due to failure of the driving mechanism, it is necessary to provide quick acting means for preventing over speeding of the turbine type starter to a dangerous degree. In practice, this is a very difficult problem to solve in view of the fact that the physical proportions of the turbine type starter are usually such that its rotating parts have very little inertia. Furthermore, it is generally impractical to provide these rotating parts of the starter with sufficient inertia to prevent overspeeding of the starter, particularly in the case of aircraft applications, since this would require more space and weight than is usually permissible. Furthermore, with increased inertia in the starting motor, the energy available for starting a given power plant would be greatly reduced because a larger portion of this energy would be required merely to accelerate the increased mass of the starter rotor. Therefore, it will be apparent that any device employed to prevent overspeeding of such a turbine type starter must be capable of acting within a very short time interval in view of the relatively low inertia of the rotating parts of the starter motor. Accordingly, it is an object of this invention to provide an improved fuel feeding system which obviates the above-mentioned difficulties.

Another object of the invention is to provide an improved fuel feeding system which will prevent turbine type starting motors from reaching an unsafe speed, and which is mechanically simple, quick acting, and light in weight.

A further object of the invention is to provide an improved fuel feeding system in which protection is provided against excessive amounts of fuel being supplied to a turbine type starter motor.

Still another object of the invention is in the provision of an arrangement wherein a turbine type starter is automatically disconnected from a prime mover and the energy supplied to the starting turbine is interrupted if there is a tendency for power to be delivered from the prime mover to the starter. Other objects and advantages will be apparent from the following description taken in connection with the accompanying drawing, in which the single figure is a diagrammatic representation of a turbine type starter motor provided with a fuel feeding system in accordance with the invention.

Referring to the drawing, a gas turbine type starter is indicated generally at 1. The starter comprises a turbine section 2, a combustion chamber 3, and a clutch portion

4. If desired, the turbine starter may be arranged to be supported by the engine that it is to start with the provision of a mounting flange 5. The turbine delivers power through reduction gearing (not shown) to the clutch 4 which is of the overriding or unidirectional type. The driven side of the clutch is attached to a shaft member 6. Shaft member 6 is provided with a splined portion 6a for engaging an engine member (not shown) in driving relation.

The term "overriding or unidirectional clutch means" as used herein, is intended to mean any type of clutch structure for the transmission of power in one direction only. For example, clutch means 4 is intended to transmit power from the turbine 2 to the driven member 6 which in turn will drive an engine to which the starter is connected, but will not permit the transfer of power from the engine through shaft member 6 to turbine 2. This is accomplished in accordance with the invention by the provision of a pressure actuated jaw type of clutch connected in the manner to be described hereinafter, or, by the provision of a well-known pawl type or sprag type of clutch means. The details of a clutch of the pressure actuated type are described with greater particularity in Patent 2,488,540—Hollingsworth, and a clutch of the sprag type is described with greater particularity in Patent 2,473,250—Hoffman.

Motive fluid for driving the turbine is generated in the combustion chamber 3 which delivers combustion products under pressure and at elevated temperatures to the turbine portion 2. The combustion products are generated by burning fuel which has been mixed with a combustion supporting fluid such as air or oxygen. The air or other combustion supporting fluid may be supplied by a storage bottle 7 of a well-known type used for the storage of air, oxygen, nitrogen, acetylene, or other fluids under high pressures. Communication is established between the fluid supply bottle 7 and combustion chamber 3 by the provision of conduits 8, 8a.

The fluid storage bottle 7 can be of any practical size and its pressure level need not be fixed to any particular pressure value. Size and weight considerations and availability of bottles will determine the precise pressure level to be used. However, since fluid supply bottles of the type described are presently available for use at pressure levels of the order of three thousand pounds per square inch, the fuel feeding system and its associated controls are illustrated for use at such a pressure level. It is to be understood, however, that the invention is not limited thereto, and that the invention can be used at any desired pressure level.

