PUBLISHED JUNE 8, 1943. BY A. P. C.

C. R. WASEIGE

FLY-WHEEL STARTERS FOR AIRCRAFT ENGINES

Filed June 29, 1940

Serial No. 343,303

3 Sheets-Sheet 1

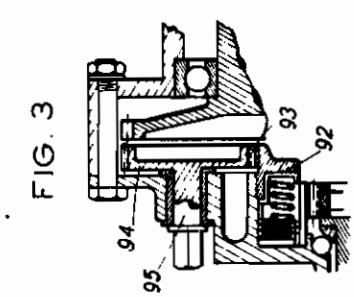

FIG. 3

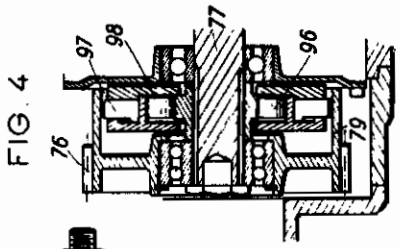

FIG. 4

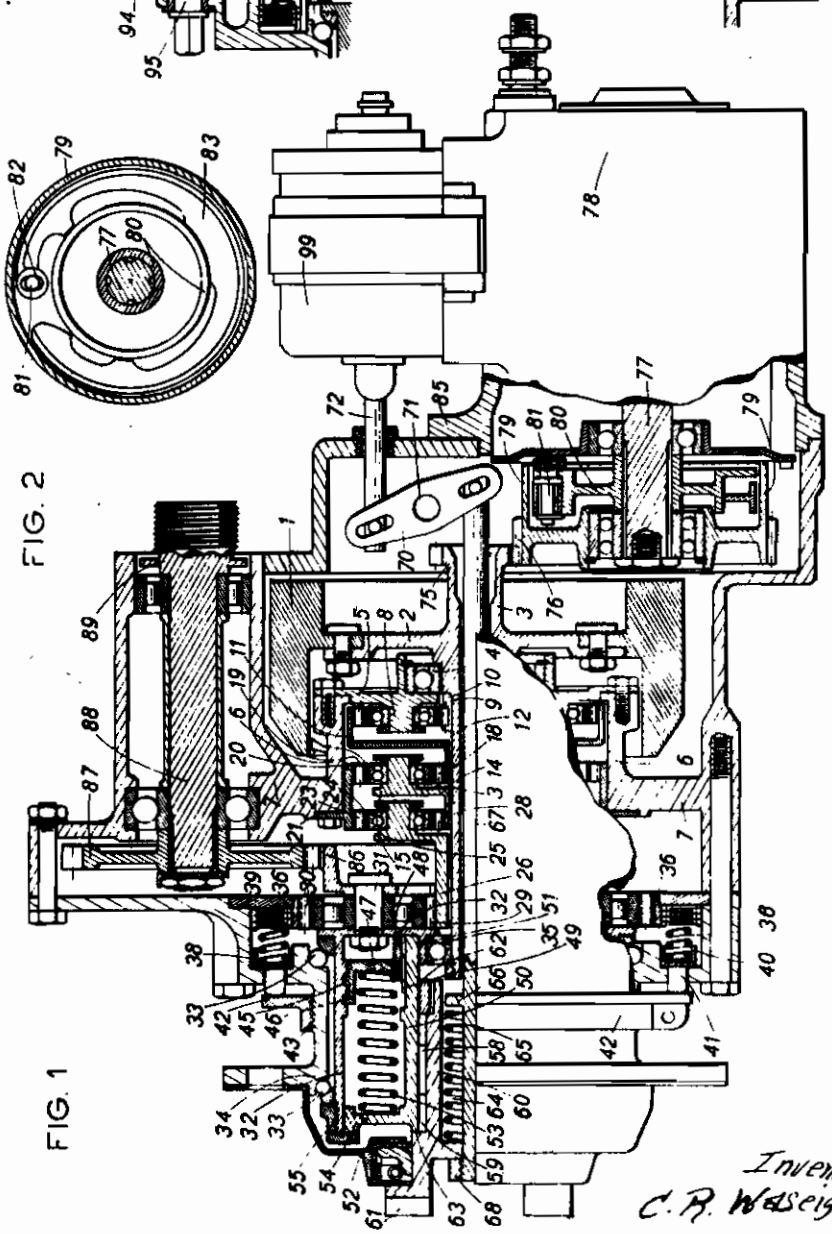

FIG. 2

FIG. 1

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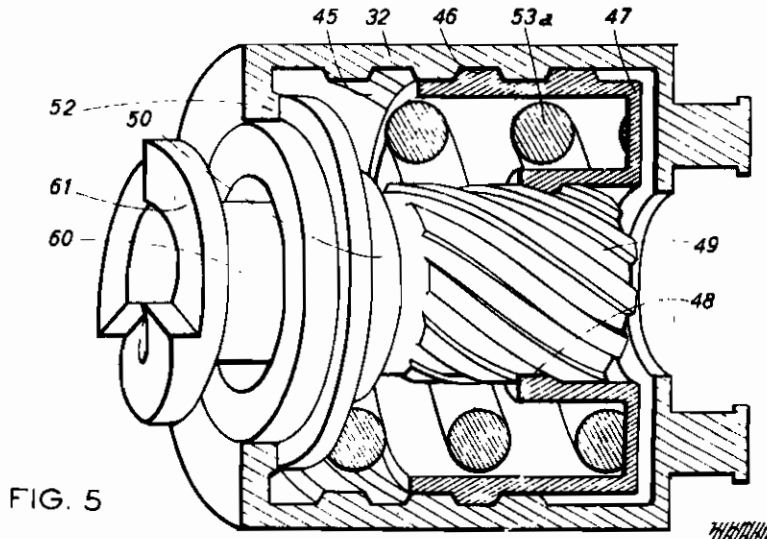

