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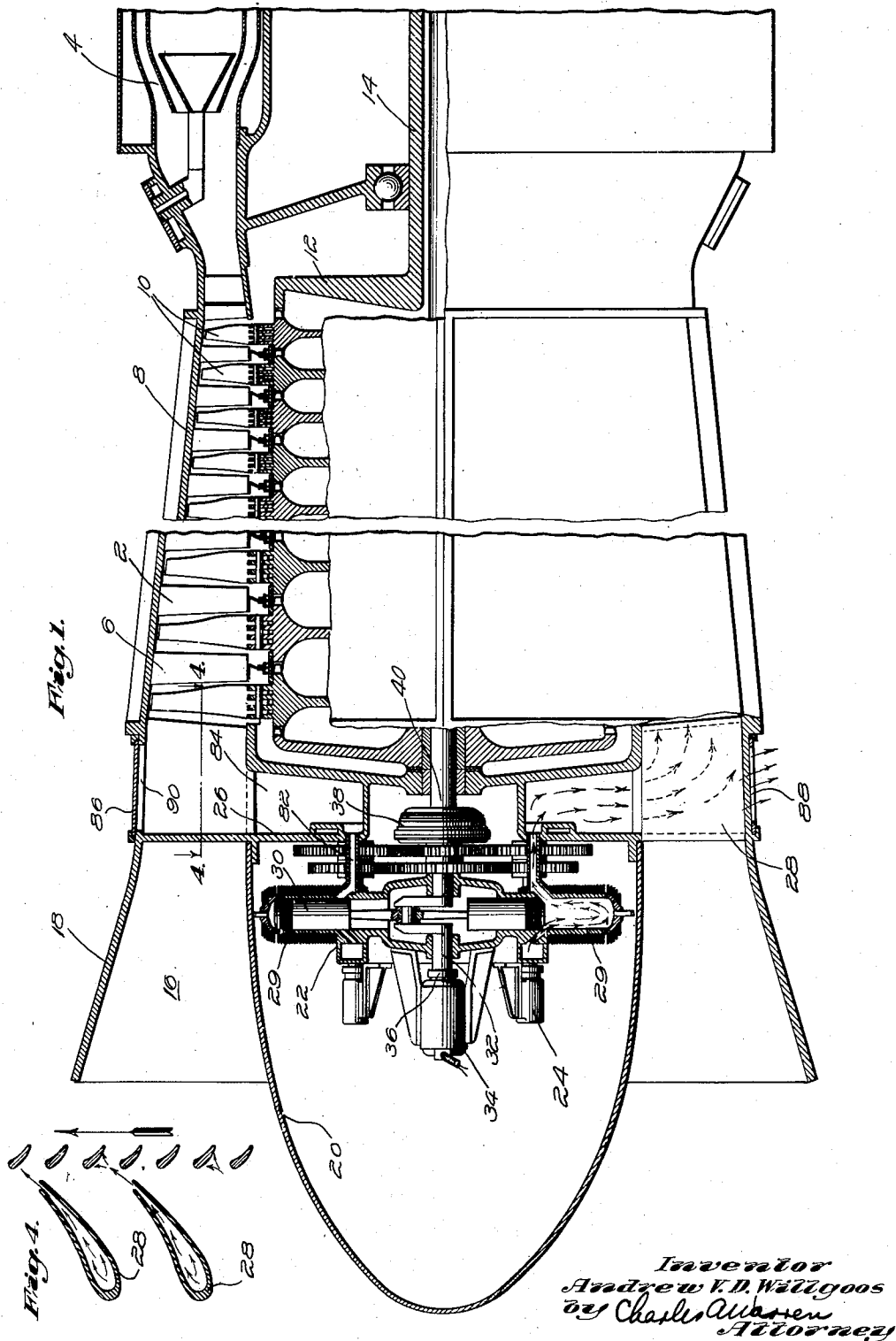
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STARTING DEVICE FOR COMPRESSOR-TURBINE UNITS

