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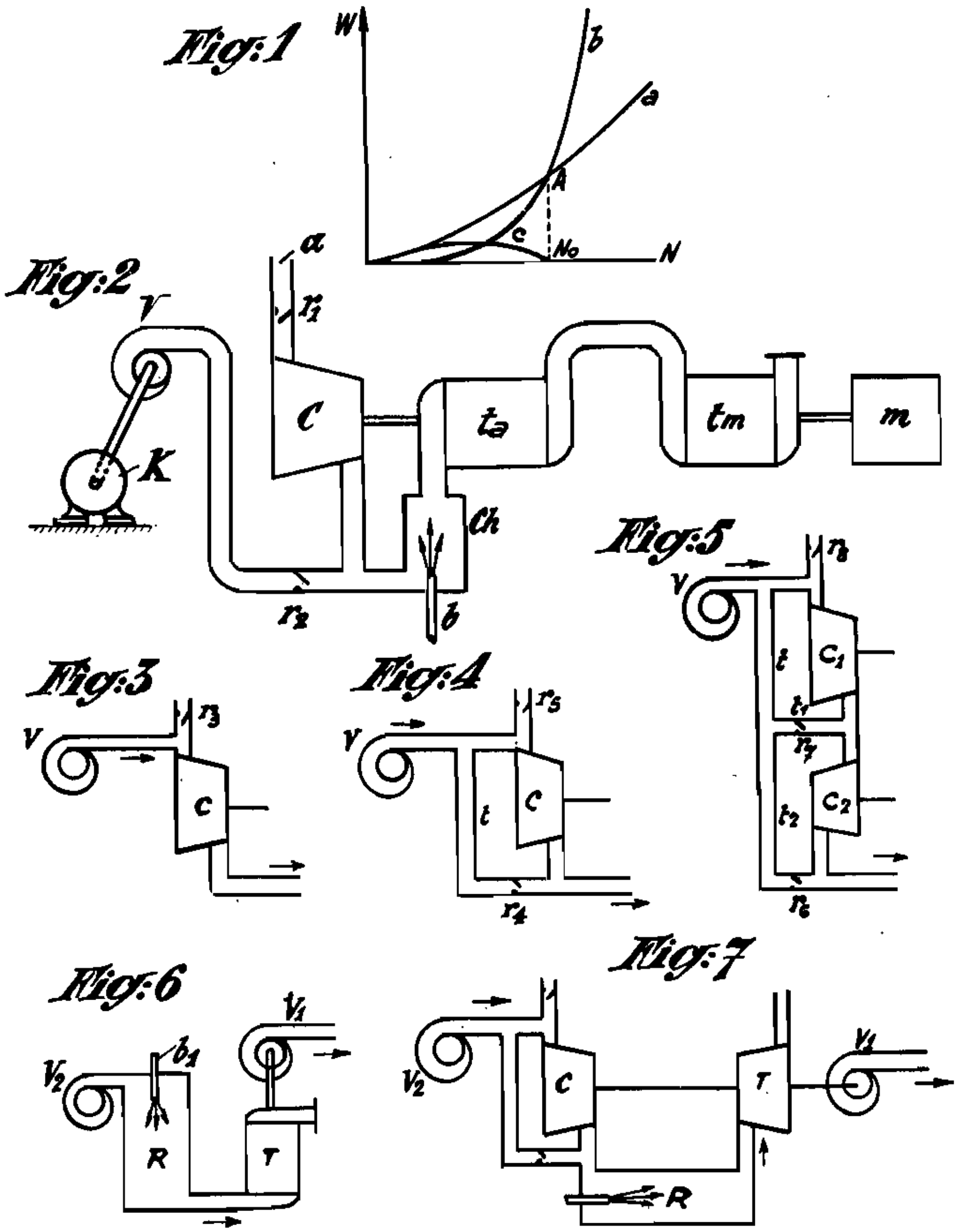

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DEVICES FOR STARTING GAS TURBINE MOTOR PLANTS

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The present invention refers to the starting of thermal gas turbine motors. Starting devices are already known in which a power supplement is supplied to these motors by means of an auxiliary motor driving directly, or by means of a clutch, or by gearing, one of the shafts of the motor to start. But in these devices it is generally necessary to have recourse to an important installed power supplement.

According to the present invention, the power supplement necessary for starting is supplied in the form of pneumatic energy by a fan operating in series or in parallel, or successively and automatically according to both of these coupling possibilities, with the compression stages of the thermal gas turbine motor. The fan can be driven directly by this auxiliary motor or by a small gas turbine receiving its power from a second fan, less powerful, driven by the auxiliary motor with amplification of this power by combustion in the midst of the air supplied, or again by an auxiliary thermal gas turbine motor set off in advance by any auxiliary motor whatever; thus, in these two latter methods of driving the starting fan a sort of relay of the power involved is obtained.

The description which follows, with reference to the appended drawing, given by way of nonlimitative example, will allow a thorough understanding of how the invention may be embodied, those peculiarities which appear both in the drawing and in the description constituting of course a part of the invention.

Fig. 1 represents curves the object of which is to render the principle on which the invention is based intelligible.

