June 28, 1960 G. A. HAWKINS 2,942,524

MACHINE GUN COOLING SYSTEM

Filed Dec. 19, 1947

8 Sheets-Sheet 1

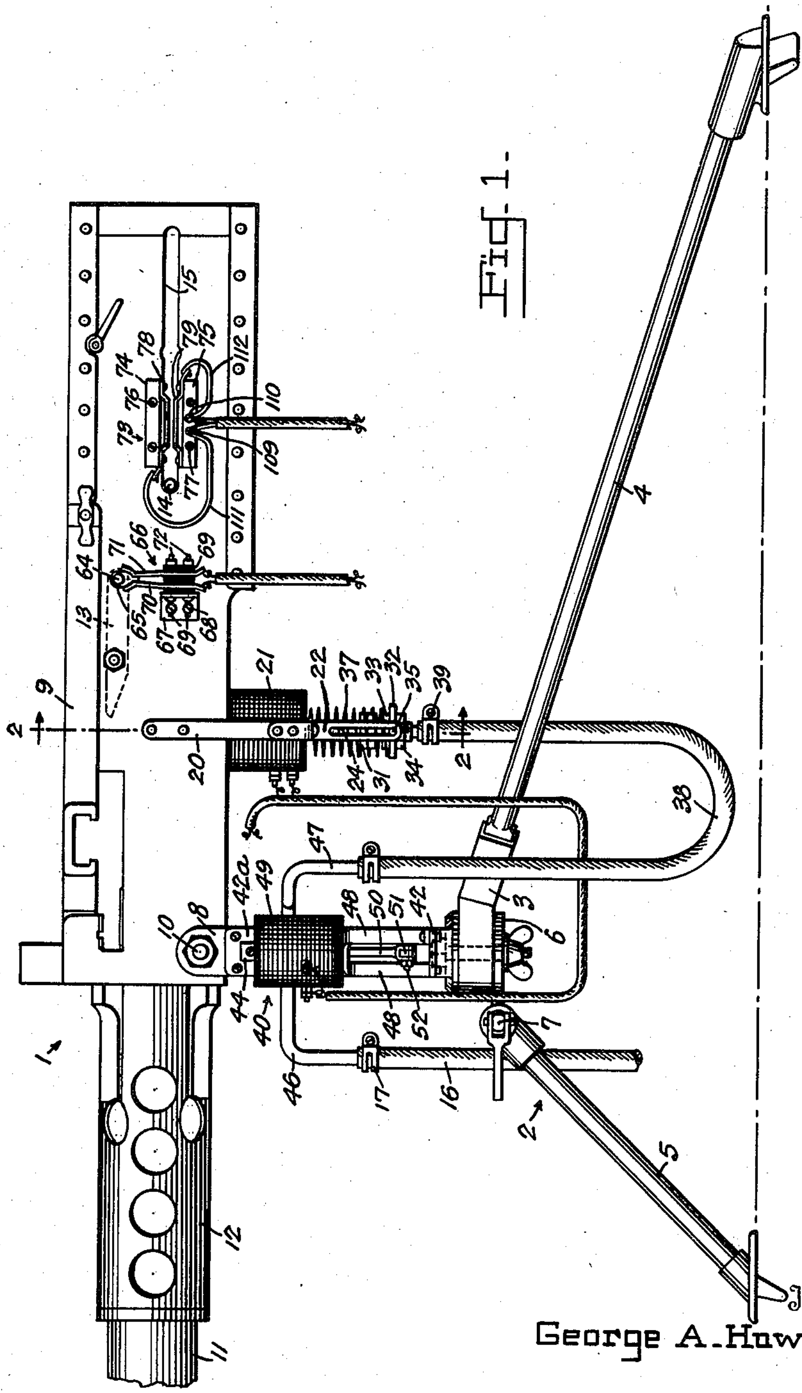

Fig. 1

Inventor

George A. Hawkins

By G. J. Kessenich, J. H. Church + A. W. Dew

Attorneys

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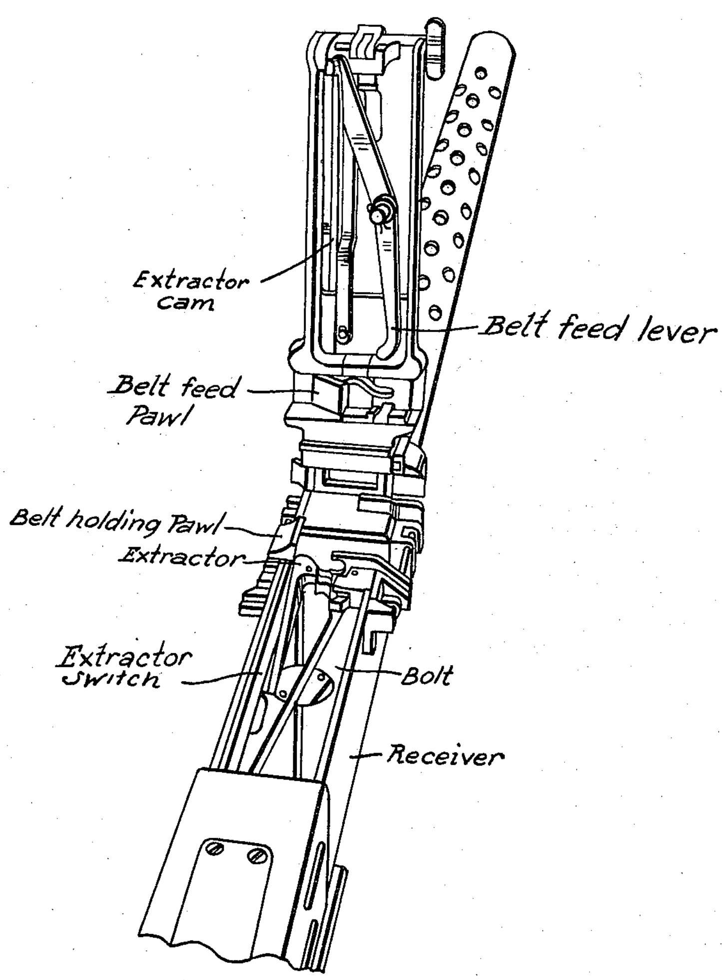