Control over the operation of the turbine type starter 1 is accomplished by the provision of a shut off valve 9 connected in series flow relation with conduit 8. As illustrated, shut off valve 9 is of a well-known type including a solenoid 10 to open the valve in response to an electrical voltage which may be applied to the solenoid and also including means biasing the valve to closed position when no voltage is applied to solenoid 10. Additional control means 11 are also connected in series flow relation with conduit 8 and shut off valve 9 at the downstream side thereof for reducing the pressure of the fluid supplied to combustion chamber 3. As illustrated in the drawings, the additional control means 11 is a constant pressure regulator which may be of any well-known type arranged to maintain the pressure at the downstream side of regulator 11 at a constant value irrespective of variations in the fluid supply pressure of bottle 7. It will be recognized that the supply pressure within bottle 7 will vary over a considerable range as fluid is drawn from the bottle. However, the invention is not limited to the use of regulating means 11 of the precise type described.

At the downstream side of regulating means 11, a pressure relief valve 12 is provided to prevent excessive

pressures from being attained in the fuel feeding system at locations downstream from the pressure relief valve.

In order to provide means for supplying fuel under pressure to the combustion chamber 3, a fuel chamber device 13 is provided. The fuel chamber device is essentially a well-known type of fluid accumulator comprising an outer casing 14 having pressure and fuel ports 15, 16 respectively. Outer casing 14 is divided into a pressure receiving chamber 17 and fuel chamber 18 which are separated by a common flexible separating wall 19. Communication is established between conduit 8 and chamber 17 by the provision of a branch conduit 20 connected to port 15. A one-way restrictor valve or shuttle valve 21 is connected in series flow relation with branch conduit 20 between conduit 8 and pressure port 15 for a purpose to be explained hereinafter.

Valve body 22 is provided with a central bore portion 23 within which is slidably disposed a piston 24. A biasing spring 25 is also provided within bore portion 23 to urge piston 24 in an upward direction. Coaxial with bore portion 23 is a second bore portion 26 in which a second piston member 27 is slidably disposed. Spaced annular recesses 28, 29 are provided at the surface of bore portion 26. Recess 29 communicates with the atmosphere and with the under side of piston 24 by passageways 30, 31, respectively. Recess 28 communicates with the upper side of piston 24 by connecting passageway 32. A passageway 33 extends diametrically across smaller piston 27 and an axially extending passageway 34 establishes communication between the lower end of piston 27 and passageway 33. The upper portion of bore 23 communicates with an inlet port 35 and the lower portion of bore 26 communicates with an outlet port 36.

Passageway 33 is spaced from the lower end portion of piston 27 by an amount corresponding to the spacing between recesses 28, 29. Likewise, the location at which passageway 32 communicates with the bore portion 23 is spaced in relation to recesses 28, 29 so that piston 24 will isolate passageway 32 when piston 24 is moved upward by an amount sufficient to establish communication between outlet port 36 and the atmosphere through passageways 30, 33, and 34.

When main control valve 9 is open so that fluid pressure is admitted to bore portion 23 through conduits 8, 20, the pressure acting against the upper face of piston 24 forces it downward against the action of biasing spring 25 until piston 24 and piston 27 assume the position indicated in the drawing. In such position, it will be apparent that valve 21 is open in the sense that a restricted passageway is provided to admit fluid to chamber 17, the restricted passageway being completed from inlet port 35, through bore portion 23, passageways 32—34, bore portion 26, to discharge port 36. During normal operation, there is no flow of fluid through conduit 20 and restrictor valve 21. The pressure acting against the upper face of piston 24 also acts in the opposite sense against the face of piston 27. However, since piston 27 is of considerably smaller cross sectional area than that of piston 24, there is always sufficient force acting against piston 24 in a downward direction to cause piston 24 and piston 27 to move downward against the action of biasing spring 25. If for any reason there is a tendency for a reverse flow of fluid to occur from chamber 17 upward through valve 21 toward pressure regulator 11 and relief valve 12, the pressure in bore portion 26 will be greater than the pressure acting against piston 24, at least momentarily. It will be apparent to those skilled in the art that, because of the fact that passageways 32—34 are restricted as compared to conduit 8*a* and the flow areas provided in combustion chamber 3 and turbine 2, the pressure in conduit 8*a* will drop at a faster rate than the rate of pressure drop in chamber 17 after valve 9 is closed. Momentarily, therefore, the pressure in chamber 17 will exceed the pressure acting against the upper face of piston 24.

