

Dec. 17, 1940.

J. P. GATY ET AL

2,225,599

SYNCHRONIZING SYSTEM FOR AIRPLANE MACHINE GUNS

Filed Aug. 19, 1938

6 Sheets-Sheet 1

Fig. 1.

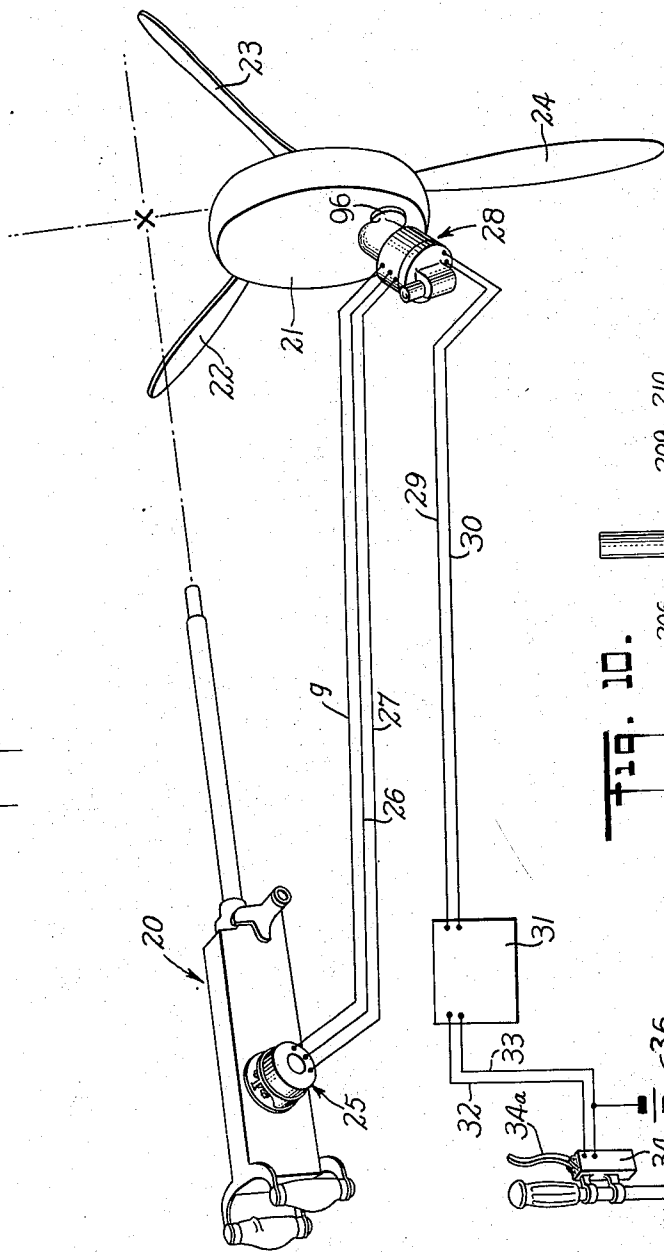
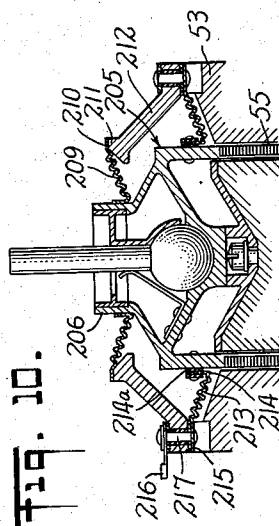


Fig. 10.



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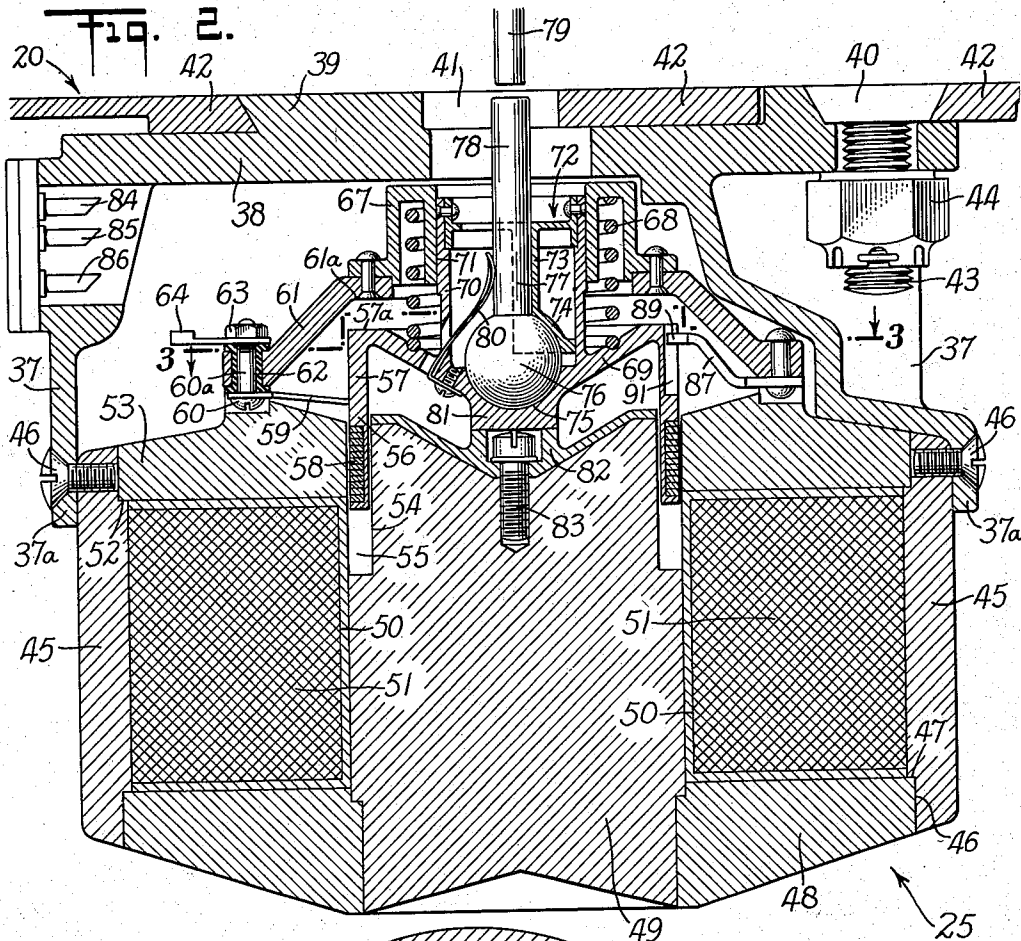
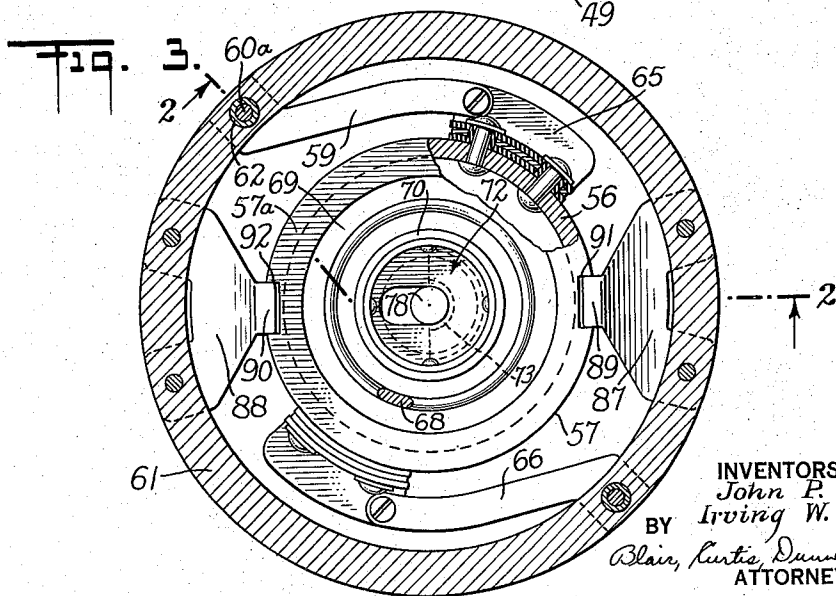
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SYNCHRONIZING SYSTEM FOR AIRPLANE MACHINE GUNS