FIG. 5

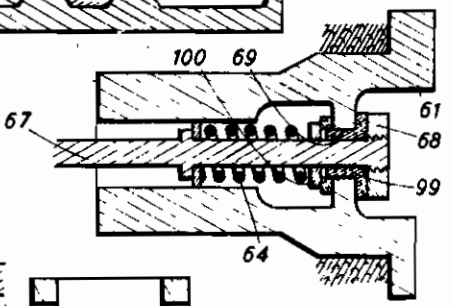

FIG 6

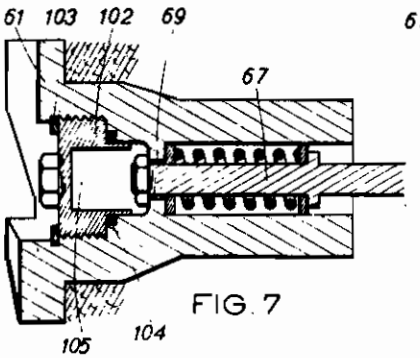

FIG. 7

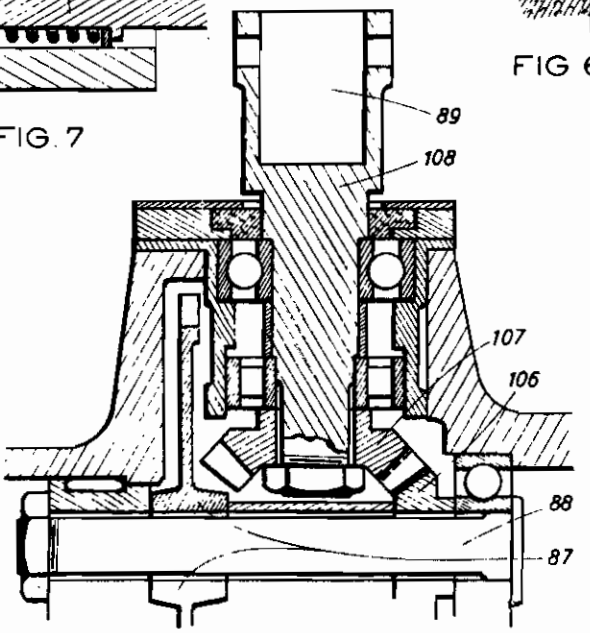

FIG. 8

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FIG. 9

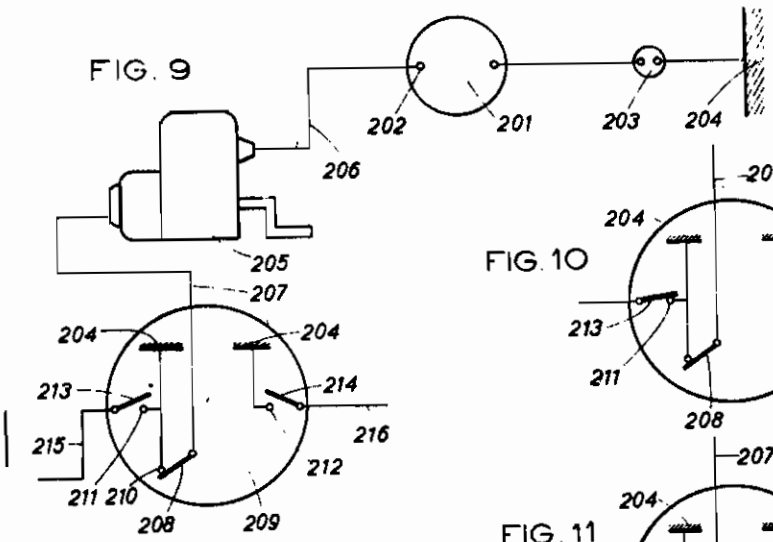


FIG. 10

FIG. 11

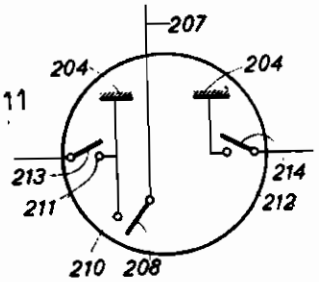


FIG. 12

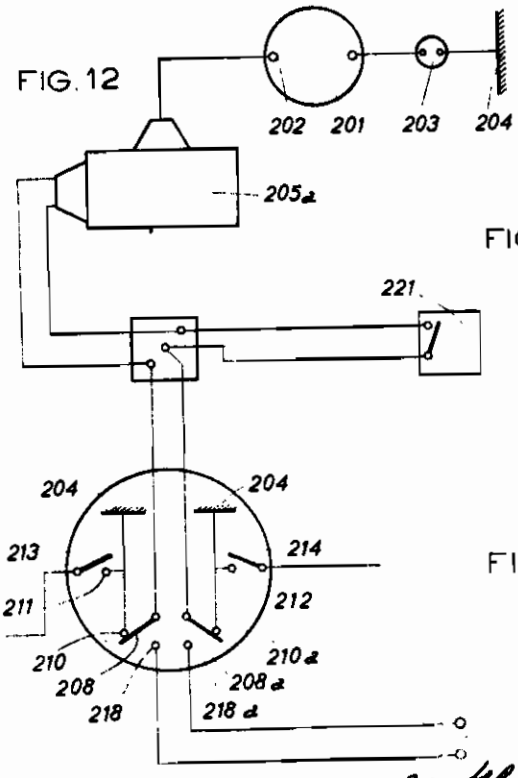


FIG. 13

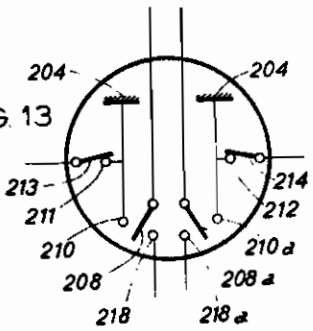
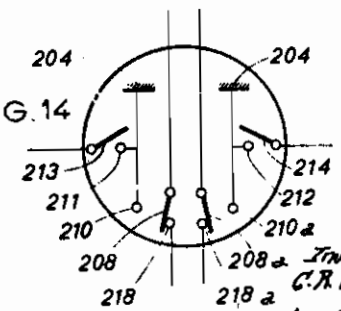


FIG. 14



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ALIEN PROPERTY CUSTODIAN

FLY-WHEEL STARTERS FOR AIRCRAFT ENGINES

Charles Raymond Waselge, Ruell, Seine-et-Oise, France; vested in the Alien Property Custodian

Application filed June 29, 1940

My invention relates to the devices used for starting internal combustion engines for aircrafts and the like and more particularly to those mechanical devices intended to rotate the engine to be started which are known by the name of fly-wheel starters, and also to electric devices for producing the ignition during starting, and has for its objects a number of improvements in this type of devices, which improvements may be used together or separately.