An important feature of my invention is that the fluid accumulator 13 serves a triple purpose. First, it provides a means for receiving fuel into the fuel feeding system, secondly, it serves as a metering device in that only a definite pre-established quantity of fuel can be supplied to the combustion chambers each time the turbine starter is operated, and thirdly, in combination with the connection to storage bottle 7 it provides a means for supplying fuel under pressure to the combustion chamber 3. The fuel is conveyed from chamber 18 to combustion chamber 3 by conduit 37. A check valve 38 is connected in series flow relation with conduit 37 to prevent flow from combustion chamber 3 to fuel chamber 18.

While a particular type of fluid accumulator has been illustrated and described it will be understood that the invention is not necessarily limited theretto and that other types of accumulators may be employed with equally good results.

If a pressure actuated clutch of the type described in the above mentioned Hollingsworth patent is employed, a branch conduit 8*b* is provided to supply fluid under pressure to the clutch. Conduit 8*b* is connected to conduit 8 at any desired location on the downstream side of control valve 9. In this way, clutch 4 will be actuated to engage shaft 6 in driving relation when fluid under pressure is being supplied to combustion chamber 3. At the same time, such an arrangement provides an automatic safety feature in that the clutch 4 will not engage shaft 6 in driving relation when no fluid is being supplied to combustion chamber 3.

If a unidirectional clutch of the pawl or sprag type is employed, conduit 8*b* is omitted. When either the pawl or the sprag type of clutch is employed, there can be no transfer of power from shaft 6 to the turbine portion 2 under any normal operating condition, but power can be transmitted in the opposite direction from turbine 2 to shaft 6.

Another safety feature is in the provision of means for preventing dangerous overspeeding of the turbine 2. This is accomplished in accordance with the invention by the provision of a switch 39. Switch 39 is of a well-known type which is normally closed and which is operable in response to rotational speed of the turbine 2 to open switch contacts 40, 41 when the operating speed of the turbine reaches a preselected value. In order to provide manual control over the operation of the turbine type starter 1, manually operable switches 42, 43 are provided. Switches 39, 42, 43, and solenoid 10 are connected in series electrically to terminals 44, 45 which are adapted to receive an electrical voltage. The means for supplying voltage to terminals 44 and 45 forms no part of the present invention, but for the purposes of illustration is shown as battery 46.

Switches 39 and 42 are of the normally closed type. Switch 43 is of the normally open type and, in addition, is of the type having a holding coil 47 for maintaining the switch in the closed position once it has been actuated by the operator. In addition, switch 43 is of the type having spring 48 biasing switch 43 to its open position, and switch 42 is of the type having a spring 49 biasing switch 42 to its closed position.

Assuming that fluid supply bottle 7 has been charged with combustion supporting fluid and that a charge of fluid fuel has been placed in fuel chamber 18, in order to put the fuel feeding system into operation, the operator manually closes switch 43. Since this switch is provided with holding coil 47 the voltage supplied to terminals 44, 45 energizes coil 47 and solenoid 10 so that switch 43 remains in its closed position and main control valve 9 is caused to open and remain open by virtue of solenoid 10 being energized. Combustion supporting fluid flows from supply bottle 7 through conduits 8, 8*a*, main control valve 9, and regulating means 11 to combustion chamber 3. Since the fluid accumulator 13 is connected to conduit