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6 Sheets-Sheet 2



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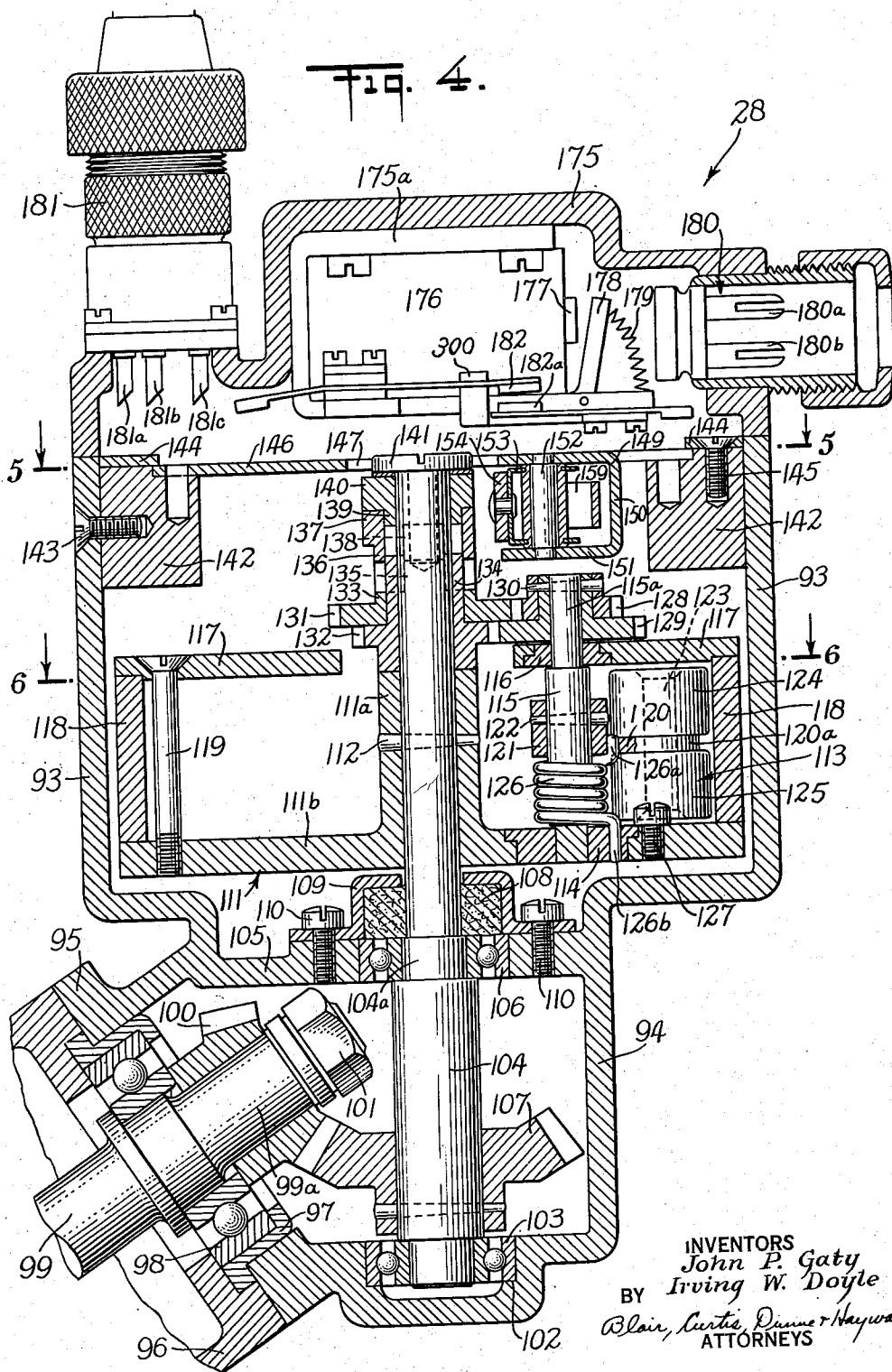
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SYNCHRONIZING SYSTEM FOR AIRPLANE MACHINE GUNS.

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6 Sheets-Sheet 3



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SYNCHRONIZING SYSTEM FOR AIRPLANE MACHINE GUNS

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Fig. 5.

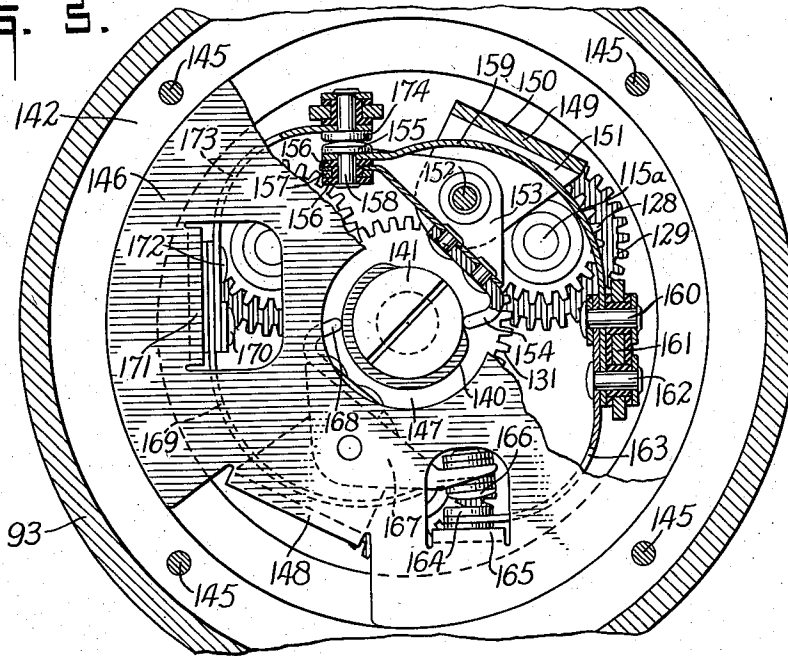
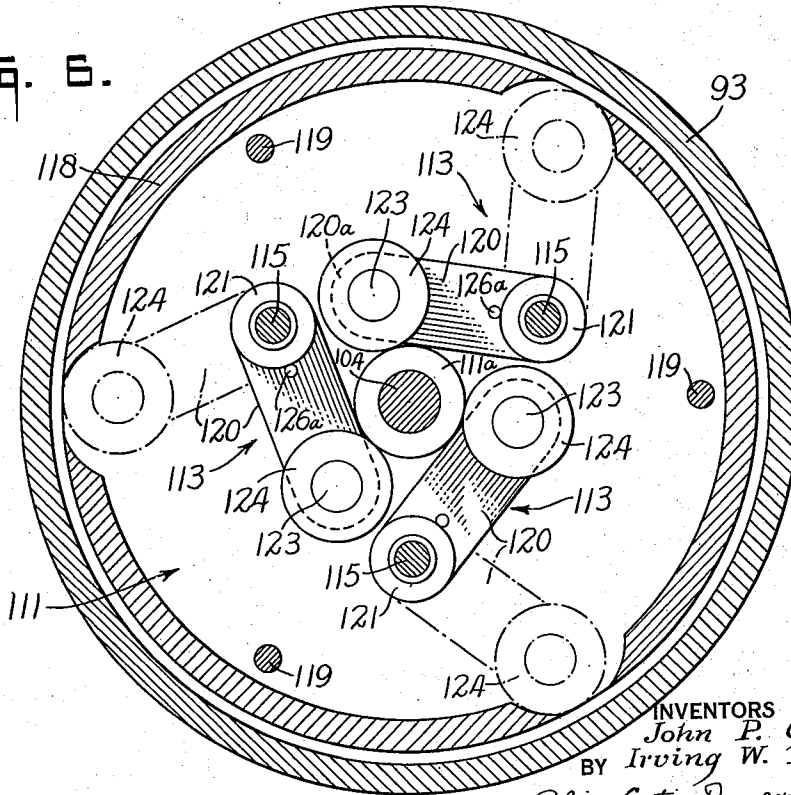