Figs. 2 to 7 illustrate in a sketch-form various embodiments of a starting device according to the invention.

When the speed of a thermal gas turbine motor increases from zero, the power taken by the air compressor, and, possibly, by the driven unit when the latter cannot be thrown out of gear or unloaded, increases with the rotation speed according to a law such as the one represented by curve *a* of Figure 1. The power output of the turbine depends on the speed and on the temperature of the motive gases and for each speed of the motive unit there is, for the turbine, a corresponding temperature limit for the mechanical organ most exposed. The maximum power which the turbine can safely deliver is then represented with relation to the speed by a curve such as *b*.

For low speeds, the curve is always located below the curve *a* which it cuts at A which point corresponds to a rotation speed number. Beyond speed number, the set is capable of operating alone and of supplying useful power. From a speed equal to zero to one number, that is while the motor comes up to speed, it is necessary to supply it with a power supplement represented by curve *c* in relation to the rotation speed.

The devices which will be described with reference to Figures 2 to 7 allow this result to be obtained in a rational manner.

In all of these figures, nothing is taken for granted as concerns the control means for the compressor of the thermal motor at rated load. In particular, the present invention applies just as well to thermal gas turbine motors with one or more lines of shafting, whether the compressor be operated or not by a turbine distinct from the motive turbine properly speaking and whatever be the grouping of the turbines connected in series or in parallel.

On Fig. 2 can be seen at C an air compressor which sucks in atmospheric air through conduit *a* and drives it towards the auxiliary turbine *ta* which is used to drive this compressor C. During this course, between the compressor C and the turbine *ta*, the air is heated in the combustion chamber *Ch* by the combustion of a liquid fuel fed by the burner *b*; the gases having performed work in the turbine *ta* then pass into the motive turbine *tm* the object of which is to supply useful power and drive an electric generator for example. The invention refers to the device which is used to start the gas turbine motor composed of the auxiliary turbine *ta*, of the compressor C and of the motive turbine *tm*. This starting device comprises a fan V which may be driven while the motor is coming up to speed by an auxiliary motor *k* (electric motor for instance). The delivery piping of this fan is connected to the delivery piping of the compressor C between this compressor and the combustion chamber *ch*. The suction end of compressor C is provided with a draught check valve r_1 the object of which is to prevent any return flow of the compressor current.

During the starting period, this check valve automatically opens when the compressor, having reached a high enough speed, the latter supplies a difference of pressure equal to that of the starting fan. r_2 is a draught check valve the object of which is to prevent the passage of the compressor current through the starting fan conducts. This check valve automatically closes when the compressor supplies a pressure greater than that of the starting fan.

Let W be the maximum power supplement to be supplied during the starting period of the thermal motor; let W_v be the power supplied to the fan having a yield ρ_v, the available power of the air driven by the fan is $\rho_v W_v$. In the combustion chamber of the thermal motor, the use in the temperature of the air multiplies the available power by an amplifying factor K. At the inlet end of the gas turbine of the motive set a power $K\rho_v W_v$ is consequently available and if the yield of the latter is ρ_t, the available supplementary power on the shaft of the turbine is $K\rho_t\rho_v W_v$, which must be at least equal to W. By this means and by burning only a small supplementary quantity of fuel the starting of the thermal motor can be ensured.

Moreover, and since the product $K\rho_t\rho_v$ is in general greater than unity, the power of the motor which drives the starting fan will be equal to

$$\frac{W}{K\rho_t\rho_v}$$

that is to say inferior to W. By an appropriate construction, the product of the yields $\rho_t\rho_v$ can, even during the low speed starting periods, be equal to 0.5; the factor K can be very substantially greater than 2 so that the factor $K\rho_t\rho_v$ can be substantially greater than unity.

According to the embodiment shown in fig. 3, the starting fan V is mounted in series with the compressor. A draught check valve is branched onto the connecting piping between the delivery end of the fan and the suction end of the compressor; it closes when the fan ensures an overpressure at the suction end of the compressor and opens when the fan is stopped or when it does not supply driving pressure.

At the beginning of the starting period, the compressor resists, to a certain extent, the passage of the air current driven by the fan, so that during this starting period this embodiment is not as good as the preceding one. When the speed of the compressor increases, the point representing the operation of the fan located on its supply-pressure curve moves towards the increasing-supply zone and so it happens that at the end of the starting period the driving pressure of the fan becomes nil. At that moment, the check valve r_3 automatically opens; the compressor directly sucks in free air and the motor controlling the starting fan can be stopped.

In the embodiment of fig. 2, at the beginning of the starting period, the discharge of the compressor is nil, then increases progresisvely so that it can be brought to operate momentarily in a pumping zone. The embodiment of fig. 2 is consequently, from this point of view, not as good as that of figure 3 in which the compressor reaches its point of normal operation within the low pressure zone.

The embodiment of fig. 4 offers the advantage of the two preceding embodiments without having any of their inconveniences. The starting fan is simultaneously connected above and below the compressor. At the beginning of the starting period, as a result of the resistance which the compressor offers, the discharge of the fan nearly entirely takes place through the pipe t by-passed with regards to the compressor and the conditions of fig. 2 then prevail.

