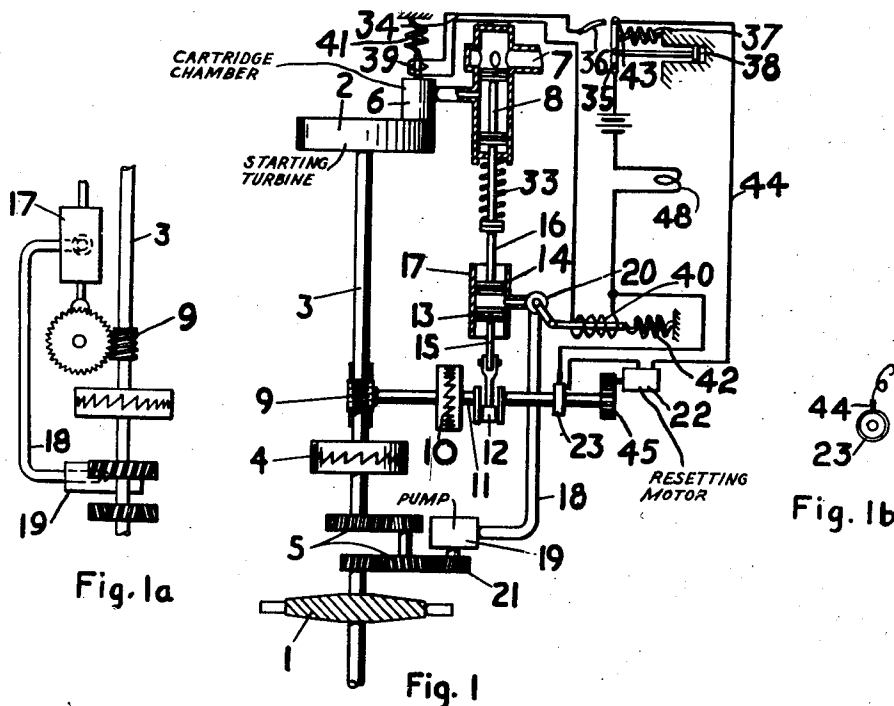
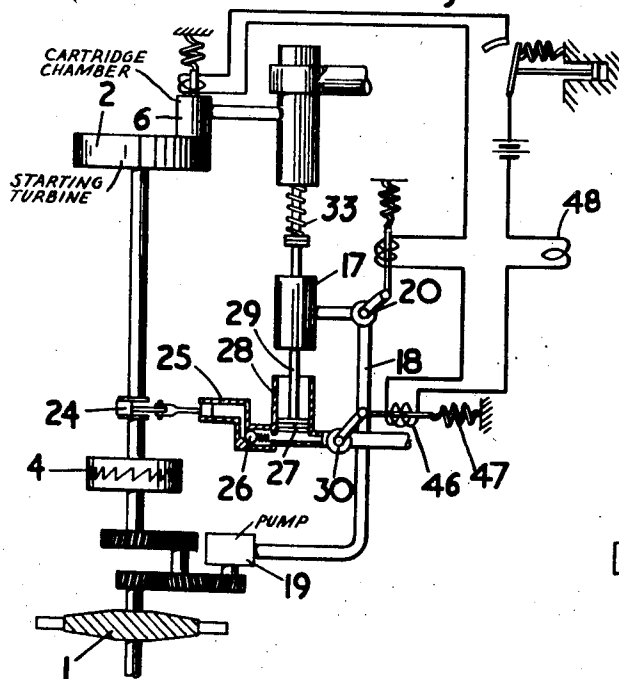
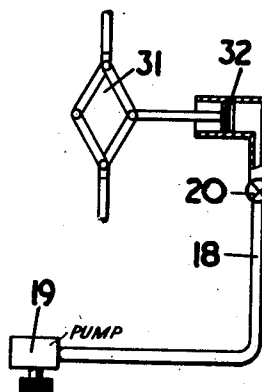


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 ROTARY STARTING MEANS FOR ROTARY ENGINES WITH CARTRIDGE
 CHAMBER AND SURPLUS GAS RELEASING MEANS
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ROTARY STARTING MEANS FOR ROTARY
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This invention relates to starting means for rotary engines of the kind in which the operating cycles of which are such as to require them to run at a given minimum rotational speed before useful power may be developed. The power necessary for accelerating the engine up to this minimum rotational speed is usually supplied by a motor, conveniently of the rotary type, which is coupled for that purpose to the engine.