Fig. 6.



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SYNCHRONIZING SYSTEM FOR AIRPLANE MACHINE GUNS

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Fig. 7.

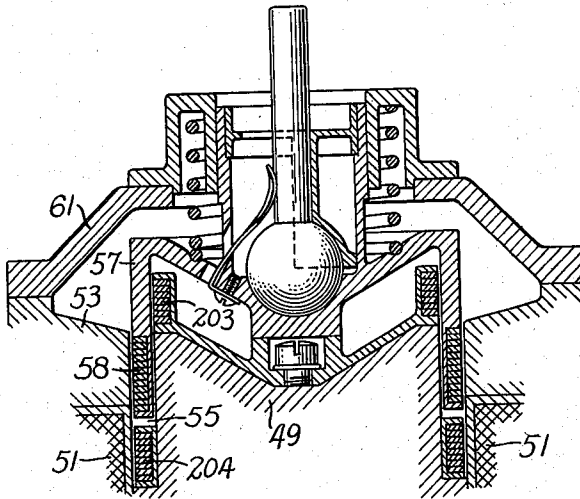


Fig. 8.

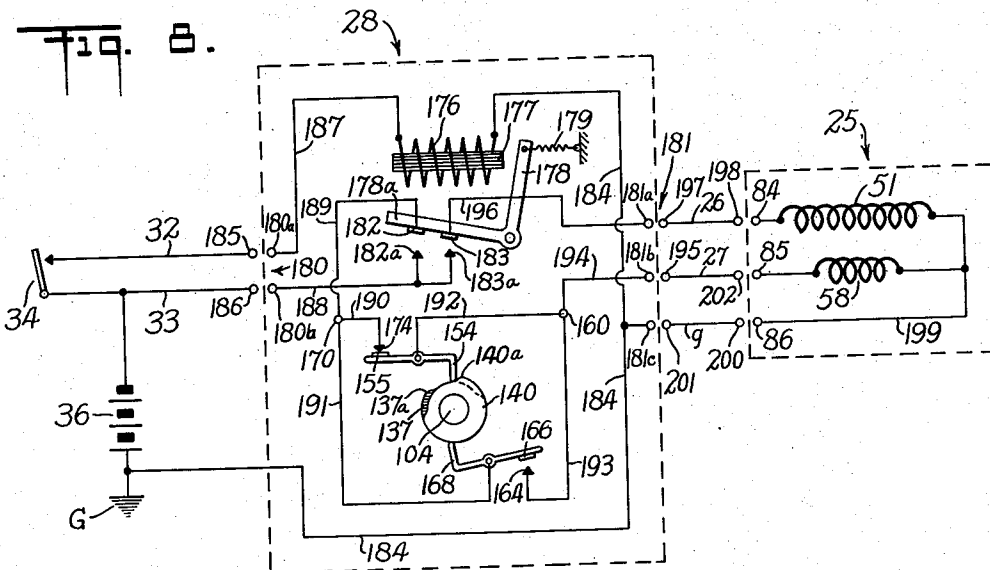
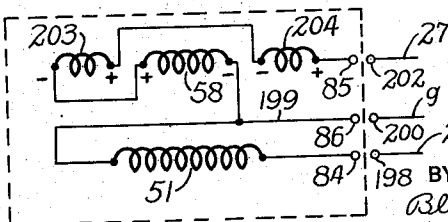


Fig. 9.



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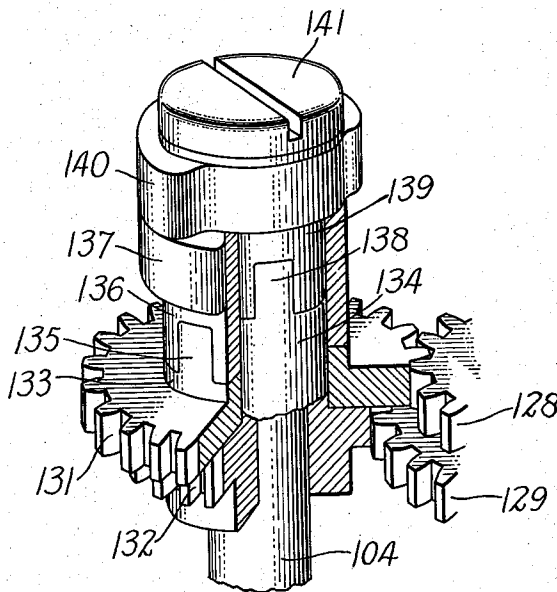
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SYNCHRONIZING SYSTEM FOR AIRPLANE MACHINE GUNS

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Fig. 11.



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UNITED STATES PATENT OFFICE

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SYNCHRONIZING SYSTEM FOR AIRPLANE
MACHINE GUNS

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Application August 19, 1938, Serial No. 225,690

13 Claims. (Cl. 89—27)

This invention relates to apparatus for synchronizing the firing of a machine gun with the rotation of an airplane propeller.

One of the objects of this invention is to provide a machine gun synchronizer characterized by simplicity, reliability and durability over an extended period of use. Another object is to provide a machine gun synchronizer which is capable of controlling the firing of the gun so that the bullet will pass through the plane of rotation of the propeller without striking the propeller blades. Another object is to provide a machine gun synchronizer which operates efficiently at any propeller speed regardless of atmospheric conditions. Other objects will be in part apparent and in part pointed out hereinafter.

The invention accordingly consists in the features of construction, combinations of elements, and arrangements of parts as will be exemplified in the structure to be hereinafter described and the scope of the application of which will be indicated in the following claims.

