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STARTING UNIT, MORE PARTICULARLY FOR INTERNAL-COMBUSTION ENGINES, AND METHOD OF OPERATING SAME

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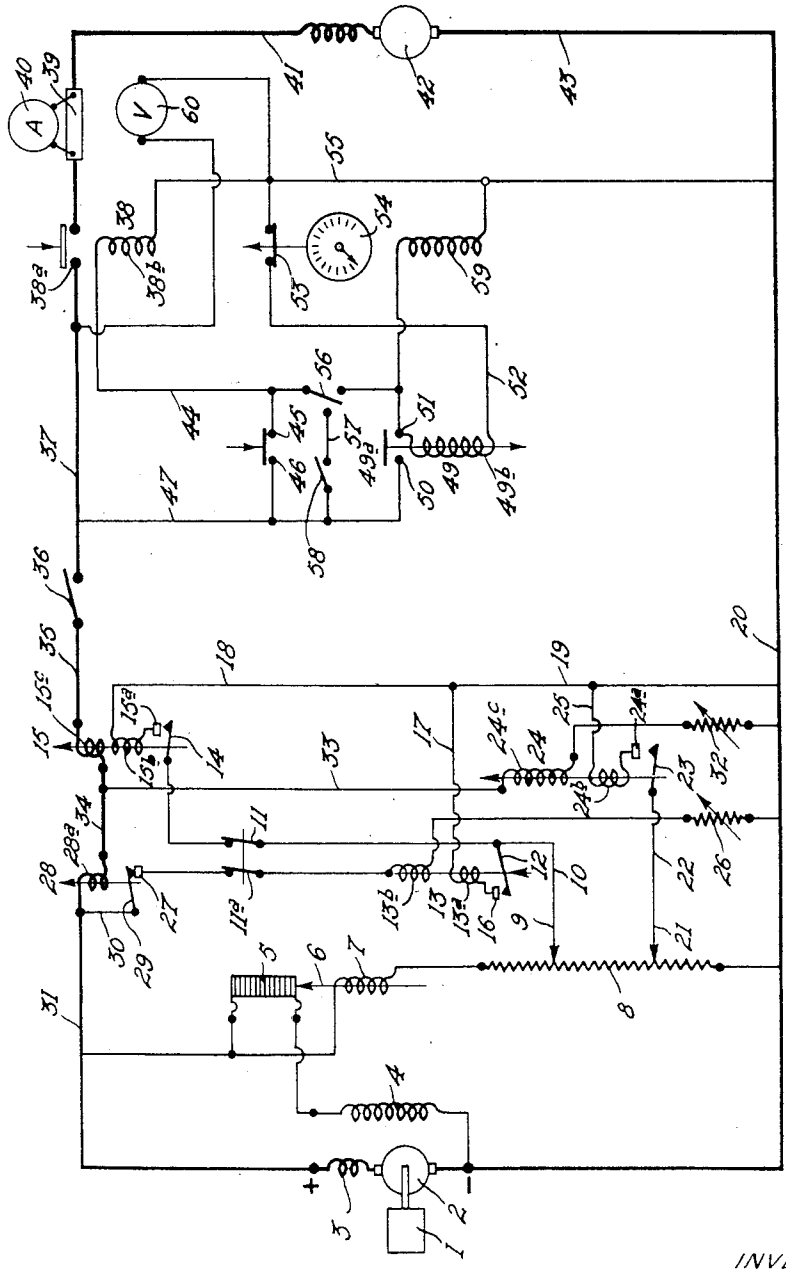

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STARTING UNIT, MORE PARTICULARLY FOR INTERNAL-COMBUSTION ENGINES, AND METHOD OF OPERATING SAME

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The electrical starting of turbo-jet engines, in particular, is effected by an electric motor which, when in operation for starting, is mechanically connected to the rotor of the gas turbine engine through a suitable reducing gear. Electric current is supplied to said electric motor from a storage battery or other constant voltage source through a set of contactors and resistances so that the current flow is conveniently controlled. The number of starting stages is generally no more than two or three in order to provide a relatively light and simple equipment. The passage from one stage to the next produces current peaks in the starting motor circuit, which may reach or exceed three times the final running intensity, and therefore the full power may not be increased by means of a higher voltage, which would result in undesirable high current intensities. As a further drawback besides the resulting heating, such current peaks cause troubles in the starting motor commutation and fatigue of the battery and/or the starting unit.