Filed May 13, 1948

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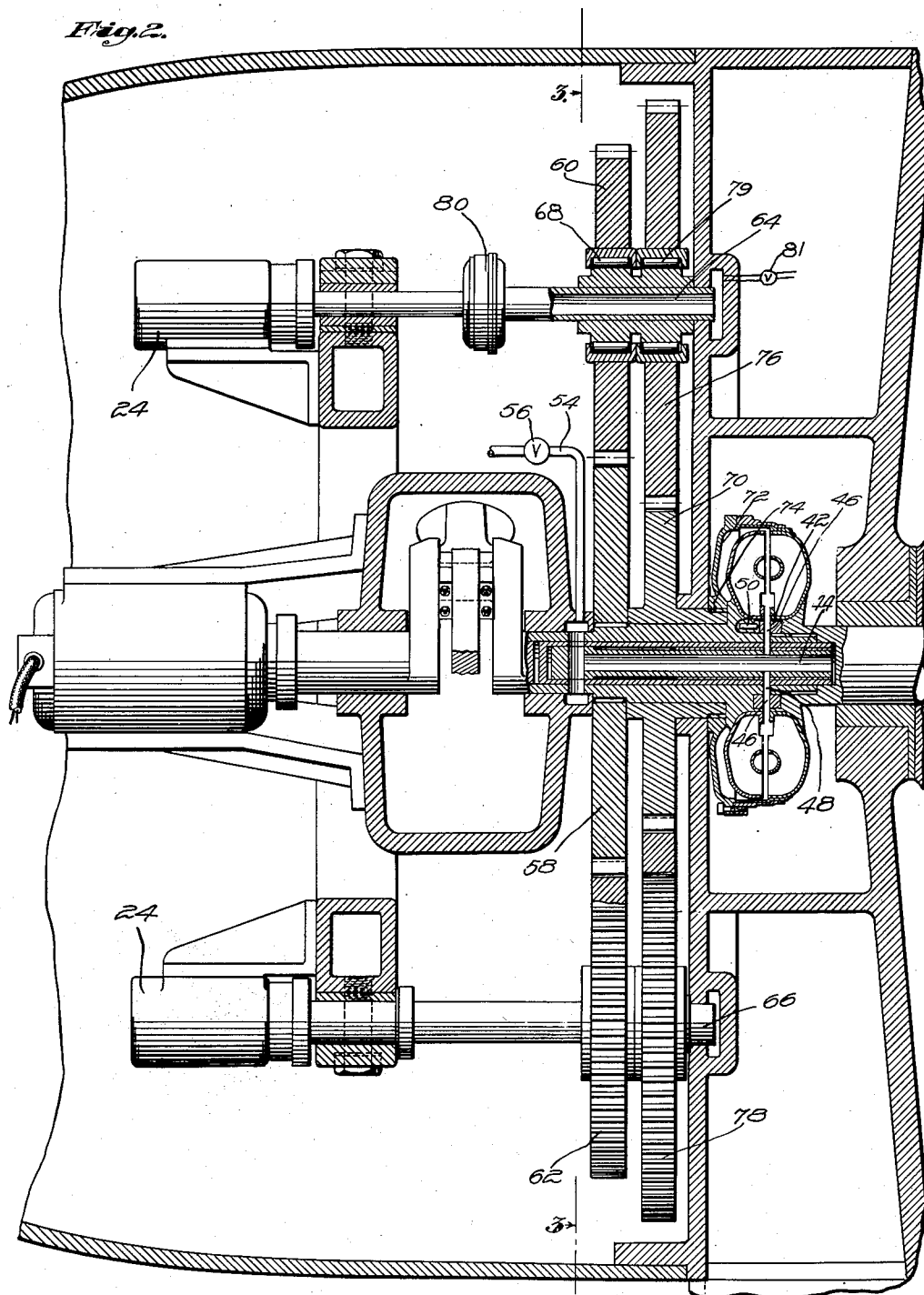
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Fig. 2.