In the drawings, in which is shown one embodiment of the synchronizing system and several other embodiments of one aspect thereof:

Figure 1 is a diagrammatic perspective view of the synchronizing system assembled with a machine gun mounted in firing relationship to an airplane motor and propeller;

Figure 2 is a section taken through the trigger motor which is attached to the machine gun, a portion of the gun also being shown in section;

Figure 3 is a horizontal section taken along the line 3—3 of Figure 2;

Figure 4 is a sectional elevation of the timing device which forms a part of the synchronizing system;

Figure 5 is a fragmentary horizontal section taken along the line 5—5 of Figure 4, a portion being broken away;

Figure 6 is a horizontal section taken along the line 6—6 of Figure 4;

Figure 7 is a fragmentary vertical section of a modified form of trigger motor;

Figure 8 is a diagrammatic electric circuit of the synchronizing system;

Figure 9 is a modification of a portion of the circuit shown in Figure 8,

Figure 10 is a fragmentary vertical section of another modification of the trigger motor; and

Figure 11 is a fragmentary perspective view of a portion of the timing mechanism shown in Figure 4.

Similar reference characters refer to similar parts throughout the several views of the drawings.

While synchronizing systems for synchronizing airplane machine gun fire with the propeller have long been in use, numerous difficulties have been inherent therein which seriously limit the effi-

ciency of the gun, and often result in expensive and sometimes fatal damage to the airplane. This is particularly true of mechanical systems of synchronization, which in spite of almost continuous development have always required careful attention, not only by the pilots who operate the guns, but also by those whose duty it is to attend to the care and adjustment aspects. Skilled ordnance men are almost prerequisite in caring for the synchronizers, and for obvious reasons such skilled attention is not always available.

The increasing use of three-bladed propellers has caused fundamental and substantial difficulties in applying common types of synchronizing systems, and these difficulties have seriously restricted the speed range of the engine at which the machine gun can safely be fired without the bullets striking the propellers. This will be readily understood when the high speed of modern airplane engines is taken into consideration, plus the fact that these engines are driving three-bladed propellers.

As is well known, it is desirable that the bullet from the gun pass through the plane of rotation of the propeller at a point substantially bisecting the angle between adjacent blades. In order to accomplish this condition at normal operating speeds the system is adjusted to actuate the firing mechanism immediately following the passing of the line of fire by any propeller blade at substantially zero R. P. M. This point is called and will hereinafter be referred to as the "zero shot." It is obvious that any substantial deviation from the median line between two adjacent blades, particularly when the gun is so positioned that the bullets pass through the plane of rotation of the propeller at a point nearer the propeller hub than the propeller tips, would cause damage to the propeller by the bullets striking it. Substantial deviation from the zero shot position is inevitable in any of the synchronizing systems now in use, because of certain time lag constants inherent in any synchronizing system. For example, the period of time between the instant the firing cycle is initiated and the instant the bullet passes through the plane of rotation of the propeller is of the order of .008 of a second. This lapse or lag is a constant, as it is occasioned by inertia of parts, necessary clearance therebetween, friction losses, time of powder burning and time of bullet flight from the gun block breach to the plane of rotation of the propeller. It is readily apparent then that if the zero shot is set to obtain passage of the bullet through the plane of rotation of the propeller at median line between blades at any given engine or propeller speed, the position of bullet passage relative to adjacent blades will vary as the engine speed varies, i. e. at engine speeds lower than that at which the zero shot is set, the bullets will pass

through the plane of rotation of the propeller closer to the preceding blade, whereas at engine speeds higher than the set speed, the bullets will pass through the plane of rotation of the propeller closer to the following propeller blade. Thus it appears that it is desirable to change the position of the zero shot as the engine speed changes to prevent damage to the propeller.

Heretofore efforts have been directed toward the reduction of the time lag between trigger release and passage of the bullet through the plane of rotation of the propeller. However, because of the use of three-bladed propellers and high speed motors, this time lag cannot be reduced sufficiently to result in safe and efficient machine gun operation at high engine speeds. Furthermore, where dependence has been placed on reduction of time lag, indifferent results have been obtained because of difficulty of adjustment, excessive motor speeds, breakage of rapidly moving parts, etc.

Electrical synchronizing systems also present, in addition to those above, other difficulties resulting from structural complexity, excessive power requirements, undue weight, delay in operation, etc. Systems of this nature which utilize an intermittently energized solenoid are unsatisfactory because of the inherent current build-up lag and the consequent force build-up lag which results in a change of phase of the firing position with relation to the propeller blades as the force requirements necessary to fire the gun change with changing temperatures. It is accordingly another object of this invention to provide a machine gun synchronizing system which obviates these various difficulties in a practical and efficient manner.

With reference to Figure 1 of the drawings, a machine gun generally indicated at 20 is operatively mounted on an airplane (not shown) in relation to a motor 21 which drives a three-bladed propeller having blades 22, 23 and 24. Gun 20 is so aimed as to fire through the plane of rotation of the propeller at a point designated X, this point being the zero shot position and bisecting the angle between adjacent blades, such as blades 22 and 23. A trigger motor, generally indicated at 25 is suitably secured to the side of machine gun 20 and is electrically connected by wires 26 and 27 and a ground wire *g* to an automatic timer generally indicated at 28 operatively mounted on and having a driving connection with motor 21. Timer 28 is in turn electrically connected by wires 29 and 30 to a junction box 31, from which wires 32 and 33 lead to a hand switch 34 mounted on the control stick 35 of the airplane. A battery 36 is connected to wire 33. As will be more fully described hereinafter, when the pilot pulls trigger or switch handle 34a, a circuit is completed to trigger motor 25, this circuit being intermittently made and broken by timer 28 to fire the gun synchronously with respect to the propeller rotation.

Referring now to Figure 2, a trigger motor 25 includes a casing 37 having a mounting plate 38 on which are formed suitable gibs 39 and 40 or the like adapted to fit into ways 41 formed in a side 42 of gun 20. Gib 40 is secured to the end of a threaded stud 43, and when a nut 44, threaded on stud 43, is taken up against the rear of mounting plate 38, gib 40 is drawn against gun side 42 to securely hold the trigger motor in place on the gun.

Casing 37 includes an annular portion 37a into which a metal ring or shell 45, formed of mag-

netic material, is set, this shell being held in place by screws 46 or the like. The bottom of shell 45 is preferably cut away at 46 to form an annular shoulder 47 against which a cap 48, preferably of soft iron, is set. A central bore in cap 48 receives a core 49, which extends upwardly, as viewed in Figure 2, through shell 45 and forms therewith an annular space 50 in which a field winding 51 is disposed. The other end of shell 45 also has an annular shoulder 52 against which an iron ring 53 is set and held in any suitable manner.

The upper end of core 49 is reduced as at 54 to provide an annular space or air gap 55, which receives the peripheral portion 56 of a floating cage 57. Cage portion 56 is suitably recessed to receive an armature coil or winding 58, the convolutions of which are preferably rectangular in cross section, and the upper end of which is secured to a resilient lead or conductor 59. Conductor 59 is held by a screw 60 extending through a bracket 61, the shank 60a of screw 60 being insulated from bracket 61 by an insulating piece 62. A nut 63 threaded on the end of the screw secures a contact 64 thereon, the contact also being insulated from bracket 61 by the top of insulator 62.