The power absorbed by the started engine, more particularly in the case of a gas turbine, increases rapidly as the speed of revolution of said started engine increases; therefore, for a quick start, the starting motor should reach as high a power as possible, which can be achieved only by increasing the voltage in the last stage of the starting operation. If the known starting rheostat devices were to be used, the number of starting stages should be considerably increased, as is the practice in electric traction for example, which would however result in unduly complicated and heavy equipment with a very low efficiency causing imperfect utilization of the power of the batteries and starting units.

The object of the present invention is to eliminate such a drawback by feeding the starter of an internal combustion engine in such a way that a constant intensity electric current is supplied under a voltage which increases from a determined minimum value during the starting period.

In a particular embodiment of a device to carry out the above specified current feeding method, the starting unit comprises an internal combustion starting engine mechanically connected to a starting electric generator the field coil of which is fed by the armature by being connected in parallel therewith, the branch circuit of the field coil comprising in series a regulator of the type comprising a pile of carbon discs, said pile being pressed or released by an electromagnetic member the circuit of which is controlled by pilot regulators of the vibrating contact type.

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Said constant current generator, the voltage of which increases from a minimum value, is preferably associated with a time-operated circuit-breaker adapted to cut off the starter from its current supply after predetermined interval of time.

In order that the invention may be more clearly understood and readily carried into practice, it will now be described more fully and illustrated, by way of example only, in the accompanying diagram, which shows the various elements of a constant current, variable tension starting unit and their connections.

The installation comprises an internal combustion starting engine 1 mechanically connected to drive a starting electric generator 2, the armature of which is connected in series with a coil 3 for compound excitation. The shunt field coil 4 of generator 2 is connected to one pole thereof directly and to the other pole through a pile 5 of carbon discs. Said pile 5 is pressed or released by the armature 6 of a solenoid the coil 7 of which is in series with a calibrating multiple tap resistor 8 in a circuit connected in parallel with said generator 2.

The calibrating resistor 8 has two tappings for feeding voltage and intensity pilot vibrator switches. Tapping 9 is connected to lead 10 which includes a switch blade 11. At a point between tapping 9 and switch 11 is connected the vibrating member 12 of the basic voltage pilot regulator 13. Beyond switch 11, lead 10 is connected to the vibrating member 14 of the intensity pilot regulator 15.

The stationary contact 16 of regulator 13 is connected to one end of the continuous oscillation keep-up coil 13a whereof the other end is connected to a lead 17. The stationary contact 15a of the intensity pilot regulator 15 is connected to one end of a continuous oscillation keep-up coil 15b the other end of which is connected to a lead 18. Lead 17 and lead 18 join into lead 19 which is connected to the outlet lead 20 of generator 2.

The tapping 21 of calibrating resistor 8 is connected through a lead 22 to the vibrating member 23 of a final voltage pilot regulator 24, the stationary contact 24a of which is connected to one end of the continuous oscillation keep-up coil 24b the other end of which is connected through lead 25 to main lead 19.

Regulator 13 includes a compensating coil 13b one end of which is connected to lead 20 through

a basic voltage adjustment rheostat 26. The other end of coil 13b is connected to the stationary contact 27 of a break relay 28 the movable blade 29 of which is connected through lead 30 to the second outlet lead 31 of generator 2. The coil 28a of relay 28 is connected in series in lead 31.

The intensity pilot regulator 15 is provided with a compensating coil 15c which also is connected in series in lead 31.

The final voltage pilot regulator 24 is provided with a compensating coil 24c one end of which is connected to lead 20 through a final voltage adjustment rheostat 32, the other end of coil 24c being connected through a lead 33 to lead 34 which connects together coils 28a and 15c.

Lead 35 connects the other end of coil 15c to a hand-operated isolating switch 36 from which a lead 37 leads to the stationary contact 38a of the main starting contactor 38. Beyond main contactor 38 is inserted the shunt 39 of an indicating ammeter 40, after which the current passes through lead 41 to feed the series type starter 42 of the internal combustion engine to be started, which starter is connected on the other side to lead 20 through a lead 43.

The coil 38b of the main contactor 38 is connected by a lead 44 to one stationary contact 45 of a starting push-button switch the other stationary contact 46 of which is connected through lead 47 to lead 37. Coil 38b may also be fed through the movable armature 49a of a holding relay 49, the stationary contacts 50, 51 of which are connected in parallel with contacts 45, 46. The coil 49b of the holding relay 49 is connected between contact 51 and a lead 52 which, through a contactor 53 the opening of which is operated by an adjustable clockwork 54, is connected to the return lead 55 connecting coil 38b to lead 20. The clockwork and the holding relay may be made inoperative by a three-way switch 56 the movable blade of which is adapted to connect lead 44 and contact 45 either to contact 51, or to an intermediary shunt circuit 57 comprising a hand-operated break switch 58. Contact 51 is also connected to one end of a coil 59 adapted to initiate the clockwork operation the other end of which is connected to lead 56. An indicating voltmeter 60 is connected between leads 37 and 55.