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Fig. 3

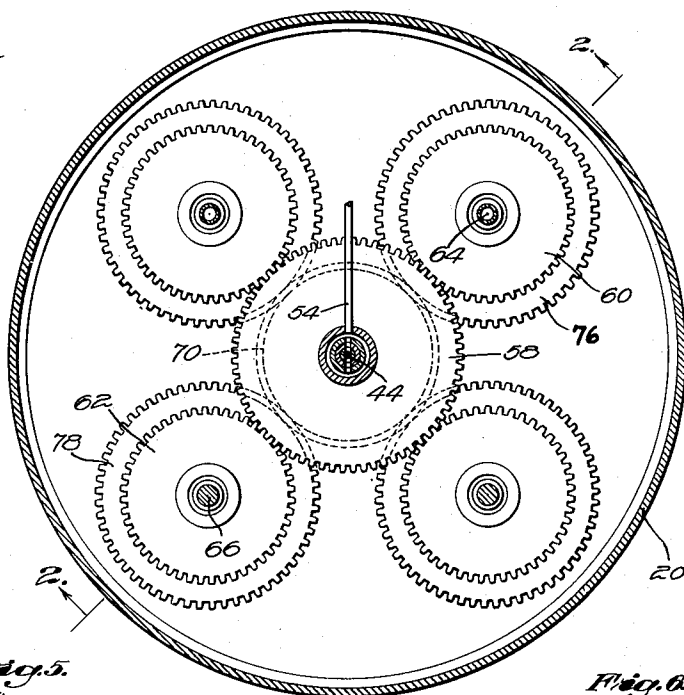


Fig. 5

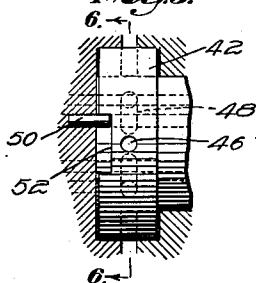


Fig. 6

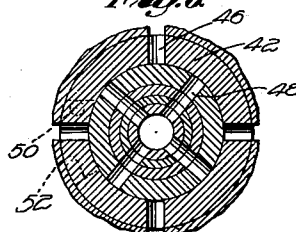
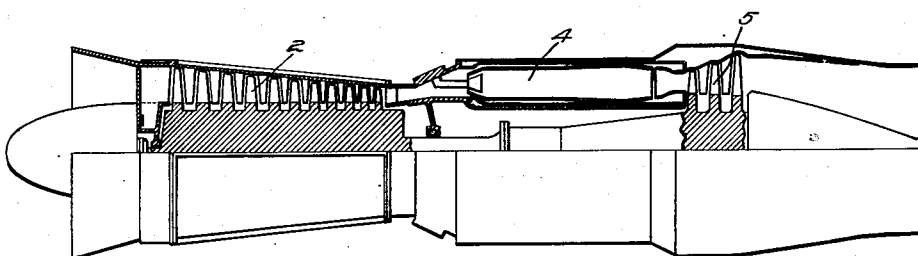


Fig. 7



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## UNITED STATES PATENT OFFICE

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## STARTING DEVICE FOR COMPRESSOR-TURBINE UNITS

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7 Claims. (Cl. 60-11)

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This invention relates to a starting device for compressor-turbine units and particularly to an arrangement for using the exhaust gas from the starting device.

Most compressors, particularly of the axial flow type, have stationary turning vanes located at the air inlet ahead of the rotor to give an initial spin to, or otherwise direct, the entering air. Under certain conditions, especially during flight, if the power plant is used in aircraft, ice may accumulate on the vanes seriously reducing the area of the air inlet. A feature of this invention is the heating of the vanes by exhaust gas from the internal combustion starting engine. Another feature is the discharge of the exhaust gas from these vanes into the inlet air for the purpose of warming any of the compressor blades for the removal of ice thereon. One feature is the discharge of the exhaust gas from the vanes in such a direction as to engage with and cause turning of the blades of the compressor rotor.