The compressor accelerates and the fraction of the air discharged by the fan and passing through the compressor increases. From a certain time on, the pressure at the delivery end of the compressor is greater than that generated at the delivery end of the fan. The check valve r_4 then automatically closes, the discharge into conduit t becomes nil and operating conditions are those of fig. 3. A check valve r_5 is mounted on a branch pipe of the connecting piping between the delivery end of the fan and the suction end of the compressor. This check valve stays closed as long as the fan ensures an overpressure; and opens to allow the compressor to suck in free air directly, as soon as the motor controlling the starting fan can be stopped.

As the operating conditions of figure 2 occur only at the beginning of the starting period during which the compressor is functioning at a low speed only, pumping risks which depend to a large extent on the compressibility of the air and on the mechanical power involved are non-existent.

Fig. 5 concerns a way of putting into practice the embodiment of fig. 4 in the case where two compressors C_1 C_2 are operated in series. The way in which the gas turbines controlling these compressors are grouped is immaterial. At the beginning of the starting period, nearly all of the discharge of the fan passes through the by-pass conduit t, the passage of the air through the compressors at rest meeting with a substantial resistance. The high pressure compressor C_2 being the smaller, starts off first; in accelerating, its resistance diminishes and a moment is reached when, thanks to the pressure it generates, the ehcck valve r_6 closes, thereby suppressing any air discharge through the by-pass conduit t_2. The speed of the low pressure compressor C_1 also increasing, a moment is reached when the check valve r_7 closes thereby suppressing any air discharge in the by-pass conduit t_1; the entire discharge of the starting fan then passes through both compressors. A check valve r_8 is mounted on a branch pipe of the connecting piping between the delivery end of the fan and the suction end of the compressor C_1. This valve remains closed as long as the fan ensures an overpressure and opens to allow the compressor C_1 to suck in free air directly as soon as the motor controlling the starting fan can be stopped.

The application of the same lay-out may be extended to a group of any number whatever of air compressors mounted in series.

According to another embodiment of the invention, the power to be installed for starting purposes is reduced by having recourse to the following system.

With reference to fig. 6, the starting fan V_1, operating in conjunction with the compressor or compressors (not shown) of the gas turbine motor, in any one of the ways which have just been described, for example as shown in fig. 4, is controlled by a small auxiliary gas turbine T. A fan V_2 supplies the necessary compressed air for this turbine which air passes into a combustion chamber R where a certain quantity of fuel is burnt by a burner b_1. This fan V_2 is driven by an auxiliary motor (electric, for instance). In the case of a motor, driving V_2, the power of which is P, the power obtained from the compressed air in the auxiliary cycle is 0.8 P if the yield of the fan V_2 is supposed to be 0.8. This power is multiplied in the combustion chamber R by a certain factor; if the value of this factor is estimated as being 2, the power available fed into the turbine T is 1.6 P and for an efficiency value of 0.8 for this turbine, the power output of same for driving the starting fan V_1 is 1,3 P.

This increase in the power supplied initially by the auxiliary motor is obtained at the cost of a certain consumption in fuel; however it is of no importance since it occurs only during the starting period.

The device which has been described can, of course, be utilized in operating fans set according to one of the several starting embodiments of Figs. 2, 3, 4, 5. The turbine T can also be coupled directly, or by means of a clutch, or by means of a speed reducer to the shaft of the main motive set.

Finally, the device may be used as a relay and each step may be multiplied in series with the preceding one thus furnishing an amplification of the starting power available. For example, the fan V_1 would discharge into a second combustion chamber similar to R_1 the gases produced driving a second turbine similar to T, but more powerful, which would in turn drive a fan more powerful than V_1 and so on up to the last fan of sufficient power to be coupled to the compressor or compressors in one of the ways described in connection with Figs. 2 to 5.

This manner of putting the invention into practice can itself be embodied in a particular way whereby the starting of the set is obtained by a thermal auxiliary gas turbine motive unit which supplies the power necessary for the driving of the starting fan V of the main set.

On Fig. 7, C is the compressor of this auxiliary unit, T its turbine and R its combustion chamber. The starting of the auxiliary unit is itself obtained either by the well known method consisting in utilizing a motor furnishing a power supplement, or by one of the devices constituting the object of the present invention. (This last case is that of Fig. 7 in which is shown a fan V_2 operating in conjunction with the compressor C in the manner described Fig. 4).

If the power necessary for starting a thermal gas turbine motor of 10,000 HP is, for instance, 500 HP the auxiliary gas turbine unit for starting purposes will have a power of 500 HP and in order to start said unit, approximately 25 HP for the fan V_2 will suffice. This auxiliary thermal motor can, once the main set has been started, be utilized for example for driving the auxiliary apparatus of the main set.

Finally, if a power installation comprises, side by side, several thermal gas turbine motors, one and only one auxiliary set will suffice to ensure the starting, one after another, of each of the main thermal motors by means of an appropriate distributing piping.

It is obvious that changes could be brought to the embodiment just described without, by so doing, going beyond the scope of the present invention.

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