As viewed in Figure 3, conductor 59 is bolted to a plate 65, which is riveted or otherwise secured to cage portion 56, but is also insulated therefrom, plate 65 being connected to the upper end of armature coil 58 (Figure 2). Preferably a second conductor 66 (Figure 3) substantially similar to conductor 59 is secured to the other end of armature coil 58 for connection to a ground wire.

Referring back to Figure 2, the upper part of bracket 61 has secured thereto in any suitable manner an annular cage or housing 67, which houses the upper end of a coil spring 68, whose lower end bears against the top 69 of cage 57, top 69 preferably being substantially in the form of an inverted cone. Extending upwardly from cage top 69 is a shell-like projection 70 whose upper end 71 is provided with a bearing surface which slidably fits within housing 67. A guide generally indicated at 72 is formed within cage projection 70 and includes a semi-tubular portion 73 terminating in a partially spherical support 74, which cooperates with a semi-spherical depression 75 in cage top 69 to rotatably retain the spherical end 76 of a plunger 77 whose shank 78 extends through semi-tubular portion 73 into way 41 formed in gun 20. The end of plunger 78 is aligned with the sear 79 of the machine gun to effect operation thereof as will be pointed out below. As noted, this spherical end 76 of plunger 77 is rotatably mounted, i. e., it may rock about the axis of its end 76. Preferably a spring 80 is secured to cage top 69 urges plunger shank 78 against the semi-tubular portion 73 of support 72, but permits counterclockwise rocking of the plunger to a limited extent to permit recharging of the gun without damage.

The under portion of cage top 69 has a boss 81 which rests against the top of a stop 82 secured to the top of core 49 by a screw 83. The outer end of plunger 78 is spaced from sear 79 so as to provide a hammer blow against the sear. Thus when unenergized the cage 69 and 70 plunger 78 are held in the position shown in Figure 2 by spring 80. The outward thrust of the plunger is limited by the travel of cage 57. Face 57a of cage 57 strikes face 61a of bracket 61 and is positively stopped thereby.

As shown in the upper left-hand corner of Figure 2, an electrical connection or plug is provided having three terminals, 84, 85 and 86, which are respectively electrically connected to field coil 51, armature coil 58 and ground wire *g* (see Figure 8). Hence, when the field coil is energized, a magnetic flux is created in the air gap or space 55 (Figure 2) in which cage portion 56 is disposed, and thus when armature coil 58 is energized by current flowing from terminal 85, cage 57 and accordingly plunger 77 is projected upwardly to actuate sear 79. When armature 58 is deenergized, spring 68 returns the several parts to their rest position against stop 82. To prevent rotation of cage 57 and its connected parts during operation thereof, suitable guides 87 and 88 (Figure 3) are provided. These guides are secured to bracket 61 and include projections 89 and 90 respectively, which extend into slots 91 and 92 (see also Figure 2) formed in cage portion 56, thus preventing rotation of the cage in either direction about the axis of plunger 77.

It will now appear that trigger motor 25 is well able to operate at a frequency substantially in excess of the firing capacity of the gun. Furthermore solenoid lag is negligible since field winding is adapted to be constantly energized during operation of the trigger motor.

As noted above, trigger motor 25 is periodically actuated by timing mechanism 28 (Figure 1) which is operated directly by the airplane motor. With reference to Figure 4, timing mechanism 28 includes a casing 93 having a reduced bottom extension 94 on one side of which is formed an annular flange 95. Flange 95 is adapted to be secured to a ring 96, which, as better shown in Figure 1, extends from the rear of motor 21. Referring back to Figure 4, a flanged ring 97 is clamped between flange 95 and motor ring 96, and in turn clamps in place an antifriction bearing 98 which rotatably mounts a shaft 99, which is connected to the motor shaft (not shown). The outer end 99a of shaft 99 carries a bevel gear 100, which may be keyed or otherwise connected to the shaft, and is held thereon as by a nut 101 threaded on the end of the shaft.

Housing extension 94 is provided with a shouldered recess 102 in which an antifriction bearing 103 is disposed to carry the lower end of a shaft 104. At the junction of casing 93 and casing extension 94, a partition 105 is formed, this partition having a bore in which another antifriction bearing 106 is placed and held preferably by a force fit. Shaft 104 has a reduced portion 104a in bearing 106, and thus the shaft is rotatably mounted in the casing. The lower end of shaft 104 has pinned thereto a bevel gear 107 which meshes with bevel 100, these gears preferably being so cut as to provide a 1 to 2 reduction therebetween. Thus shaft 99 and gear 100 rotate at motor speed, whereas gear 107 and shaft 104 rotate at one-half of motor speed. To prevent escape of lubrication from the bottom of casing extension 94 upwardly into the casing proper, we have provided a suitable gland 108 which is held in place by a cap 109 or the like secured to partition 105 by screws 110.

The upper end of shaft 104, which extends into casing 93, is further reduced and has pinned thereto, so as to rotate therewith, a cage generally indicated at 111. Cage 111 includes a hub portion 111a, which is secured to shaft 104 by a pin 112, and a disc-like bottom portion 111b,

which carries preferably three spring biased cam adjusting devices, one of which is generally indicated at 113. For purposes of clarity, only one of these devices has been shown in Figure 4, and as all are substantially identical, but one will be described.

Bottom 111b of cage 111 has three equally spaced holes therein, each one of which carries a loosely mounted bushing 114, which in turn pivotally supports the reduced end of a shaft 115. The upper reduced end of this shaft is similarly mounted in a bushing 116 carried in a top or cover plate 117, which is held against a ring 118 by suitable screws extending through plate 117 and threaded into cage bottom 111b. An arm 120 has a hub 121, which is secured to shaft 115 substantially centrally thereof by a pin 122. The other end 120a of arm 120 encircles a stud 123, which carries a pair of weights 124 and 125 disposed on opposite sides of arm 20 end 120a (see also Figure 6).

A spring 126 (Figure 4) is coiled about the lower end of shaft 115 between arm hub 121 and bushing 114, the upper end 126a of the spring extending through a hole in arm 120 (see Figure 6) and the lower spring end 126b (Figure 4) extending into a hole formed in bushing 114. With the arm and weights in the position shown in Figure 6, bushing 114 (Figure 4) may be turned to tension spring 126 as desired and the tension is maintained by setting the head of a screw 127, which is threaded into cage bottom 111b, against the top of bushing 114. It may now be seen that as shaft 104 and cage 111 are rotated upon operation of the airplane motor, centrifugal force generated thereby throws each of the sets of counterweights 124 and 125 radially outwardly from shaft 104 and hence draws each of arms 120 therewith toward the dotted line position shown in Figure 6. As the weights and arms are equidistantly spaced circumferentially about shaft 104, the whole device is in perfect balance. This radial movement of arms 120 with respect to shaft 104 results in clockwise rotation of each of shafts 115 as viewed in Figure 6.

Referring back to Figure 4, each upper end 115a of each shaft 115 carries a pair of gears 128 and 129 which are pinned to the shaft by a pin 130. Preferably gear 128 has less teeth than gear 129 and these gears mesh respectively with a pair of gears 131 and 132 loosely mounted on the upper end of shaft 104. As gear 131 meshes with gear 128 and as gear 132 meshes with gear 129, gears 131 and 132 turn at different rates about shaft 104 when gears 128 and 129 are turned by the pivotal action of shaft 115 resulting from the radial outward movement caused by centrifugal force generated during the rotation of cage 111.