The above described equipment operates as follows:

When the starting engine 1 is running, starting generator 2 rotates. With isolator 36 closed, and switch 56 off bridge 57 and closed to holding relay coil 49b, if the push-button which connects contacts 45 and 46 is depressed, then the current issued from generator 2, under basic voltage, will excite the holding relay coil 49b, the coil 59 which initiates the clockwork operation and the coil 38b of the main starting relay 38. The basic voltage pilot regulator 13 operates to maintain the conditions for the generation of an electric current under a voltage lower than the final voltage, which, while sufficient to permit the operating relays to be instantaneously actuated, will keep down to a safe value the intensity of the current absorbed by the starter 42 the circuit of which is completed immediately relay 38 operates.

As soon as the contactor of relay 38 closes, the flow of current causes relay 28 to break and almost immediately thereafter pilot regulator 13 ceases to operate while the intensity pilot regulator 15 becomes operative alone.

Said pilot regulator 15 periodically short-circuits, at a suitable frequency, the part of calibrating resistor 8 comprised between lead 20 and tapping 9, and the current passing through solenoid 7 so controls the compression of carbon pile 5 that the field coil 4 of the generator is fed with such a current that the current supplied to starter 42 is maintained to a constant value.

The characteristic of starter 42 being of the series type, the arrangement is self-regulating since, as the speed of starter 42 is allowed to increase, the counter-electromotive force of said starter armature may also rise, so that the voltage may rise precisely in relation to the more or less rapid acceleration of the starter 42, which is connected to the internal combustion engine, not shown, to be started. During acceleration, the increase of motor 42 counter-electromotive force would cause the intensity to drop but for the action of regulator 15 on pile 5 to maintain a constant intensity.

As a constant value of the intensity is maintained, the voltage will not rise above the maximum value assigned to the starting installation by the calibration of rheostat 32. When the voltage reaches said maximum value, the final voltage regulator 24 becomes operative and fixes a limit to the compression of carbon pile 5 by periodically short-circuiting, at the suitable frequency, the part of resistor 3 comprised between tapping 21 and lead 20. After the final voltage has been reached, the starting operation may continue with a decreasing current intensity.

In practice, however, clockwork 54 breaks contact 53 and cuts off the current from holding coil 49, so that main contactor 38 opens.

Such a starting arrangement may in practice be applied to any existing starters. The suitable constant current value can be determined by the sole condition that the heat losses be the same as in the case of a constant voltage supply. As most of the losses are caused by Joule effect in the starter windings, the constant intensity which will produce the same heat losses by Joule effect as the variable intensity of the constant voltage supply in the same total time is easily calculated by integrating the heat function deduced from the curve of said variable intensity plotted against time. In the practical case of a starter for modern aircraft turbo-jet engines, said constant current is about 740 amperes when the final voltage is limited to 28 volts, which is the standard voltage actually. The final power obtained is 20.7 kilowatts, which is nearly double the power that can be attained when constant voltage starting is used. Such increased power does not prejudice the starter, the heating of which is the same, if not even less. The starter has an easier operation due to elimination of high current peaks. As the power increases progressively, damages to the starter collector and to the movable members of the connections are avoided. Furthermore, the operating time for the starter is reduced since the speed increases more rapidly and consequently the ignition of the jet engine is more quickly obtained. The starter heating limitations could actually be made still wider and the constant current could be chosen greater than specified above, the starting time being further reduced accordingly.

It may be noted that the operation of such a starting unit is adapted to suit various conditions of utilization, according to the quicker or slower acceleration of the started engine in different temperature or altitude conditions. The

self-regulation by the starter itself cooperating with the intensity and voltage pilot regulators will give the same results in any case. Moreover, the unit may be adapted to constant voltage operation for feeding circuits on board aircraft while on the ground (such as circuits for lighting, cabin air-conditioning, radio-transmitters and/or receivers power supply intercommunications on board, signal systems or other accessories) by opening switches 11 and 11*a* so as to cut off the basic voltage and intensity pilot regulators 13 and 15 and keep only the final voltage pilot regulator 24 in operation. Through the action of said regulator, adjusted by means of rheostat 32, the unit constituted by engine 1 end generator 2 is made to operate to supply a constant voltage current irrespective of the current flow. Furthermore, by changing the position of switch 56, clockwork 54 is made inoperative, main contactor 38 then being closed either by depressing the push-button which connects contacts 45, 46, in which case the main contactor will only be closed while the push-button is held, or through switch 58 which directly controls the main contactor and allows to keep it steadily closed.