It is known that such starters essentially comprise an electric or other motor which enables a high speed to be imparted to a fly-wheel which is connected by a mechanism including a high ratio reducing gear to a claw that a control enables to be coupled to the engine to be started when said fly-wheel has accumulated sufficient energy.

A first improvement in starters consists in that, in combination with a torque limiting device interposed in the transmission from the fly-wheel to the coupling claw for the engine to be started, there exists a resilient metal device which is adapted to be tensioned progressively by the action of a momentary difference in speed between two members of the said transmission which are connected to each other without reducing gearing by means which enable them to effect an angular displacement relatively to each other, the degree of tension of said resilient device determining the driving torque applied to the said coupling claw and said torque limiting device being in this case adapted only to slip in the event of there being an abnormally high resisting torque.

This combination of means has the advantage of preventing slipping of the torque limiting device when the starter is coupled to the engine to be started, slipping only occurring for a resisting torque which is much greater than the torque required to start the rotation of the engine crankshaft, that is to say in case of abnormal resistance or of back-firing in the engine; furthermore, the driving torque of the coupling claw increases very gradually from a small or zero value up to that required for rotating the crankshaft.

In a preferred embodiment, the transmission mechanism comprises two rotary members which are rotatable about the same axis while being stationary with respect to said axis in a direction parallel thereto and one of which is driven by the fly-wheel of the starter and the other is rotatable integral with the coupling claw for the engine, and the transmission between said two rotary members is ensured by a movable member which is slidable parallel to said shaft and is connected, for this purpose, to said two rotary members respectively by means of slidable keying means, at least one of which is formed by reversible ramps, helical or the like, said movable member being subjected to the action of a resilient device which urges it parallel to said axis in the opposite direction to the movement it effects under the action of said ramps when the aforesaid driven rotary member rotates slower than the driving rotary member.

Advantageously, the driving rotary member is formed by a barrel and the driven member by a coaxial sleeve on which the stem of the coupling claw is slidably keyed; the movable member being provided with splines adapted to cooperate with splines provided on the facing surfaces of the barrel and of the sleeve respectively and being subjected to the action of one or a series of springs lodged in the barrel.

It is advantageous for both the aforesaid splines to be formed by helical ramps so as to increase the angle of displacement between the two members of the resilient coupling.

Another improvement according to my invention relates to starters in which the claw is provided with an axial hole for the passage of a slidable rod terminated by an abutment against which said claw is urged by a resilient means and provided for ensuring the fluid-tightness of said hole so as to prevent any inlet of oil into the case of the starter.

According to one embodiment, said fluid-tightness is ensured by means of a ring made of plastic material of U-shaped cross-section, which is inserted in said hole and the two arms of which are radial and are in contact with the two outer and inner faces of the claw, said resilient means including a spring which bears against said ring and keeps it compressed.

According to another embodiment, a fluid-tight plug is fitted in the centre of the outer face of the claw and is provided with an inner chamber which enables said rod and its abutment to effect their movements when the claw is sliding.

Another of said improvements consists in that, the apparatus being of the type which includes a coupling claw adapted to be actuated by a barrel which is rotated, through an epicyclic reducer train and a torque limiting device operating by friction, by a fly-wheel driven at high speed, said torque limiting device is interposed between the case of the reducer and a normally stationary sun-wheel of said epicyclic train, the

slipping in case of overload being thus effected between said wheel and the case.

This arrangement enables the diameter of the discs of the torque limiting device to be considerably increased and consequently the number or the pressure of the springs to be decreased.

A still further improvement consists in the fact that a device for adjusting a torque limiting device interposed in the transmission between the fly-wheel and the coupling claw for the engine is accessible from the outside.