Gears 131 and 132 respectively are formed on the lower ends of concentric sleeves 133 and 134 loosely mounted for rotation on shaft 104. The upper end of sleeve 133 is provided with a tongue 135 which interfits with a slot formed in the bottom end of a sleeve 136, whose upper end carries a single lobe cam 137. Thus sleeves 133 and 136 are coupled together. The upper end of sleeve 134 has a tongue 138 which interfits with a slot formed in a sleeve 139 whose upper end carries a cam 140 similar in contour to cam 137. Accordingly, sleeves 134 and 139 are coupled together. The cams, the sleeves and gears 131 and 132 are held against axial displacement from shaft 104 by a screw 141 threaded into the

top of shaft 104. Sleeves 133, 134, 136 and 139 are all rotatable with respect to shaft 104. Also, coupled sleeves 133 and 136 are rotatable relative to coupled sleeves 134 and 139.

As is more clearly shown in Figure 11, inner coupled sleeves 134 and 139 are oscillatable as a unit about shaft 104 by reason of meshing gears 129 and 132. Similarly, coupled sleeves 133 and 136 are oscillatable as a unit about shaft 104 and are also movable relative to inner sleeves 134 and 139 by reason of meshing gears 128 and 131. Relative movement between the pairs of coupled sleeves occurs only upon a variation in speed of the propeller motor which drives the timing device.

When shaft 104 is at rest, the circumferential distance between lobes 137a and 140a on cams 137 and 140 is small. However, when this shaft and cage 111 are rotating at a speed sufficient to generate centrifugal force to effect pivoting of shafts 115 as pointed out above, gears 131 and 132 are shifted relative to one another and relative to shaft 104, and accordingly shift the positions of cams 137 and 140 so as to separate their lobes to produce a low spot or dwell the extent of which, i. e., the circumferential distance, between lobes 137a and 140a and also the position of lobes 137a and 140a relative to shaft 104, varies directly as the centrifugal force generated by rotation of cage 111 and therefore varies directly as the speed of the airplane motor. It will also be obvious from the above that the cams rotate at the same speed as cage 111 by virtue of their connection therewith through gears 128, 129, 131 and 132.

Still referring to Figure 4, the upper edge of casing 93 has a ring 142 secured therein as by screws 143. A supplemental ring 144 is attached to the top of ring 142 as by screws 145, and holds in place a contact supporting disc 146 having a central opening 147 to provide clearance for the top of shaft 104. Preferably disc 146 is stamped or otherwise fabricated to provide a pair of contact supporting brackets 148 and 149 (Figure 5).

As shown in Figure 4, bracket 149, which is substantially similar to bracket 148, includes a downwardly extending portion 150 and a transverse portion 151. Transverse portion 151 has a bore coaxial with a bore in disc 146, which receive the ends of a stud 152, disposed between the disc and bracket portion 151. Stud 152 pivotally supports a cradle 153 which, as is better shown in Figure 5, carries at one end a cam follower 154, and at the other end a contact 155. Contact 155 is insulated from cradle 153 by suitable dielectric washers 156, and a dielectric bushing 157. Contact 155 is formed on the end of a stud 158 which extends through the end of cradle 153, and this stud also supports one end of a spring conductor 159, whose other end is electrically connected to a terminal 160 which extends through, but is insulated from a plate 161 downstruck from disc 146. Plate 161 also carries another terminal 162 which is electrically insulated from the plate, but is electrically connected to a conductor 163 leading to a contact 164. Contact 164 is carried by a downstruck portion 165 of disc 146, and this contact cooperates with a contact 166 mounted on one end of, but insulated from a second cradle 167 carried by bracket 148 in substantially the same manner as that pointed out with respect to cradle 153. The other end of cradle 167 has secured thereto a cam follower 168.

Contact 166 is electrically connected to a resil-

ient conductor 169 substantially similar to conductor 159, conductor 169 being electrically connected to a terminal 170 secured to but insulated from a plate 171 downstruck from disc 146. Plate 171 also carries another terminal 172 which is electrically connected by a conductor 173 to a contact 174 which cooperates with movable contact 155 on the end of cradle 153. Terminals 170 and 172 are inflow terminals, whereas terminals 160 and 162 are outflow terminals.

It will now appear that as shaft 104 carrying cams 137 and 140 rotates, followers 168 and 154, respectively, are moved to effect engagement between contacts 166, 164 and 155, 174, respectively. When the followers hit the dwell or low spot between lobes 137a and 140a (Figure 8) contacts 155 and 166 (Figure 5) cooperate with their respective cooperating contacts 174 and 164 because of the bias of resilient conductors 159 and 169.

The upper part of timer casing 93 has suitably secured thereto a housing 175 in which a bracket 175a is attached. This bracket carries a solenoid 176 having a core 177 arranged to attract a pivoted armature 178 when the solenoid is energized. As will be described in greater detail hereinafter, solenoid 176 is energized from a battery when a switch is closed by the pilot of the airplane, and resulting attraction of armature 178 against the bias of a spring 179 to depress a hook 300. This closes contacts 182, 182a and 183, 183a (Figure 8) to permit a flow of current to terminals 170 and 172 (Figure 5) which are connected as described to the timer contacts or breaker points 155 and 166. Current is supplied to solenoid 176 from a socket 180 having terminals 180a and 180b adapted to receive a plug (not shown) leading from the battery and the pilot's control switch 34. An electrical connection 181 having terminals 181a, 181b and 181c is carried by housing 175, this connection being adapted to receive a cable carrying wires 26 and 27 and g (Figures 1 and 8) which connect the timer 28 to the trigger motor 25.

With reference now to Figure 8, which diagrammatically shows the electric circuit by which trigger motor 28, timer 25, battery 36 and pilot switch 34 are connected. Battery 36 is connected to line 33 which, with line 32, is preferably disposed in a cable (not shown) terminating in a plug having a pair of terminals 185 and 186 for lines 32 and 33. Lines 32 and 33 are connected upon closing of pilot switch 34. When the plug which carries terminals 185 and 186 is plugged into socket 180 of the timer 28, terminal 185 mates with terminal 180a to connect line 32 to a line 187 whose other end is connected to solenoid winding 176. As noted above the other end of solenoid winding 176 connects with a wire 184 leading to ground G, and hence back to battery 36. Completion of this circuit by the closing of pilot switch 34 energizes solenoid 176 and attracts armature 178 to close contacts 182, 182a and contacts 183, 183a. Contacts 182a and 183a are connected to a line 188 leading to terminal 180b which mates with terminal 186 of line 33.

When contacts 182 and 183a are closed by energization of solenoid 176, battery 36 is connected with a line 196 as follows: Battery 36, line 33, terminals 186 and 180b, line 188, contacts 183a, 183. Line 196 runs to terminal 181a of connection 181 and mates with a terminal 197 on the end of line 26 when this line is plugged in. The other end of line 26 has a terminal 198 which

mates with field coil terminal 84 in trigger motor 25, the other end of field coil 51 being connected to a line 199 which is connected to ground G as follows: Terminals 86 and 200, ground line g, terminals 201, 181c, line 184, hence to ground.