When a compressor-turbine power plant is shut down, it is advantageous to continue spinning the rotors for a short time to prevent uneven cooling which might cause warping or damage to the compressor, turbine, shaft bearings, or other parts through the transfer of heat from the turbine rotor. A feature of the invention is the use of a starting engine for continuing the spinning of the power plant after the fuel is shut off. This continued rotation will provide sufficient ventilation for cooling the power plant. During this cooling, exhaust gas from the engine may be delivered to the air stream through the power plant to prevent cooling too rapidly.

A feature of the invention is the interconnection of the starting engine and the compressor-turbine unit by a hydraulic coupling that will become inoperative as soon as the compressor rotor overruns the starting engine. Another feature is the arrangement of the hydraulic coupling so that it may be filled for the purpose of cranking the starting engine from the turbine.

In some installations it may be advantageous to operate the power plant accessories without operation of the power plant itself. A feature of the invention is an arrangement for driving the accessories from the starting engine or from the compressor rotor selectively.

Other objects and advantages will be apparent from the specification and claims, and from the accompanying drawings which illustrate an embodiment of the invention.

Fig. 1 is a sectional view through the power plant.

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Fig. 2 is a sectional view similar to Fig. 1 substantially on line 2-2 of Fig. 3 showing the connection between the starting engine and the power plant on a larger scale.

Fig. 3 is a sectional view along line 3-3 of Fig. 2.

Fig. 4 is a fragmentary sectional view substantially along line 4-4 of Fig. 1.

Fig. 5 is a view of a part of the control valve for one of the fluid couplings.

Fig. 6 is a fragmentary sectional view on line 6-6 of Fig. 5.

Fig. 7 is an elevation view of the power plant.

With reference first to Figs. 1 and 7, the power plant is shown only fragmentarily and includes a compressor 2 delivering air to one or more combustion chambers 4 in which the air is heated before it reaches the turbine 5. The compressor shown is of the axial flow type having a number of rows of stationary vanes 6 supported by a casing 8 and alternating with rows of blades 10 on the rotor 12. The latter is connected as by a shaft 14 to the turbine rotor by which the compressor is driven. The compressor has an annular inlet 16, the outer wall of which is formed by an extension 18 of the casing and the inner wall of which is formed by a dome 20 within which are located the starting engine 22 together with the accessories 24 and the mechanism by which the accessories are driven as will hereinafter appear. The accessories and the starting motor are preferably carried by a supporting member 26 positioned within the casing 8 by a row of compressor inlet vanes 28, the latter being hollow as shown more clearly in Fig. 4. The vanes 28 may be arranged in the form of airfoils for imparting a tangential motion to the air in the direction of rotation of the rotor 12.

The starting engine is shown as a radial diesel, although the specific engine construction is not important. It has been found that, with a radial engine, it is possible to locate the accessory drives between the adjacent cylinders 29 of the engine. The pistons 30 for the engine are connected to a crankshaft 32. A starting motor 34 is mounted at one end of the crankshaft for starting the engine 22. An overrunning clutch 36 permits the starting motor 34 to be stopped after it has cranked the engine.