The source from which the motor derives its energy is usually some form of energy reservoir from which the stored energy may be released when required. Such energy source may be one from which a predetermined quantity of energy may be released sufficient to accelerate the rotary engine, initially stationary, up to the required minimum rotational speed mentioned; the available energy, once released, being wholly dissipated. It is with starting means relying on an energy source of this kind, an example of which is a combustible cartridge, that the invention is concerned.

A disadvantage associated with such an arrangement is that, should it be required to start the engine when the latter is already rotating (at a speed between rest and the minimum required speed mentioned), the predetermined quantity of energy available at the source is then greater than is actually required for starting the engine. Since the engine, once having started, ceases to load the starting motor, the excess energy remaining at the reservoir may be permitted to expand itself in accelerating the unloaded starting motor or, alternatively, must be diverted away from the starting motor until it is wholly dissipated. In the first instance, since the excess energy may be a high proportion of the total energy available, the speed ultimately reached by the unloaded starting motor may cause serious damage to it. To avoid difficulties inherent in designing the motor for safe operation at speeds in excess of that corresponding to the minimum starting speed of the engine, the alternative expedient is adopted, and the invention proposes a controlling mechanism for diverting the excess energy from the starter motor when the latter speed is reached.

It has been proposed for this purpose to provide a speed responsive element, for example a centrifugal governor, which when the required engine speed is reached, operates to divert the excess energy. Such an arrangement has the disadvantage, however, that it is not positive in operation and may not actuate within the narrow limits of engine speed called for to preclude the possibility of dangerously overspeeding the

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starting motor. The present invention has for its object to provide a more reliable means of controlling the energy supplied to the starting motor.

The invention has for its basis the assumption that, for a given combination of engine and starting motor, the number of revolutions made by the engine on being started from rest and accelerated up to the minimum starting speed is approximately constant; similarly, in starting from any given speed intermediate between rest and the minimum starting speed, the number of revolutions made by the engine is again approximately constant. It is proposed, therefore, to divert the energy supply from the starting motor when a number of revolutions, dependent on the speed of the engine on starting, have been made.

Accordingly the invention provides a starting apparatus, suitable for use with a rotary engine of the kind indicated, comprising a rotary starting motor for supplying power to accelerate the rotary engine to its starting speed, and an energy reservoir from which energy may be released and supplied to the starting motor for the generation of such power, and means for terminating the supply of energy to the starting motor independence upon the number of revolutions made by said motor subsequent to the release of the energy in the reservoir, characterised by the provision of means for automatically modifying the number of revolutions of said motor required to actuate said energy supply terminating means in accordance with the rotational speed of the engine substantially at the instant of energy release.

The invention is deemed to be of particular importance in its embodiment in a plant incorporating a gas turbine, a turbo-starter and a starting energy reservoir in the form of a cartridge which, when ignited, releases a charge of energised gas to the starting turbine. An arrangement of this kind is commonly used in aircraft and the need for starting the main turbine in flight when it is already revolving frequently arises. In such a plant the starting turbine is conveniently coupled to the engine through a reduction gear to provide the necessary starting torque, the starter turbine thus running at a higher speed than the main turbine unit. A coupling of the ratchet type is also provided which permits the main turbine on starting to run away from the starter turbine, provided of course that the supply of energised gas to the latter is terminated; failing this, the starter turbine may follow up the main turbine and overspeed with dangerous results.

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By way of example, some constructional embodiments of the invention intended for use in such circumstances will now be described with reference to the accompanying drawings, in which

Fig. 1 illustrates somewhat diagrammatically one embodiment of the invention,

Fig. 1a is a view, looking to the right, of a portion of the mechanism shown in Fig. 1,

Fig. 1b is a view in elevation, looking to the right, of another portion of the mechanism shown in Fig. 1,

Fig. 2 is a view similar to Fig. 1 of a modified form of the invention, and

Fig. 3 illustrates a further modification of the structure illustrated in Figs. 1 and 2.

Figure 1 of the drawing represents a schematic arrangement of one such embodiment in which a gas turbine rotor 1 is driven for starting purposes by a starter turbine 2 through a shaft 3, a ratchet type coupling 4 and reduction gearing 5; the starter turbine is energised by gases generated from a cartridge in the chamber 6 from which a vent 7 to atmosphere is provided controlled by a piston valve 8. The starter turbine also drives, through a reduction gear 9 comprising a worm and wormwheel (shown in the part elevation of Figure 1a) and a ratchet type coupling 10, a shaft 11 carrying a crank 12, the reduction gear 9 being such that the number of revolutions of the starting turbine in accelerating the main turbine from rest to its starting speed will throw the crank through less than half a revolution. The crank 12 is connected by a link mechanism (to be described more fully below) to the piston valve 8 so that the valve opens when the starting turbine has completed the requisite number of revolutions to accelerate the main turbine to its starting speed. The arrangement described thus provides a positive starter turbine cutout when starting the main turbine from rest.