Fig. 1a



INVENTOR.
George A. Hawkins
BY
G. J. Kessenich, J. H. Church & A. W. Dew
Attorneys.

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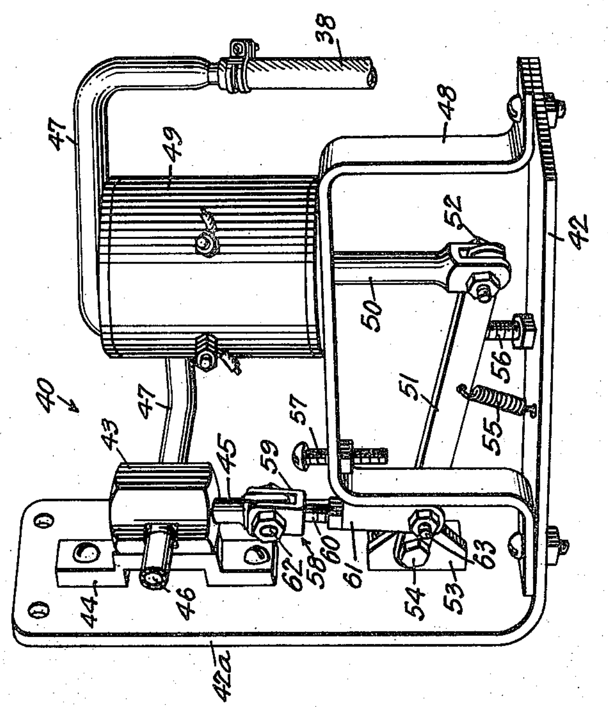

Fig. 4.

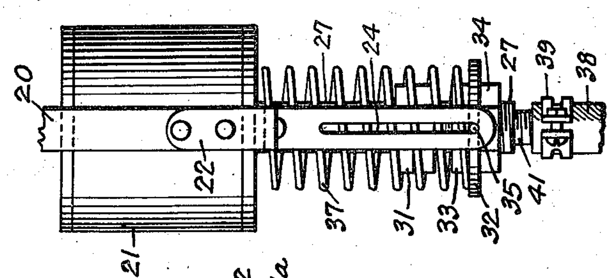

Fig. 3.