Armature terminal 182 is connected to a line 189 which leads to timer terminal or binding post 170. This last terminal has connected thereto wires 190 and 191, which are respectively connected to stationary timer contact 174 and movable timer contact 166. Hence, when timer contacts 155 and 174 are closed, wire 190 is connected to a line 192, which is connected to timer terminal or binding post 160. When timer contacts 164 and 166 are closed, line 191 is in circuit with a line 193 also connected to binding post 160. This binding post is connected by a wire 194 to terminal 181b of electrical connection 181 and is adapted to mate with a terminal 195 connected to line 27 when the cable (not shown) which carries lines 26, 27 and g is plugged into connection 181.

The other end of line 27 has a terminal 202 adapted to mate with terminal 85, which is connected to armature coil 58 of timer 25. The other end of the armature coil is connected to line 199 and hence to ground G as noted above with respect to field coil 51.

It will now appear that when the pilot closes pilot switch 34, solenoid 176 is energized to close armature contacts 182, 182a and 183, 183a. Closing of these contacts completes the circuits to field coil 51 and armature coil 58 of trigger motor 25. It should be here noted that when pilot switch 34 is closed, field coil 51 is constantly energized whereas armature coil 58 is intermittently energized by virtue of cams 137 and 140 of the timing mechanism.

The simplicity and reliability of our synchronizing system substantially precludes the necessity of subsequent adjustment or care after initial installation and setting. As there are no moving parts utilized to transfer impulses from the timer to the trigger motor temperature variations have no effect on the operation of the system.

As noted above, cams 137 and 140 are relatively movable and their lobes 137a and 140a are near together or far apart, depending upon the engine speed. As the cam lobes separate the low spot or dwell therebetween increases, this dwell increasing in extent as the motor speed rises, and it is only when either of the followers 154 or 168 is engaging the dwell that current flows to the trigger motor armature 58. As hereinbefore noted, there are certain constant time elements which cause a time lag between closing of contacts 155, 174 or 166, 164 and passing of the bullet through the plane of rotation of the propeller, and this time lag is compensated for by the variation in the phase relationship or, in other words, by the shift of cams 137 and 140 counterclockwise relative to shaft 104 as the engine speed increases. Thus when the motor is speeded up, the dwell increases in extent and the position of closing of contact is also advanced relative to the motor shaft and hence propeller blades so that the electric impulse is transmitted sooner, and hence the gun is fired sooner, with the ultimate result that the bullet passes through the median line between propeller blades regardless of the rate at which the propeller is whirling. In effect, the gun is shot sooner or later after the passage of an oncoming propeller blade through the line of fire of the gun ac-

cordingly as the propeller is rotating faster or slower.

To facilitate a thorough understanding of this invention and the operation of the synchronizing system, we include herein a factual computation to illustrate the amount of automatic correction of the zero shot with relation to a propeller rotating at 800 R. P. M. (the lowest speed probably at which a machine would be fired) and 3000 R. P. M. (approximately top propeller speed).

Conversion of time into arc of propeller rotation in 1/1000 second

R. P. M.	Degrees
800.....	4.8
3000.....	18.0

Time lag factors (approximate)

	Seconds
Firing pin fall after release of sear.....	.005
Primer lag and bullet travel to gun muzzle.....	.0015
Bullet travel—muzzle to the plane of rotation of the propeller (4').....	.0015
Synchronizer delay (timer contact to sear release).....	.007
Total time lag.....	.0150

Rotation of propeller during time lag period

At 3000 R. P. M., lag = $18^\circ \times 15 = 270^\circ$
 At 800 R. P. M., lag = $4.8^\circ \times 15 = 72^\circ$
 Amount of automatic correction, 198°

Hence the zero shot for a dead engine should occur at substantially 72° ahead of a line bisecting the angle between two propeller blades, or 12° ahead of the center line of any blade of a three-bladed propeller. This timing would maintain the theoretical point of bullet passage through the plane of rotation of the propeller at a point midway between the blades for all engine speeds between 800 and 3000 R. P. M. It will be understood that these figures are approximations and are not to be construed in a limiting sense, but as illustrative of the automatic correction afforded by our synchronizing system.

Under certain circumstances it may be desirable, or in some instances even necessary, to reduce the trigger motor lag still further. This is accomplished by reducing the reactance of the armature coil circuit in the impulse motor to a minimum in order first, to allow rapid build up of the armature current to a maximum and accordingly to reduce the over all time lag of operation to a minimum, and, second, to reduce the arcing of the timer contacts and hence to increase their life. To this end, the fragmentary modification of the impulse motor shown in Figure 7 is directed. This form of motor is similar in many respects to the motor shown in Figure 2, and accordingly includes field winding 51, core 49, cap or cover 53, bracket 61 and cage 57 with its associated moving parts as described above. Cage 57 thus includes armature coil 58 which floats in air gap 55. Associated with armature coil 58 and electrically connected therewith are a set of compensation coils 203 and 204 preferably arranged respectively above and below coil 58 as shown in Figure 7. Coils 203 and 204, as shown in Figure 9, are connected in series with the main armature coil 58, and together have the same number of turns as the main armature coil. However, the compensating coils are oppositely wound with respect to armature coil 58 so

that their flux linkage or polarity will be in the opposite direction to the main armature coil flux linkage. In all other respects the circuit in Figure 9 is the same as that in Figure 8, and the operation of this modification is substantially the same as that of the trigger motor in Figure 2, with the exceptions noted.

With reference to Figure 10, wherein there is shown a fragmentary section of a third form of trigger motor, a cage generally indicated at 205 floats in air gap 55 as described with respect to motor 25 in Figure 2. Cage 205 includes an annular super-structure 206, in the interior of which is formed guiding and supporting surfaces generally similar to those described in connection with trigger motor 25. Super-structure 206 has connected thereto the upturned inner periphery of a resilient diaphragm 209, whose outer periphery 210 is secured to the ring-like upper edge 211 of a bracket 212. The lower part of bracket 212 is secured to ring 53 which with the bracket clamps in operative position the outer peripheral edge 215 of lower resilient diaphragm 213. The inner edge 214 of diaphragm 213 supports cage 205 and is insulated therefrom by insulator 214a, and is also electrically connected to coil 55. A contact 216 is electrically connected to diaphragm 213 by way of a rivet or screw 217 which is insulated from bracket 212. It may now be seen that lower diaphragm 213, through its conductivity, affords a good electrical connection between coil 55 and contact 216, whereas the resiliency of both diaphragm 209 and 213 bias cage 205 toward its bottom position as shown in Figure 10, upon de-energization of armature coil 55, as hereinbefore described.

From this description it is readily apparent that each of the diaphragms 209 and 213 provide a means whereby the cage and plunger are permitted limited travel in a direction parallel to the longitudinal axis of the plunger with substantially no movement in a direction transverse to said axis.

Accordingly we have provided a synchronizing system for a machine gun which efficiently and practically attains the various objects hereinbefore set forth.

As many possible embodiments may be made of the above invention and as many changes might be made in the embodiment above set forth, it is to be understood that all matter hereinbefore set forth, or shown in the accompanying drawings, is to be interpreted as illustrative and not in a limiting sense.

We claim:

1. A synchronizing system of the character described for synchronizing the fire of a machine gun with respect to a motor driven airplane propeller so as to fire through the plane of rotation of the propeller between adjacent blades comprising, in combination, an electrically actuated firing mechanism including an impulse device associated with the firing mechanism of said gun, said impulse device including means for creating a substantially permanent magnetic flux and an intermittently excitable member which when energized is adapted to create an impulse which operates said gun firing mechanism, a circuit including a source of power connected to said device, and means for intermittently energizing said circuit to excite said device and thereby create a firing impulse.