Another improvement is that the electric motor for actuating the fly-wheel is a moderate speed one of the order of eight to ten thousand revolutions per minute and gearing up means are interposed between said motor and said fy-wheel, the whole gearing up means being preferably secured to said motor and being removable as a unit with same. It is thus possible:

(1) To use an electric motor having a higher efficiency than that of very high speed electric motors,

(2) To increase the speed of the fly-whcel to be started and thus decrease its weight.

Another improvement which is also an object of the invention relates to the electrie apparatus used for starting an aircraft engine. This improvement consists in a switch provided with two contacts which are connected to the frame and respectively co-operate with two movable contacts, one connected to one of the magnetos of the engine to be started and the other to the second magneto, and at least a third fixed contact which is likewise connected to the frame and cooperates with a third movable contact connected to the auxiliary starting generator.

In the case in which said generator is a coil, the switch is provided with a fourth fixed contact which is identical to the third and which cooperates with a fourth movable contact, these two movable contacts being adapted to occupy three positions and to contact respectively with two other fixed contacts connected to the two poles of the source of current.

Other improvements will furthermore become apparent from the ensuing description of an exemplary embodiment of an electric starter provided with all the aforesaid improvements and of apparatus for the ignition during starting.

Said exemplary embodiment is shown in longitudinal seetion in Fig. 1 of the accompanying drawings:

Fig. 2 is a partial section along the line II—II of Fig. 1;

Fig. 3 shows a modification of construction of a detail; and

Fig. 4 a modification of another detail;

Fig. 5 reproduces in perspective the front part of Fig. 1, slightly modified;

Figs. 6 and 7 are partial views showing modifications of Fig. 1.

Fig. 8 is a detail.

Fig. 9 shows diagrammatically an apparatus for the ignition during starting, including a starting magneto.

Figs. 10 and 11 show the controlling switch in two other operative positions.

Figs. 12, 13 and 14 are respectively similar to Figs. 9, 10 and 11 in the case of apparatus provided with a starting coil.

The starter shown includes, like all fly-wheel starters, a fly-wheel 1. Said fly-wheel 1 is bolted on a plate 2 secured to a hollow elongated hub 3 supported near said plate by a bearing 4 carried by a plate 5 fixed on the end of a cylindrical box 6 carried by a partition 7 inside the case of the apparatus. Said plate 2 carries, on the opposite side to that on which is located the fly-wheel 1, a plurality of shafts 8 which are angularly distributed about the hub 3 and on which are respectively mounted pinions 9 meshing on the one hand with a common pinion 10 secured to the hub 3, and on the other hand with an internally toothed pinion 11, the hub 12 of which is loosely mounted on the hub 3 of the fly-wheel. Beside said hub 12 the hub 3 carries, likewise loosely mounted, the hub 14 of a planet wheel carrier plate 15 on which are mounted a plurality of pinions 17 meshing with a sun-wheel 18 secured to the hub 12 and with a sun-wheel 19 carried by a sleeve 20 centred in the box 6 and provided with an external collar 21 fixed on the end of the box 6 opposite that carrying the plate 5. Said sleeve 20 carries a second sun-wheel 23 with which mesh planet wheels 24 mounted on a planet wheel carrier plate 25, the hub 26 of which is likewise loosely mounted on the hub 3. The planet gears 24 mesh on the other hand with a sun-wheel 28 secured to the hub 14. A pinion 29 is secured to the hub 26 and meshes with a plurality of pinions 30 carried by shafts 31 fixed to the end of a rotary barrel 32 centred by means of ball bearings 33 in a bearing surface 34 of the case. At the centre of the end of said barrel 32 is lodged a ball bearing 35 which acts as a bearing for the end of the hub 3. Said pinions 30 mesh with a sun-wheel 36 which carries on the outside thereof splines on which are fitted the annular discs of a torque limiting device of the usual friction type, the springs 38 of which press all said discs against a plate 39 which is fixed to the case and which centres the wheel 36 by means of a smooth bearing surface provided in the latter. Each of the springs 38 has one of its ends fitted in a cup 40 secured to fingers 41 which pass through the wall of the case and project outside same where all said fingers are in contact with a plate 42 adapted to screw on a screw-thread 43 provided on the outside of the cylindrical bearing surface 34.