Of course, without departing from the scope of the invention, modifications may be made to the above described embodiment.

What I claim is:

1. A method for supplying the electric current to the electrical starter of an internal combustion engine, more particularly for turbo-jet engine, by means of a starting generator driven by a starting engine, comprising, in succession, the steps of controlling before starting the tension of the current supplied by the generator to have a constant tension equal to the necessary tension value at the beginning of the starting operation, then, when the starting operation begins, of controlling the current supplied by the generator to have a constant intensity equal to that necessary for performing the starting operation while the tension of said supplied current increases, and, when said tension attains the value of the final tension for the starting operation, of controlling the tension of the supplied current to said final value.

2. A method for supplying the electric current to the electrical starter of an internal combustion engine, more particularly for turbo-jet engine, by means of a starting generator driven by a starting engine, said starter having a series winding, comprising, in succession, the steps of controlling before starting the tension of the current supplied by the generator to have a constant tension equal to the necessary tension value at the beginning of the starting operation, then, when the starting operation begins, of controlling the current supplied by the generator to have a constant intensity equal to that necessary for performing the starting operation while the tension of said supplied current increases, and, when the counter-electromotive force of the starter attains a value equal to that of the final tension for the starting operation, of controlling the tension of the supplied current to said final value.

3. A starting unit for internal combustion engines, more particularly for turbo-jet engines, comprising, in combination, a starting engine, a starting generator connected with said starting engine, an electrical starter supplied by said generator, means for maintaining before the starting the tension of the current supplied by the starting generator to the value necessary for the beginning of the starting operation, means for eliminating said maintaining means at the beginning of the starting operation, means for maintaining at the beginning and during the performing of the starting operation the current supplied by said generator to a constant starting operation, means for maintaining at the end of the starting operation the increasing tension of the current supplied by said generator to the starter at a value equal to the final tension necessary for said starting operation, when the then increasing tension attains said final value, and means for automatically cutting the supplying of said starter after a predetermined time.

4. A starting unit for internal combustion engines, more particularly for turbo-jet engines, comprising, in combination, a starting engine, a starting generator connected with said starting engine and having a shunt field coil, an electrical starter having a series winding, main leads connecting said starter with said starting generator, an adjustable regulator connected in series with said shunt field coil, a device for modifying the adjustment of said regulator, a voltage pilot regulator connected with said device and acting for maintaining the tension of the current supplied by the generator to the necessary value at the beginning of the starting operation, an intensity pilot regulator connected with said device for maintaining the current supplied by the generator to a constant intensity equal to that necessary for performing the starting operation, means for substituting said intensity pilot regulator for said voltage pilot regulator at the beginning of the starting operation, a second voltage pilot regulator connected with said device for maintaining the tension of the supplied current to the value of the final tension for the starting operation when the counter-electromotive force of said starter attains the value of said final tension, a main contactor inserted in one of said main leads, means for closing said main contactor at the beginning of the starting operation, means for maintaining said contactor in closed position during the starting operation, means for opening said contactor after a predetermined time, and means for avoiding at will the action of said maintaining and opening means on said main contactor.

5. A starting unit for internal combustion engines, more particularly for turbo-jet engines, comprising, in combination, a starting engine, a starting generator connected with said starting engine and having a shunt field coil, an electrical starter having a series winding, main leads connecting said starter with said starting generator; an adjustable regulator connected in series with said shunt field coil and having a pile of carbon discs, a compression and release device adapted to act on said discs, and a solenoid the armature of which is connected with said device; a circuit connecting said solenoid in parallel with the generator, a calibrating resistor mounted in series in said circuit, two tappings displaceable along said calibrating resistor; a final voltage pilot regulator connected with one of said tappings; an initial voltage pilot regulator, and an intensity pilot regulator, said initial voltage and intensity pilot regulators being connected in parallel with the second tapping; means for substituting said intensity pilot regulator to said initial voltage pilot regulator at the beginning of the starting operation; a main contactor inserted in one of said main leads, means for closing said main contactor at the beginning of the starting operation,

means for maintaining said contactor in closed position during the starting operation, means for opening said contactor after a predetermined time, and means for avoiding at will the action of said maintaining and opening means on said main contactor.