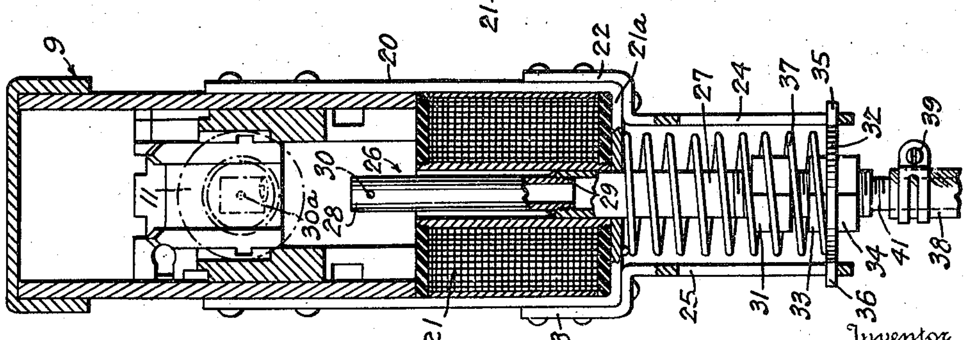

Fig. 2.

Inventor

George A. Hawkins

By G. J. Kesenich, J. H. Church & A. W. Dew

Attorneys.

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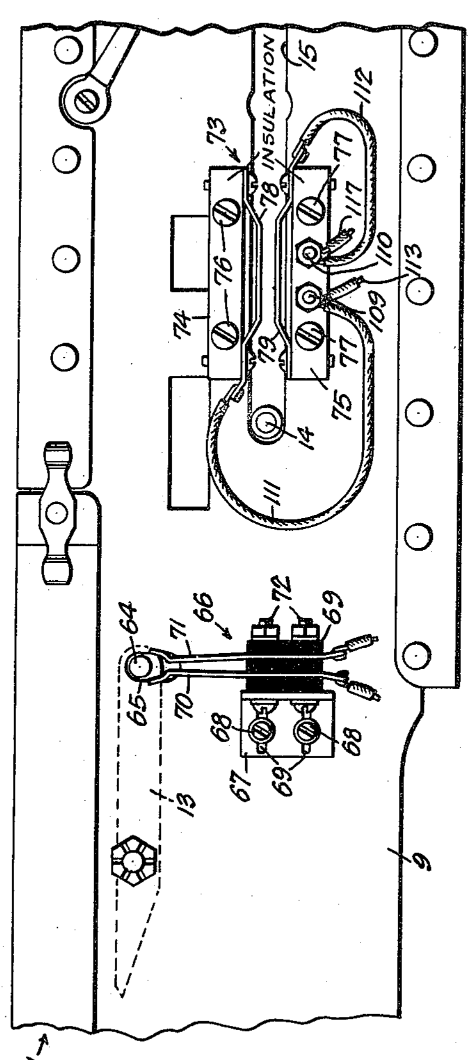
Fig. 5.



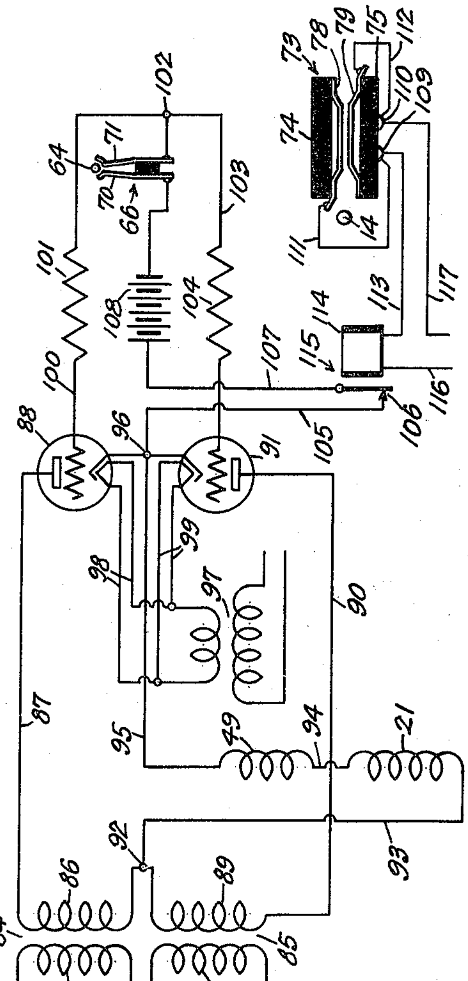


Fig. 6.