The inner face of the cylindrical part of the barrel 32 is provided with helical ramps with a reversible pitch 45 engaging with corresponding ramps 46 provided on the cylindrical periphery of movable piece having the form of a cup 47 and provided at its centre with a hole in the wall of which are formed splines 48 which may be formed by helical ramps and engaged with corresponding splines or ramps 49 of a sleeve 50 coaxial with the barrel and centered at its end on a cylindrical bearing surface 51 projecting from the end of the barrel 32. At its other end, the sleeve 50 carries a plate 52, a strong spring coaxial with the barrel or a series of springs 53 in ring formation are arranged inside the barrel 32 between the cup 47 and said plate 52. A retaining ring 54, which a splined fit in the barrel 32 secures to the latter, holds the sleeve 50 axially, being itself retained longitudinally by means of a nut 55 screwed on the end of the barrel 32.

On the inside of the bore of said sleeve 50 are formed splines 58 which fit into longitudinal splines cut on the stem 60 of the coupling claw 61 for the engine to be started, it being thus possible for said claw to slide longitudinally relatively to the sleeve 50. This possible movement is limited by two shoulders 62 and 63 which respectively abut at the end of the splines 58 and at the end of the sleeve 50. Said stem 60 is provided on the opposite side to the claw 61 with

an axial recess 84 in which is lodged a spring 65 interposed between the bottom of said recess and a shoulder 68 of a long rod 67 lodged in the axis of the hollow hub 3 and the stem 60, through both of which it passes freely from end to end as well as the bottom of said recess 64. It can also slide longitudinally and a nut 68 is screwed on its end and projects outside in the axis of the claw 61, said nut thus forming an abutment against the body of said claw for limiting the axial movement of the rod under the pressure of the spring 65. The opposite end of the central rod 67 is attached to one of the arms of an equalizing lever 70 which is carried by a fixed spindle 71 inside the case and the other arm of which is engaged by a slidable rod 72 projecting outside the case.

The end of the hub 3 nearest the fly-wheel 1 is secured to a pinion 75 which meshes with a wheel 76 of larger diameter which is loosely mounted on the shaft 77 of a moderate speed electric motor 78, of the order of eight to ten thousand revolutions for example. Said wheel 76 furthermore has a rim 79 inside which is arranged a plate 80, the hub of which is keyed on the shaft 77. A shaft 81 fixed on the plate 80, near the periphery thereof, passes through a radially ovalized eye 82 at the end of a resilient circular jaw 83. The latter is centred at three points on the plate in such a manner that in the inoperative position there is a clearance between said jaw 63 and the rim 79 which surrounds it, but under the action of centrifugal force the jaw opens resiliently and rubs against said rim 79, thereby ensuring the drive of the wheel 76. The clutch is constructed so as to be self-tightening but not self-locking. It thus has a variable driving capacity, at the same speed, according to whether the one or the other of its parts is the driving part and the other the resisting part. The whole gearing-up arrangement 76—83 is adapted to be able to pass through the orifice of the case in which fits the end of the motor 78 and can thus be removed and placed in position as an integral unit with said motor, the case of which carries a flange 85 for fixing on the edges of said orifice.

On the end of the barrel 32 there is furthermore fixed a gear 86 which is concentric with the barrel and which meshes with a wheel 87 fast on a shaft 88 which is journalled in the case and which projects outside same by means of a head 89 adapted to receive a crank handle or other manually actuable member.

The operation is as follows:

When the electric motor 78 is started, the centrifugal friction clutch 79—83 is not engaged, so that the motor starts unloaded and the current taken is comparatively small; the shaft 77 of the motor drives the plate 80 at increasing speed; the jaw 83 then gradually opens under the action of the increasing centrifugal force and rubs against the rim 79 when the motor is rotating at a predetermined speed, thereby ensuring the drive of the wheel 78 and of the fly-wheel 1 through the gearing-up mechanism 78—75. This rotation of the fly-wheel 1 is transmitted to the barrel 32 by means of the reducing pinions 18, 9 and 11 and of the epicyclic reducing trains 18, 17, 19, 28, 24, 23 and 29, 30, 36, the sun-wheel 38 being held stationary by the friction device 37 to 40. As nothing prevents the rotation of the claw 61 and of the sleeve 50 which is secured thereto, the cup 47 which rotates integral with the sleeve 50 is rotated by the helical ramps 45 without tending to screw into the barrel 32.