The crankshaft 32 is also connected through a fluid coupling 38 to the forwardly extending shaft 40 on which the compressor rotor is mounted. The fluid coupling, as better shown in Fig. 2, may be conventional, the impeller and runner of

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the coupling being connected respectively to the crankshaft and to the shaft 40. The flow of fluid into the coupling may be controlled by an annular ring valve 42, which, in the normal position, admits fluid from a passage 44 in the crankshaft to the coupling. The ring valve 42 during the starting of the power plant is held in such a position that the ports 46 in the valve are in alignment with the ports 48 in the crankshaft. The valve is held in this position by a projecting pin 50 mounted in the crankshaft and engaging in a slot 52 in the ring. When the power plant begins to operate under its own power and overspeeds the starting engine, the frictional drag on the ring 42 moves it angularly with respect to the crankshaft as limited by the pin 50 so that the ports 46 and 48 are out of alignment, as shown in Fig. 5, and the admission of fluid to the coupling is discontinued. Small bleeds, not shown, in the coupling housing provide for the circulation of fluid through the coupling to prevent overheating and permit any fluid remaining in the coupling after the supply is shut off to be drained. In addition to the automatic shut off of the fluid supply to the fluid coupling, the conduit 54 through which the fluid is supplied may be provided with a manually controlled valve 56. By closing this valve no fluid reaches the fluid coupling and the starting engine may operate independently of the main power plant.

The accessories 24, Fig. 2, may be driven selectively by the starting engine or by the power plant. One arrangement by which the drive from the starting engine may be accomplished includes a gear 58 keyed to the crankshaft and meshing with cooperating gears 60 and 62 on the accessory drive shafts 64 and 66. An over-running clutch 68 may be provided in the hub of the gear 60 (and 62) for driving the accessory shaft when gear 60 or 62 is rotated in the accessory driving direction. The clutch 68 will permit the accessory drive shaft to rotate with-in gear 60 or 62 in the same direction.

The drive from the power plant is similar and includes a central gear 70 connected to the main shaft 40 through the medium of the housing 72 on the fluid coupling. The housing 72, as shown, may have a spline connection 74 with the hub of gear 70. This gear 70 meshes with gears 76 and 78 mounted on and connected as by over-running clutches 79 to the same accessory drive shafts 64 and 66. Thus, the accessory drive shafts may be rotated by the gears 76 and 78 while the gears 60 and 62 are stationary or the accessories may be driven through the gears 60 and 62 while the gears 76 and 78 are stationary.

For relieving the load on the starting engine while it is being started, or while it is starting the main power plant, certain accessories may be disconnected from the drive as by hydraulic couplings located in the accessory drive connections. For example, as shown in Fig. 2, shaft 64 may be coupled to its accessory by a hydraulic coupling 80 to which fluid may be supplied through the hollow shaft 64. A suitable valve 81 in the supply line provides for controlling the supply of fluid.

It will be understood that it may be advantageous to drive the power plant accessories at a time when the power plant is not operating. The above described accessory drive makes possible operation of the accessories directly from the starting engine while the latter is disconnected from the power plant.

It may be necessary prior to starting of the

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power plant, or during operation, to prevent the formation of ice in the compressor or to remove an accumulation of ice already formed. This may be accomplished by delivering exhaust gas from the starting engine into the air stream entering the compressor. To this end, the exhaust ports of the engine cylinders are connected as by ducts 82, Fig. 1, to a chamber 84 in the housing 26. This chamber communicates, as shown, with the hollow vanes 28 which are open at their trailing edges, as shown in Fig. 4, for the discharge of the exhaust gas into the air stream as it enters the compressor. The formation of ice on the guide vanes is accordingly prevented and the air passing through the compressor is warmed sufficiently to prevent any ice formation in any part of the compressor. It may be understood that the delivery of the exhaust gas to the air stream may occur prior to starting of the power plant where ice has already formed within the compressor since the starting engine may operate independently of the main power plant. The hot gas may also be delivered to the compressor during operation of the main power plant. During the cooling down period of the power plant when it has shut down, the warm exhaust gases may be admitted to the air stream to reduce the rate of cooling of the power plant parts located within the stream.

It may be noted that the gas discharging from vanes 28 has a tangential velocity in the direction of rotation of the compressor rotor. The impact of this gas on the vanes 10 of the first compressor stage (see Fig. 4) exerts a torque on the rotor to assist the starting engine in setting the rotor in motion.