Inventor

George A. Hawkins

By G. J. Kessenich, J. H. Church + A. W. Dew

Attorneys

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Fig. 7.

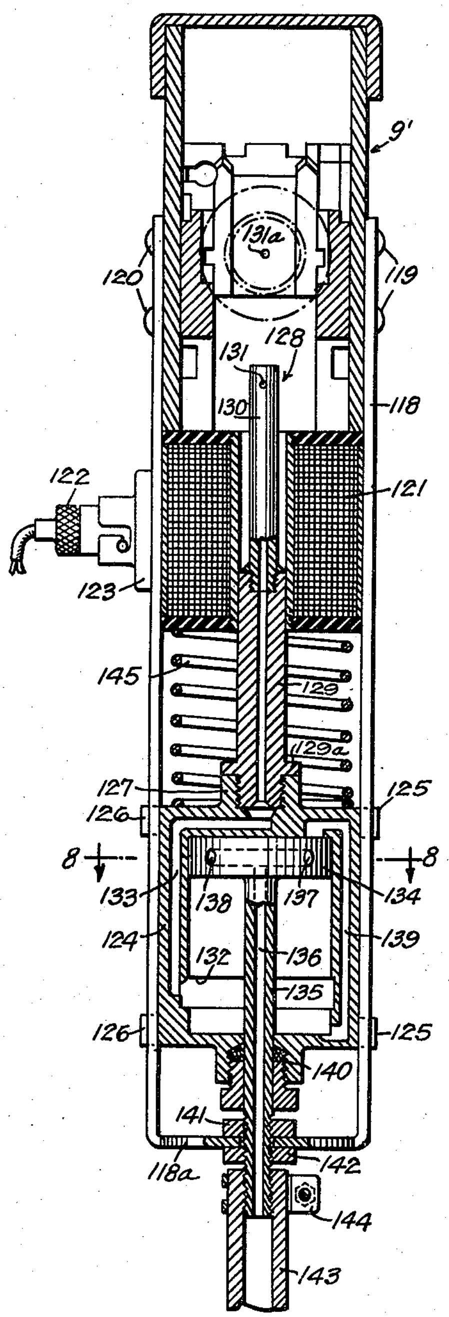


Fig. 8.

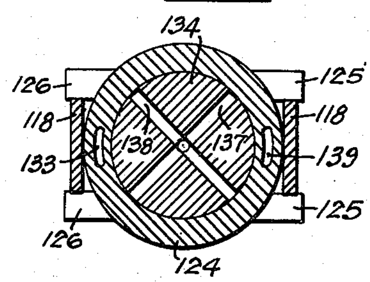
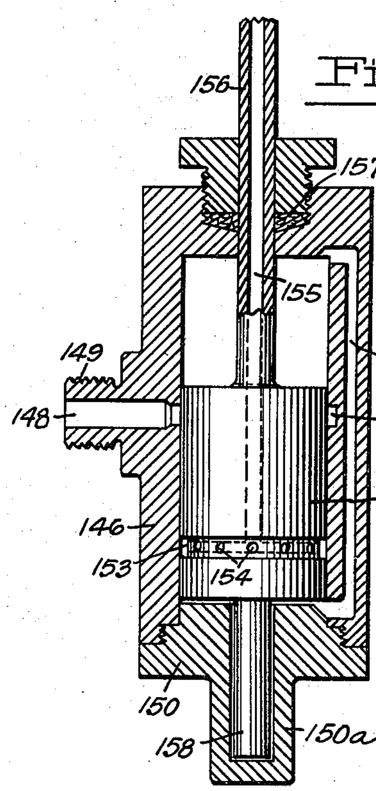


Fig. 9.



Inventor
George A. Hawkins

By G. J. Kessenich, J. H. Church & A. W. Dew
Attorneys

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Fig. 10.