When the fly-wheel 1 has received sufficient impetus, the rod 72 is pulled, which is effected in this case by means of an electromagnet 90 which is energized at the selected instant; the rod 68 is then pushed in the direction *f* and tends to compress the spring 65 which in turn pushes back the claw 61 and brings it into engagement with that of the engine.

As soon as the two claws engage, the claw 61 is brought to a standstill and a relative rotation then exists between the sleeve 50 and the barrel 32, which results in an axial movement of the cup 47 against the action of the springs 53 which it gradually compresses until the torque transmitted by said cup to the claw 61, which torque depends on the tension of said springs, is sufficient to set in rotation the crankshaft of the engine to be started. As soon as the engine starts to rotate under its own power, the starting claw pushes back the claw 61 which returns to the position of Fig. 1, against spring 65, while the springs 53 contract and return the cup 47 to its inoperative position.

In the event of there being an abnormally high but limited resisting torque, slipping of the friction device 37 to 40 occurs and consequently a corresponding rotation of the sun-wheel 36. The value of the maximum torque which said limiting device 39—40 enables to transmit can be readily controlled, without its being necessary to remove the apparatus, by simply manipulating the nut 42 which is outside the apparatus.

On the other hand, the clutch 83—79 is so constructed that, when the resisting torque becomes abnormally high and produces a slowing down of the fly-wheel and of the electric motor 78, its driving torque is less than that of the motor at a speed for which the back electromotive force of the motor is sufficient to limit the intensity of the current of the motor to a value than can be permanently supported by the windings. Slipping then occurs of the jaw 83 relatively to the rim 78 and the automatic release of the clutch thus obtained enables the current to be left on the electric motor 78 without danger of a short-circuit, since said motor can thus continue to rotate at a fair speed while the speed of the fly-wheel continues to decrease.

In the event of failure of the electric motor, the fly-wheel 1 may be started by hand by means of the shaft 88 which enables the barrel 32, and consequently the fly-wheel, to be rotated through the reducing transmission between the fly-wheel and the barrel, which transmission in this case operates with a gear up ratio.

It will be observed that said transmission has a considerable ratio for a very reduced bulk and weight.

Fig. 3 shows a modification of construction of the device for adjusting the torque limiting device 37 to 48. In this modification, the cup 40 for seating the springs 38 is pressed against a screw-threaded part 92 which screws in the case and carries teeth 93 with which engages a pinion 94 carried by a shaft 95 which projects from the case. It is obvious that by rotating said shaft 95, the screw-threaded part 92 is screwed more or less into the case thereby adjusting the springs.

In the modification of Fig. 4, the centrifugal clutch with a self-tightening resilient jaw is replaced by the combination with a free-wheel 98 of a centrifugal clutch, the driving capacity of which is identical in both directions of rotation, said clutch being provided with masses 97 which are movable radially in a cage 99 so as to engage

the rim 79 under the action of centrifugal force, said cage 98 being carried by the shaft 77 by means of said free-wheel 96. When the electric motor is started the clutch 79—97 is not engaged and the shaft 77 only drives the cage 98 through the free-wheel 96; it therefore starts with practically no load; when it has been started, the masses 97 rub against the rim 79 and ensure the drive of the wheel 76 and of the whole of the mechanism the latter actuates. The free-wheel 96 enables said wheel 76 to rotate faster than the shaft 77 so that if the supply current of the electric motor is cut off, the latter will not be rotated by the flywheel and will not exert braking action thereon. Fig. 5 reproduces in perspective the front part of Fig. 1, the springs 53 being replaced by a single spring coaxial with the claw 53a. Fig. 6 shows a means for preventing the oil from the engine or the like from penetrating into the case of the starter through the passage 68 provided in the claw 61 for the rod 67 which is provided with an abutment 66 against which the sleeve is pressed by the spring 64. Said means consists in a ring 98 made of plastic material, the cross-section of which is U-shaped, the two lips of the U respectively bearing against the front and rear transverse faces of the claw 61. Said ring may be made in two parts, as shown, and on it bears the spring 64 by means of a washer 100. Under these conditions, the material of said ring is compressed and presses intimately against the walls of the passage 68 and against the rod 67.