6. A starting unit for internal combustion engines, more particularly for turbo-jet engines, comprising, in combination, a starting engine, a starting generator connected with said starting engine and having a shunt field coil, an electrical starter having a series winding, main leads connecting said starter with said starting generator; an adjustable regulator connected in series with said shunt field coil and having a pile of carbon discs, a compression and release device adapted to act on said discs, and a solenoid the armature of which is connected with said device; a circuit connecting said solenoid in parallel with the generator, a calibrating resistor mounted in series in said circuit, two tappings displaceable along said calibrating resistor; a final voltage pilot regulator of the vibrating contact type connected with one of said tappings for maintaining the tension of the supplied current to the value of the final tension for the starting operation when the counterelectromotive force of said starter attains the value of said final tension, the vibrating contact of said final voltage pilot regulator short-circuiting the part of the calibrating resistor comprised beyond said tapping; an initial voltage pilot regulator of the vibrating contact type for maintaining the tension of the current supplied by the generator to the necessary value at the beginning of the starting operation, an intensity pilot regulator of the vibrating contact type for maintaining the current supplied by the generator to a constant intensity equal to that necessary for performing the starting operation, said initial voltage and intensity pilot regulators being connected in parallel with the second tapping, the vibrating contacts of said both regulators short-circuiting the part of the calibrating resistor comprised beyond said second tapping; means for substituting said intensity pilot regulator to said initial voltage pilot regulator at the beginning of the starting operation; a main contactor inserted in one of said main leads, means for closing said main contactor at the beginning of the starting operation, means for maintaining said contactor in closed position during the starting operation, means for opening said contactor after a predetermined time, and means for avoiding at will the action of said maintaining and opening means on said main contactor.

7. A starting unit for internal combustion engines, more particularly for turbo-jet engines, comprising, in combination, a starting engine, a starting generator connected with said starting engine and having a shunt field coil, an electrical starter having a series winding, main leads connecting said starter with said starting generator; an adjustable regulator connected in series with said shunt field coil and having a pile of carbon discs, a compression and release device adapted to act on said discs, and a solenoid the armature of which is connected with said device; a circuit connecting said solenoid in parallel with the generator, a calibrating resistor mounted in series in said circuit, two tappings displaceable along said calibrating resistor; a final voltage pilot regulator of the vibrating contact type connected with one of said tappings for maintaining the tension of the supplied current to the value of the final tension for the starting operation when the counter-electromotive force of said starter attains the value of said final tension, the vibrating contact of said final voltage pilot regulator short-circuiting the part of the calibrating resistor comprised beyond said tapping, said final voltage pilot regulator having a compensating coil, a circuit connecting said compensating coil in parallel with the generator, and an adjusting rheostat inserted in said circuit; an initial voltage pilot regulator of the vibrating contact type having a compensating coil mounted in series in one of the main leads for maintaining the tension of the current supplied by the generator to the necessary value at the beginning of the starting operation; an intensity pilot regulator of the vibrating contact type for maintaining the current supplied by the generator to a constant intensity equal to that necessary for performing the starting operation, said initial voltage and intensity pilot regulators being connected in parallel with the second tapping, the vibrating contacts of said both regulators short-circuiting the part of the calibrating resistor comprised beyond said second tapping, said initial voltage pilot regulator having a compensating coil, a circuit connecting said last compensating coil in parallel with the generator, an adjusting rheostat inserted in said last circuit, a movable contact inserted in said last circuit, and an operating coil connected in series in one of the main leads for opening said movable contact immediately the current is supplied to the starting motor; a main contactor inserted in one of said main leads, means for closing said main contactor at the beginning of the starting operation, means for maintaining said contactor in closed position during the starting operation, means for opening said contactor after a predetermined time, and means for avoiding at will the action of said maintaining and opening means on said main contactor.

8. A starting unit, according to claim 7, wherein the means for closing, maintaining and opening the main contactor and the means for avoiding the action of the maintaining and opening means comprise a main coil for operating the main contactor mounted in parallel between the main leads, a starting push-button mounted in series with said main coil, a holding relay connected with said main coil, an adjustable electrically actuated clockwork having a contactor inserted in series between the coil of the holding relay and said main coil and an operating coil mounted in parallel between the coil of said holding relay and said main coil, a three-way switch mounted in series between the coil of the holding relay and said main coil, an intermediary shunt circuit connecting one of the contacts of said three-way switch with the line connecting the holding relay with one of the main leads and a hand-operated break switch inserted in series in said intermediary shunt circuit.

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