When the power plant is in operation and heating of the air entering the compressor would not be advantageous, the exhaust gas may be discharged directly through the inlet vanes 28 to the atmosphere through ports in an annular ring 86 which surrounds the compressor casing externally of the vanes 28 and may be moved annularly to place the ports 88 in the ring in alignment with similar ports 90 in the casing which communicate with the hollow interiors of the inlet vanes. To assure flow through ports 88 and 90, the width of the opening in the trailing edge of vanes 28, as can be seen in Fig. 4, is relatively narrow so that the pressure drop across the opening is substantial.

It may be advantageous to provide for motor-ing the power plant, as, for example, when the power plant is being shut down. It has been found, if the power plant is turned over slowly during its cooling period, that the rate of cooling for all the parts is more uniform and damage to the power plant by reason of differential cooling is less probable. With the arrangement above described, the starting engine may be used to turn the rotor of the power plant slowly during such cooling down period. During this cooling down period, any desirable part of the exhaust gas may be discharged into the air flowing through the power plant for controlling the rate of cooling.

It is to be understood that the invention is not limited to the specific embodiment herein illustrated and described, but may be used in other ways without departure from its spirit as defined by the following claims.

I claim:

1. In a power plant, a compressor, a turbine connected to and driving the compressor, a com-

bustion chamber between the compressor and the turbine, and an internal combustion engine mechanically connected to the compressor and turbine for starting the power plant, in combination with means for discharging exhaust gas from the engine into the compressor inlet.

2. In a power plant, a compressor including a bladed rotor and having a series of stationary hollow vanes at its inlet end arranged for imparting a tangential motion to the inlet air, a reciprocating engine for driving the compressor rotor, means for discharging exhaust gas from the engine through said hollow vanes, each of said vanes having an opening defined by and extending along the trailing edge thereof and through which exhaust gas is discharged from within said vanes into the airstream entering the compressor, said trailing edge openings directing said exhaust gas against said bladed rotor to cause turning of the rotor.

3. In a power plant, a compressor, a turbine connected to and driving the compressor, a combustion chamber between the compressor and the turbine, and an internal combustion engine connected to the compressor and turbine for starting, in combination with means for discharging exhaust gas from the engine into the compressor inlet and a releasable driving means between the engine and the compressor and turbine, such that the engine may operate independently of the compressor and turbine.

4. A gas turbine power plant including a compressor having an air inlet, means for heating the compressed air from the compressor, and a turbine driven by the heated air, said turbine and compressor rotors being interconnected such that the turbine drives the compressor, in combination with an internal combustion engine, and means for discharging exhaust gas from the engine into the compressor inlet.

5. A gas turbine power plant including a compressor having an air inlet, means for heating the compressed air from the compressor and a turbine driven by the heated air, said turbine and compressor rotors being interconnected such that the turbine drives the compressor, in combination with an internal combustion engine for starting the power plant, a releasable connection between the engine and the compressor and turbine, means for releasing the connection when the compressor and turbine overrun the engine, and means for

discharging exhaust gas from the engine into the air in the compressor.

6. In a gas turbine power plant including a compressor and turbine, each having a rotor, and a burner in which air from the compressor is heated before it reaches the turbine, the steps which involve spinning the rotors from an internal combustion engine after shut down of the power plant and simultaneously admitting exhaust gas from the engine to the compressor inlet.

7. A gas turbine power plant including a compressor having an air inlet, a compressor rotor, means for heating the compressed air from the compressor, and a turbine rotor driven by the heated air, said turbine and compressor rotors being interconnected such that the turbine rotor drives the compressor rotor, and accessories driven by said turbine rotor, in combination with an internal combustion engine, an hydraulic coupling connecting said engine and said power plant, said coupling comprising essentially an impeller and a rotor surrounded by a housing and means for driving said accessories selectively by said power plant through said coupling housing or by said engine.

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