As shown in the modification of Fig. 7, the same result could be obtained simply by means of a screw-threaded plug 102 adapted to close a central recess of the claw 61, fluid-tightness being ensured by means of two rings 103 and 104.

Said plug is provided with an inner chamber 105 of sufficient depth to enable the abutment 66 of the road 67 to effect its movement.

Finally, Fig. 8 shows a modification of the manual starting device, according to which the shaft 88 is enclosed in the case and is connected by a single pair of gears 106—107 to a shaft 108 which is arranged perpendicular to the axis of the claw and is provided with a very accessible head 89 which is intended to receive a removable crank handle or the like. The manual starting can thus be effected under the best conditions.

In Fig. 9, which shows diagrammatically the electric apparatus for the ignition during starting, 201 designates the magneto for normal operation and 202 the starting contact with which said magneto is provided, 203 designates one of the spark plugs and 204 the metal mass of the engine; 205 is the starting magneto, the secondary of which is connected by a wire 206 to the starting contact 202 of the normal operation magneto 201, whereas its primary is connected by a wire 207 to a movable contact 208 of a switch 209. Said contact 208 co-operates with a contact 210 and the switch is provided with two other contacts 211 and 212 which are connected to the frame 204 and co-operate respectively with movable contacts 213 and 214 respectively connected by the wires 215 and 216 to the normal operation magnetos of the engine.

The operation of this apparatus is as follows:

In the inoperative position (Fig. 10) the three movable contacts 208, 213 and 214 are respectively connected to the corresponding contacts 208, 211 and 212 and the respective primaries of the three magnetos are connected to the frame. The ignition is cut off and there is absolute safety.

In order to start the engine, (Fig. 11), the movable contacts 208, 213 and 214 are separated from the contacts 208, 211 and 212 and the primaries of the three magnetos are insulated from the frame. The three magnetos can therefore all supply current at once.

In normal operation (Fig. 9), the movable contacts 213 and 214 are separated from the contacts 211 and 212 but the movable contact 208 is on the contact 208. The normal operation magnetos therefore continue to supply current whereas the starting magneto 205 no longer supplies current, its primary being connected to the frame and the high frequency oscillations being short-circuited to the frame.

The apparatus shown in Fig. 12 differs from the previous one by the fact that the high tension starting generator is formed by a coil 205a. One of the ends of the primary of said coil is connected to the movable contact 208 as was the above starting magneto 205 but the switch is provided with a contact 218 which co-operates with said movable contact 208 and which is connected by a conductor 219 to one of the poles of a source of current 220. The other end of said primary is connected to a shielded switch 221 which is itself connected to a movable contact 205a of the switch, which contact is similar to the contact 208, and which co-operates with two contacts 210a and 216 respectively connected to the contact 212 and, through a conductor 222, to the second pole of said source of current.

The operation is the same as in the previous case and it is obvious (Fig. 12) that in normal operation, the coil 205a is completely insulated from the source of current 220 while the normal operation magnetos are connected to the frame through the coil 205 owing to the fact that the movable contacts 208 and 208a are connected to the contacts 210 and 210a.

When inoperative, (Fig. 13) the normal operation magnetos are directly connected to the frame, the movable contacts 213 and 214 being respectively connected to the contacts 211 and 212 and the coil is again completely insulated from the source of current 220, the contacts 208 and 208a being open.

In the position for starting ignition (Fig. 13), the contacts 106 and 108a are connected to the contacts 118 and 118a and the coil 105a is thus connected to the source of current 120, whereas the contacts 113 and 114 are open and the corresponding magnetos are insulated from the frame.

Whether the starting high tension generator is a magneto or a coil, the movable contacts of the switch are preferably conjugated with each other in such a manner as to be operable by means of a common hand or foot operated member.

While I have illustrated and described the preferred form of construction for carrying my invention into effect, this is capable of variation and modification, without departing from the spirit of the invention.

CHARLES RAYMOND WASEIGE.