In order to provide for starts from any main turbine speed intermediate between rest and the minimum starting speed the link mechanism connecting the crank and the relief valve includes an element which is variable, in accordance with that intermediate speed, in such a way that the throw of the crank and thus the number of revolutions of the starter turbine required to open the piston valve 8 is appropriately reduced and the valve is therefore opened sooner after the cartridge is fired than is the case when the engine is started from rest. Such an element is afforded by a link of variable length consisting of two opposed pistons 13 and 14, whose push rods 15 and 16 are connected to the crank 12 and the valve 8 respectively, which are surrounded by a hydraulic cylinder 17. This cylinder is connected by a pipe 18 to the discharge of a rotary liquid pump 19 which is driven from the main turbine 1 and is of such a type that its discharge pressure is a function of the speed of the main turbine; the piston displacement under such pressure is similarly a function of the main turbine speed, since a compression spring 33, provided to resist movement of the piston valve 8 in the opening or upward, direction, also provides bias on one of the opposed pistons against a pressure rise between them. The relative positioning adopted by the pistons 13 and 14, and therefore the effective length of the link, when the main turbine is rotating at the intermediate speed is dependent on that speed. An electrical starting circuit 34 contains a manually operable switch arm 35 which, for starting, is brought into contact with an arcuate contact shoe 36 against the action of a re-

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turn spring 37. A dashpot 38 affords a time delay before contact between the switch arm 35 and shoe 36 is broken. The circuit includes a first solenoid 39 which when energised fires a starting cartridge and a second solenoid 40 which closes an isolating cock 20 in the pipe 18 and so cuts off the cylinder 17 from the liquid pump 19. Thus, when the starting switch is operated the length of the link thereafter will be constant and will correspond to the intermediate speed at that instant. The effect on the piston valve 8 of subsequent movements of crank 12 is accordingly modified and consequently the number of revolutions of the starting motor required to open the valve will be similarly modified.

It is apparent that the inclusion of this refinement does not affect the operation of the cut-out when starting the main turbine from rest since, in that case, the simultaneous firing of the cartridge and isolation of the pressure cylinder 17 leaves the opening of the relief valve solely dependent on starting turbine revolutions.

The fluid pump 19 may conveniently be that supplying lubricating oil to the main turbine, and may be driven through a gear wheel 21 from the starter turbine reduction gear 5.

Adjustment of the mechanism connecting the crank and relief valve for starting a stationary or moving engine would be determined during the engine starting tests.

The time delay afforded by the dashpot 38 before contact between the switch arm 35 and shoe 36 is broken is sufficient to permit starting and opening of the piston valve 8. When the contact is broken the cartridge firing and cock operating solenoids, 39 and 40, are reset by the action of return springs 41 and 42 respectively and, simultaneously, the switch arm engages a second contact 43 to complete an electrical resetting circuit 44. The latter includes a motor 22 which drives the crankshaft 11 through a reduction gear 45, to throw the crank 12 over the remainder of its revolution back to its initial position for starting as illustrated in Figure 1; when it reaches this position a rotary contact breaker 23 carried on the crank shaft (shown in elevation at Figure 1b) breaks the resetting circuit. The cycle of operations initiated by operation of the switch arm 35 is then completed and the device is ready for another start. The rotary contact breaker 23 is effective only in the initial position of the crankshaft and becomes ineffective immediately a partial throw of the crank 12 occurs, as on starting, but by then the resetting circuit is broken by movement of the starting switch arm 35 away from the contact 43, and is only completed upon its return. The electrical system also includes the main turbine igniter 48, which thus operates during starting.

As an alternative to the scheme described in the foregoing a further embodiment of the invention will now be described with reference to Figure 2 of the drawings. The arrangement of the piston valve and variable link mechanism is retained as in the previous embodiment. The starting turbine, in this case, drives, through a crank and connecting rod 24 a positive displacement hydraulic pump 25 which supplies fluid through a non-return valve 26 to the pressure side of a piston 27 contained in a cylinder 28. The push rod 29 of the piston 27 is connected to one end of the variable link mechanism previously described with reference to Figure 1. The output of the positive displacement pump 25 and the size of the cylinder 28 are so arranged that, when starting

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the main turbine from rest, the delivery from the pump when the main turbine starting speed is reached, will have moved the piston 27 in the cylinder sufficiently to open the piston valve 8. The correction to the displacement of the valve for starting the main turbine from an intermediate speed acts in the same manner as before. For resetting after starting in this embodiment, the cylinder 28 is provided with a relief cock 30 on the pressure side of the piston 27 which, when opened, allows the piston valve, returning under the action of the spring 19, to reset the piston. The operation of the cock 30 is effected by a third solenoid 46 in the starting circuit simultaneously with and in a manner identical to that of the isolating cock 20. This solenoid has a return spring 47 so that the release cock 30 is closed and opened when the starting circuit is respectively made and broken by operation of the starting switch. A separate electrical resetting circuit is, therefore, unnecessary in this embodiment.