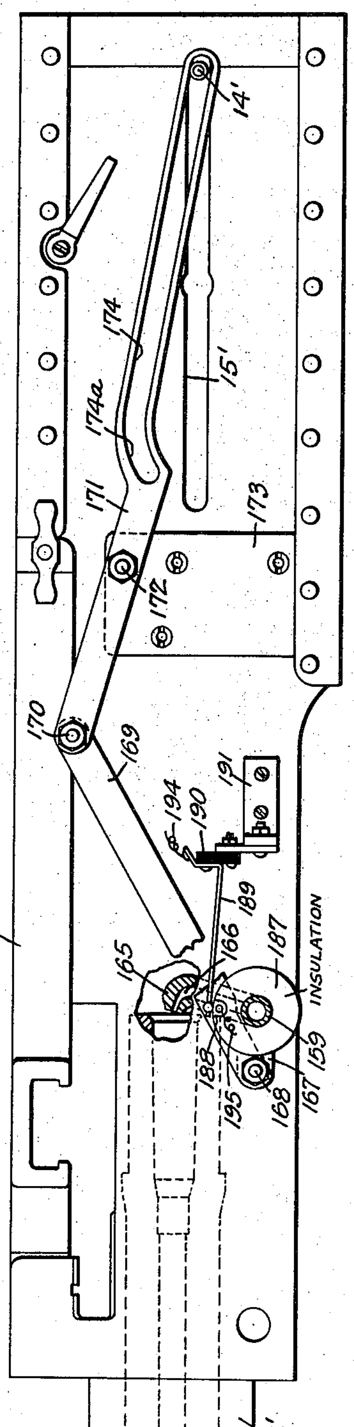
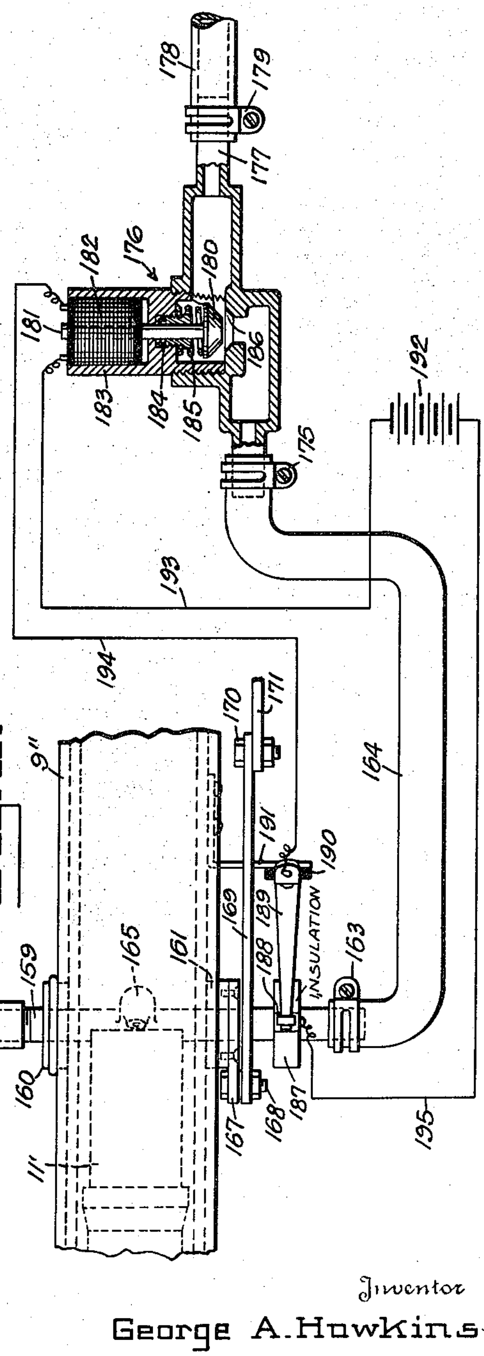


Fig. 11.