2. A synchronizing system of the character described for synchronizing the fire of a machine gun with respect to a motor driven airplane pro-

PELLER so as to fire through the plane of rotation of the propeller between adjacent blades comprising, in combination, an electrically actuated firing mechanism including an impulse device associated with the firing mechanism of said gun, said impulse device including means for creating a substantially permanent magnetic flux and an intermittently excitable member which when energized is adapted to create an impulse which operates said gun firing mechanism, a circuit including a source of power connected to said device, means for intermittently energizing said circuit to excite said device and thereby create a firing impulse, and means operated by the propeller motor for energizing said circuit at predetermined times so that the firing impulse is so timed that the gun fires between adjacent blades of the propeller.

3. A synchronizing system of the character described for synchronizing the fire of a machine gun with respect to a motor driven airplane propeller so as to fire through the plane of rotation of the propeller between adjacent blades comprising, in combination, an electrically actuated firing mechanism including an impulse device associated with said gun, said impulse device including means for creating a substantially permanent magnetic flux and also an excitable member which when energized creates a magnetic flux whose lines of force are opposed to those of said means, movable means associated with said member adapted to operate the firing mechanism of the gun upon creation of an impulse, and means for exciting said member intermittently in timed relation to propeller rotation so that the gun fires only between adjacent propeller blades.

4. A synchronizing system of the character described for synchronizing the fire of a machine gun with respect to a motor driven airplane propeller so as to fire through the plane of rotation of the propeller between adjacent blades comprising, in combination, an electrically actuated firing mechanism including an impulse device associated with said gun, said device having two elements which when energized create an impulse which operates the firing mechanism of the gun, means for maintaining one of said elements constantly energized whereby said impulse is created immediately upon energization of the other of said elements without the lag which would otherwise occur, and means for intermittently energizing the other of said elements to create said impulse.

5. A synchronizing system of the character described for synchronizing the fire of a machine gun with respect to a motor driven airplane propeller so as to fire through the plane of rotation of the propeller between adjacent blades comprising, in combination, an electrically actuated firing mechanism including an impulse device associated with said gun, said device having two elements which when energized create an impulse which operates the firing mechanism of the gun, means for maintaining one of said elements constantly energized whereby said impulse is created immediately upon energization of the other of said elements without the lag which would otherwise occur, means for intermittently energizing the other of said elements to create said impulse, and means for reducing the reactance in said second-mentioned element upon energization thereof.

6. A synchronizing system of the character described for synchronizing the fire of a machine gun with respect to a motor driven airplane pro-

5 peller so as to fire through the plane of rotation of the propeller between adjacent blades comprising, in combination, an electrically actuated firing mechanism including an impulse device associated with said gun, said device having two
 10 elements which when energized create an impulse which operates the firing mechanism of the gun, means for maintaining one of said elements constantly energized whereby said impulse
 15 is created immediately upon energization of the other of said elements without the lag which would otherwise occur, means for intermittently energizing the other of said elements to create said impulse, said second-mentioned element including a coil, and coil means whose polarity is
 20 opposite to that of said second-mentioned element whereby upon energization of said coil and said coil means reactance in said element is substantially neutralized.

25 7. An impulse motor adapted to be connected to a machine gun for actuating the sear pin thereof, said motor comprising, in combination, a casing, a field coil disposed about a metallic core and mounted in said casing, said field coil being
 30 adapted to be constantly energized to create a substantially permanent magnetic flux, a movable armature coil adapted to be intermittently energized and disposed within the magnetic field created by said first-mentioned coil, a sear operating plunger connected to said armature coil and movable therewith upon energization thereof
 35 from a normal to an extended position, and means for reducing the reactance of said armature coil upon energization thereof.

40 8. An impulse motor adapted to be connected to a machine gun for actuating the sear pin thereof, said motor comprising, in combination, a casing, a field coil disposed about a metallic core and mounted in said casing, a movable coil support mounted in said casing for movement
 45 away from and toward said core, an armature coil mounted on said support, said field coil being adapted to be constantly energized so that upon energization of said armature coil said support is
 50 impelled away from said core, and a member secured to said support and adapted upon movement thereof to strike said sear to fire the gun, the end of said member being spaced from the end of said sear so that said member strikes said sear with a hammer blow.

55 9. A synchronizing system of the character described for synchronizing the fire of a machine gun with respect to a motor driven airplane propeller so as to fire through the plane of rotation of the propeller between adjacent blades comprising, in combination, a firing mechanism including an electrically actuated impulse device operatively associated with said gun and adapted upon energization to fire the gun, said impulse
 60 device including, means for creating a substantially permanent magnetic flux and an intermittently excitable member which when energized is adapted to create an impulse, means for utilizing said impulse to fire the gun, a circuit including
 65 a source of power connected to said device, and means for intermittently energizing said circuit to excite said device and thereby create a firing impulse.

70 10. An impulse motor adapted to be connected to a machine gun for actuating the sear pin

thereof, said motor comprising, in combination, a casing, means in said casing for creating a substantially permanent magnetic flux, said means including a core and field coil disposed thereabout, means forming an air gap at one end of
 5 said core, a cylindrical member reciprocally disposed in said gap, an energizable armature coil mounted on said cylindrical member, said coil when energized being adapted to create an impulse which effects movement of said member,
 10 means for biasing said member oppositely to the effect of said impulse, and a part secured to said support and adapted to coact with said sear pin upon creation of an impulse.

11. An impulse motor adapted to be connected 15 to a machine gun for actuating the sear pin thereof, said motor comprising, in combination, a casing, means in said casing for creating a substantially permanent magnetic flux, said means including a core and field coil disposed thereabout,
 20 means forming an air gap at one end of said core, a cylindrical member reciprocally disposed in said gap, an energizable armature coil mounted on said cylindrical member, said coil when energized being adapted to create an impulse which
 25 effects movement of said member, means for biasing said member oppositely to the effect of said impulse, a plunger associated with said member and adapted to coact with said sear pin upon the creation of an impulse, and means
 30 mounting said plunger on said member for limited movement with respect thereto in directions other than axial.

12. An impulse motor adapted to be connected 35 to a machine gun for actuating the sear pin thereof, said motor comprising, in combination, a casing, means in said casing for creating a substantially permanent magnetic flux, said means including a core and field coil disposed thereabout, means forming an air gap at one end of
 40 said core, a cylindrical member reciprocally disposed in said gap, an energizable armature coil mounted on said cylindrical member, said coil when energized being adapted to create an impulse which effects movement of said member,
 45 means for biasing said member oppositely to the effect of said impulse, a plunger associated with said member and adapted to coact with said sear pin upon the creation of an impulse, means mounting said plunger on said member for limited
 50 movement with respect thereto in directions other than axial, and means constantly urging said plunger into a coaxial position with respect to said member.

13. An impulse motor adapted to be connected 55 to a machine gun for actuating the sear pin thereof, said motor comprising, in combination, a casing, means in said casing for creating a substantially permanent magnetic flux, said means including a field coil disposed about a
 60 metallic core, a cylindrical member movably disposed within said casing adjacent one end of said core and substantially coaxial therewith, an armature coil carried by said member adapted upon energization to create an impulse which
 65 moves said member axially of said core, and means for restraining rotational movement of said member relative to said core.

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