As a refinement to each of the embodiments of the invention described, the exhaust valve could be either a balanced piston or poppet and could be designed to open very quickly, once it has commenced to exhaust, to prevent undue scoring by hot gases.

It will be realised that the variable link for applying a correction to the piston valve displacement in accordance with the main turbine speed may have other embodiments than that described. One alternative is shown in Figure 3 in which the link comprises four pin-jointed members forming a quadrilateral 31 opposite corners of which are connected respectively to the piston valve push rod and to the crank 12 in the embodiment of Figure 1 or to the piston 27 in the embodiment of Figure 2, whilst a third corner is connected to a piston 32 which is subjected, on one side, to pressure from the discharge of the rotary fluid pump 19.

I claim:

1. A starting apparatus suitable for use with a rotary engine of the kind indicated comprising a rotary starter motor for supplying power to accelerate the rotary engine to its starting speed, an energy reservoir from which energy may be released and supplied to the starter motor for the generation of such power, and means for terminating the supply of energy to the starting motor in dependence upon the number of revolutions made by said motor subsequent to the release of energy from the reservoir, characterised by the provision of means for automatically modifying the number of revolutions of said motor required to actuate said energy supply terminating means in accordance with the rotational speed of the engine substantially at the instant of energy release.

2. A starting apparatus suitable for use with a rotary engine of the kind indicated having a rotary starter motor for supplying power to accelerate the rotary engine to its starting speed, means affording a supply of pressurized gas releasable to drive said starter motor, valve means operable to divert said gas supply, after release, from said starter motor, and a valve operating mechanism comprising an element moveable in dependence upon the number of revolutions made by said starter motor after release of said gas supply and means transmitting the movement of said element to said valve means including a link

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mechanism of length variable in dependence upon the speed of the engine substantially at the instant of release of said gas supply, whereby the number of revolutions required of said starter motor to operate said valve means is modified in accordance with the rotational speed of the engine substantially at the instant of energy release.

3. A starting apparatus as claimed in claim 2 wherein is provided a fluid pump driven by the engine and discharging fluid having a pressure dependent on the speed of the engine, a piston movable under the pressure of said fluid to vary the length of said link mechanism and valve means operable substantially at the instant of release of said pressurised gas supply to the starter motor to interrupt the fluid connection between the pump and piston so as to maintain the length of the link mechanism thereafter constant and at a value corresponding to the engine speed substantially at the instant of release of said pressurised gas supply.

4. A starting apparatus as claimed in claim 3, wherein said link mechanism includes two opposed pistons operating in a common cylinder which receives fluid discharged by said engine driven pump, one piston being connected to said movable element of said valve operating mechanism and the other being connected to said valve means operable to divert the gas supply from the starter motor.

5. A starting apparatus as claimed in claim 3, wherein said link mechanism includes four links pin-jointed to form a quadrilateral, opposite corners of which are connected respectively to said movable element of said valve operating mechanism and to said valve means operable to divert the gas supply to the starter motor, and a third corner of which is connected to said piston.

6. A starting apparatus as claimed in claim 2, wherein said valve operating mechanism includes a crank shaft drivable by the starter motor so that the angular movement of the crank is dependent upon the number of revolutions of the starter motor.

7. A starting apparatus as claimed in claim 6, wherein the drive between the starter motor and said crank includes a coupling permitting movement of the crank in one direction independently of the drive, whereby the crank may be restored to a given angular position subsequent to operation of the starter motor.

8. A starting apparatus as claimed in claim 2 wherein said valve operating mechanism includes a fluid pump drivable by and discharging a quantity of fluid dependent on the number of revolutions of said starter motor, a cylinder connected to receive the fluid discharge by said pump, and a piston movable in said cylinder in accordance with the quantity of such fluid.

9. A starting apparatus as claimed in claim 8 wherein said cylinder is provided with a cock operable to permit discharge of fluid from the cylinder subsequent to operation of the starter motor.

10. A starting apparatus as claimed in claim 2 wherein said valve means operable to divert the gas supply from the starter motor is spring biased toward its inoperative position.

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No references cited.