8 by conduit 20, fluid pressure is admitted to pressure chamber 17 thereby causing the fuel charge in chamber 18 to be forced through check valve 38 and conduit 37 to combustion chamber 3. The combustion supporting fluid from conduit 8 and the fuel from conduit 37 are mixed and burned in combustion chamber 3 to provide motive fluid for driving the turbine 2. When main control valve 9 is in the open position, fluid under pressure is supplied to pressure actuated clutch 4 through conduit 8b so that turbine 2 and shaft 6 are connected in driving relation. If a clutch of the pawl or sprag type is employed, turbine 2 and shaft 6 will be connected in driving relation as long as sufficient energy is being delivered to the turbine so that there is a tendency for energy to be transferred from the turbine 2 to driven shaft 6. If, for any reason, there is a tendency for energy to be transferred in a reverse direction, that is, from shaft 6 to the turbine portion 2, these elements become disconnected from driving relation and clutch 4 will slip.

In the event that an excess amount of energy is supplied to the turbine for any given operating condition, turbine overspeeding is prevented since speed responsive switch 39 will open contacts 40, 41 and thus deenergize solenoid 10 at some preselected operating speed of the turbine. When solenoid 10 is deenergized the main control valve 9 will quickly return to its closed position under the influence of its biasing means (not shown). In addition, the operator can discontinue the operation of the starter 1 before turbine 2 has reached any dangerous overspeed condition by merely opening switch 42. By opening switch 42 solenoid 10 and holding coil 47 are deenergized thereby causing main control valve 9 to close under the action of its biasing means, and switch 43 to open and remain open under the action of biasing spring 43.

Under certain operating conditions, there may be a tendency for a backward flow of fluid through conduits 37 and 20. Such backward flow is prevented by check valve 38 and valve 21, respectively. In addition to operating somewhat in the manner of a check valve, the one-way restrictor valve 21 also operates to establish communication between chamber 17 and the atmosphere when fluid pressure is removed from the upstream side of the valve. Check valve 38 is of the type wherein the valve is provided with relatively strong biasing means urging the valve to its closed position so as to prevent fuel in chamber 18, conduit 51 at the downstream side of valve 52, and in conduit 37 between valve 38 and port 16 from passing through check valve 38 into chamber 3 due to the weight of such fuel during periods when valve 9 is closed. Such arrangement permits fuel chamber 18 to be filled with a fresh charge from a fuel reservoir 50 through conduit 51 by gravity action by opening valve 52 during periods when the starter turbine 1 is not in operation thereby avoiding the necessity for heavy, complicated, and expensive high-pressure fuel pumping means. After fuel chamber 18 has been filled, valve 52 is again closed so that only a "metered" amount of fuel is admitted to the starter turbine during its operation.

While a particular embodiment of the invention has been illustrated and described it will be obvious to those skilled in the art that various changes and modifications may be made without departing from the invention, and it is intended to cover in the appended claims all such changes and modifications that come within the true spirit and scope of the invention.

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

1. In a fluid feeding system, the combination comprising means for supplying fluid under pressure, a turbine power plant including a combustion chamber and a turbine, a pair of terminals adapted to receive electrical voltage, normally closed speed responsive switch means including means rotated by said turbine and operable to open at a preselected operating speed of said turbine,

first conduit means including normally closed electrically actuated valve means connecting said supply means to said combustion chamber, means including normally open switch means for energizing said valve means, and means connecting the normally open and the normally closed switch means and said valve means electrically in series with said terminals, whereby said speed responsive switch means open at said preselected operating speed of said turbine to de-energize said valve means and interrupt the supply of fluid in the combustion chamber, and clutch means included in said turbine, said clutch means operable in response to fluid pressure to engage a member in driving relation, and second conduit means connecting said clutch means to the first conduit means at a location between said valve means and said combustion chamber, whereby said clutch is engaged when fluid is being supplied to the combustion chamber and is disengaged when the supply of fluid is interrupted.

2. In a fluid feeding system, the combination comprising means for supplying fluid under pressure, a turbine power plant including a combustion chamber and a turbine, a pair of terminals adapted to receive an electrical voltage, normally closed speed responsive switch means including means rotated by said turbine operable to open at a preselected operating speed of said turbine, conduit means including normally closed electrically actuated valve means connecting said supply means to said combustion chamber, means including normally open switch means for energizing said valve means, and means connecting the normally open and the normally closed switch means and said valve means electrically in series with said terminals, whereby said speed responsive switch means opens at said preselected operating speed of said turbine to de-energize said valve means and interrupt the supply of fluid to the combustion chamer, an accumulater having a pressure receiving chamber and a fuel chamber with a movable wall between said chambers, second conduit means connecting the fuel chamber to the combustion chamber, means for supplying fuel to said fuel chamber, and third conduit means connecting the pressure receiving chamber to the first conduit means at the downstream side of the electrically actuated valve means.

3. In a fluid feeding system, the combination comprising means for supplying combustion supporting fluid under pressure, a turbine power plant including a combustion chamber and a turbine having clutch means operable in response to fluid pressure to engage a member in driving relation, first conduit means including normally closed voltage responsive valve means connecting said supply means to said combustion chamber, an accumulator having a pressure receiving chamber and a fuel chamber with a movable wall between said chambers, second conduit means connecting the fuel chamber to the combustion chamber, means for supplying a preselected amount of fuel to the fuel chamber, third conduit means connecting the pressure receiving chamber to the first conduit means at a location between said valve means and said combustion chamber, fourth conduit means connecting said clutch means to the first conduit means at a location between said valve means and said combustion chamber, a pair of terminals adapted to receive an electrical voltage, normally closed speed responsive switch means operable to open at a preselected operating speed of said turbine, means including normally open switch means for energizing the valve means, and means electrically connecting said valve means and said switch means in series with said terminals, whereby fluid under pressure and a preselected amount of fuel are supplied to the combustion chamber and the clutch means is engaged when said valve means is energized and the supply of fluid is interrupted and the clutch is disengaged at a preselected operating speed of the turbine.

4. A fuel feeding system comprising means for supplying combustion supporting fluid under pressure, walls defining a combustion chamber, first conduit means including a valve connecting said supply means to said

reaction chamber, an accumulator having a pressure chamber and a fuel chamber with a movable wall therebetween and having a pressure port communicating with the pressure chamber and a fuel port communicating with the fuel chamber, second conduit means connecting said fuel port to said combustion chamber, accumulator discharging means including third conduit means connecting said pressure port to said first conduit means at the downstream side of said valve, and means for charging said fuel chamber with a predetermined quantity of a second fluid when said valve is in a closed position whereby fuel and combustion supporting fluids are supplied to said combustion chamber when said valve is in an open position.

5. Apparatus in accordance with claim 4 wherein said third conduit means includes means establishing communication between said pressure port and the first conduit means at a location between said combustion chamber and said valve when the pressure at said location is at least equal to the pressure in said third conduit means and for interrupting said communication and establishing communication between said pressure port and the atmosphere when the pressure at said pressure port exceeds the pressure in said first conduit means.

6. A fluid feeding system comprising means for supplying a first fluid under pressure, walls defining a first chamber wherein said first fluid chemically unites with a second fluid in an exothermal reaction, first conduit means including a valve connecting said supply means to said first chamber, an accumulator having a second chamber and a third chamber with a movable wall therebetween and having a pressure port communicating with said second chamber, and a second port communicating with said

third chamber, second conduit means connecting said second port to said first chamber, accumulator discharging means including third conduit means connecting said pressure port to said first conduit means at the downstream side of said valve and means for charging said third chamber with a predetermined quantity of said second fluid when said valve is in a closed position whereby said first and second fluids are supplied to said first chamber when said valve is in an open position.

7. Apparatus in accordance with claim 6 wherein said third conduit means includes means establishing communication between said pressure port and the first conduit means at a location between said first chamber and said valve when the pressure at said location is at least equal to the pressure in said third conduit means and for interrupting said communication and establishing communication between said pressure port and the atmosphere when the pressure at said pressure port exceeds the pressure in said first conduit means.

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