Inventor
George A. Hawkins

By G. J. Kessenich, J. H. Church & A. W. Dew
Attorneys

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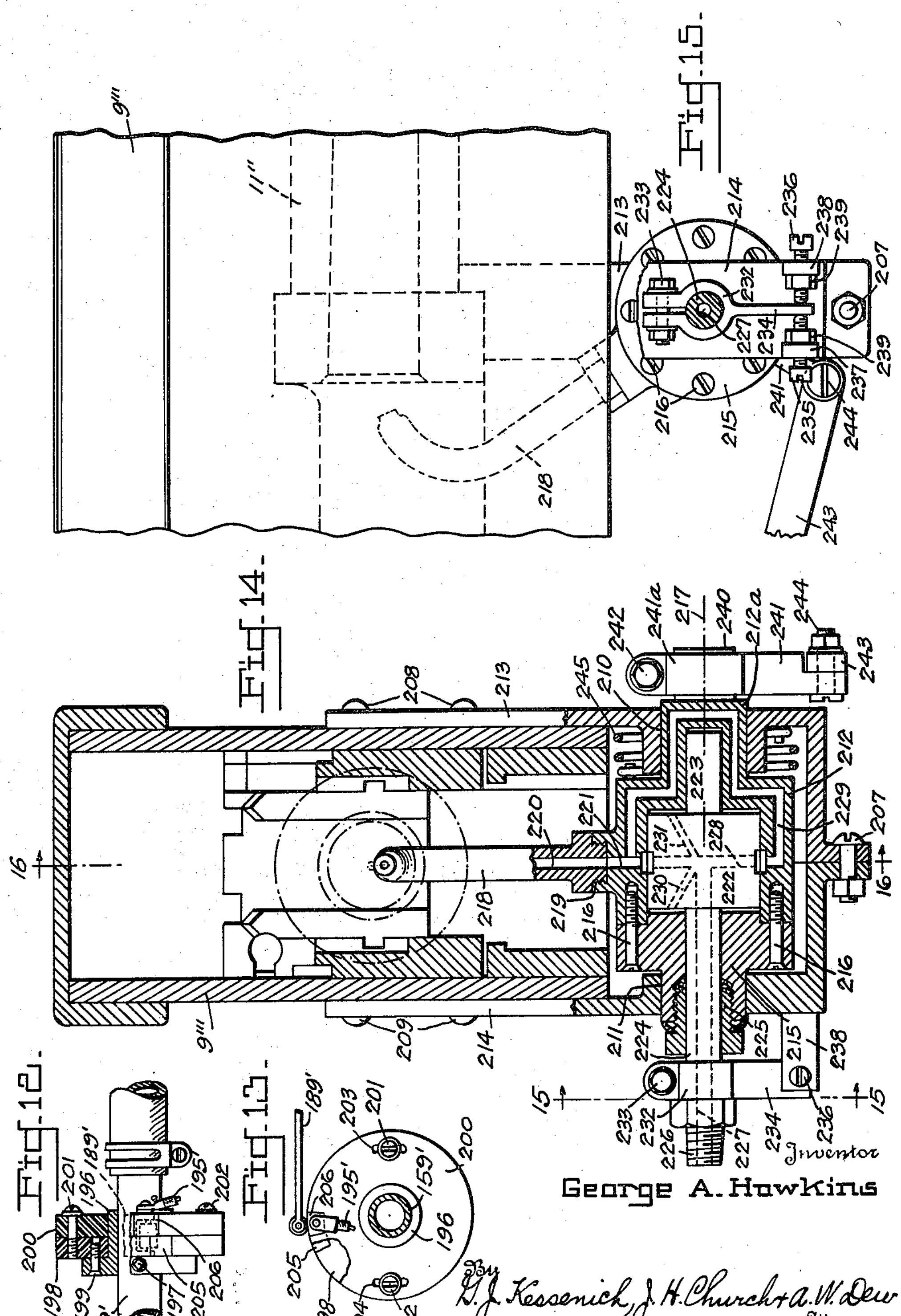

Inventor
George A. Hawkins

By G. J. Kessenich, J. H. Church & A. W. Dew
Attorneys

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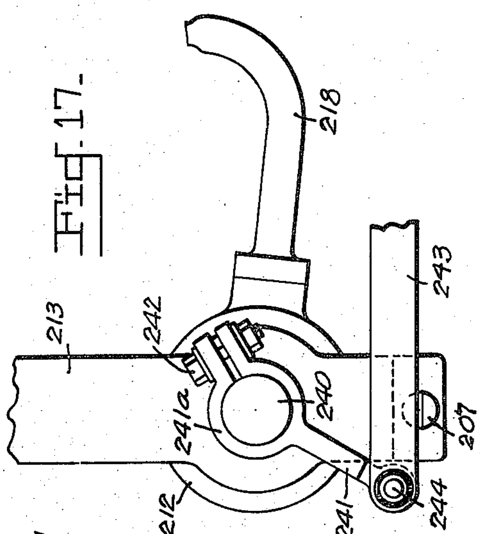
Fig. 17.



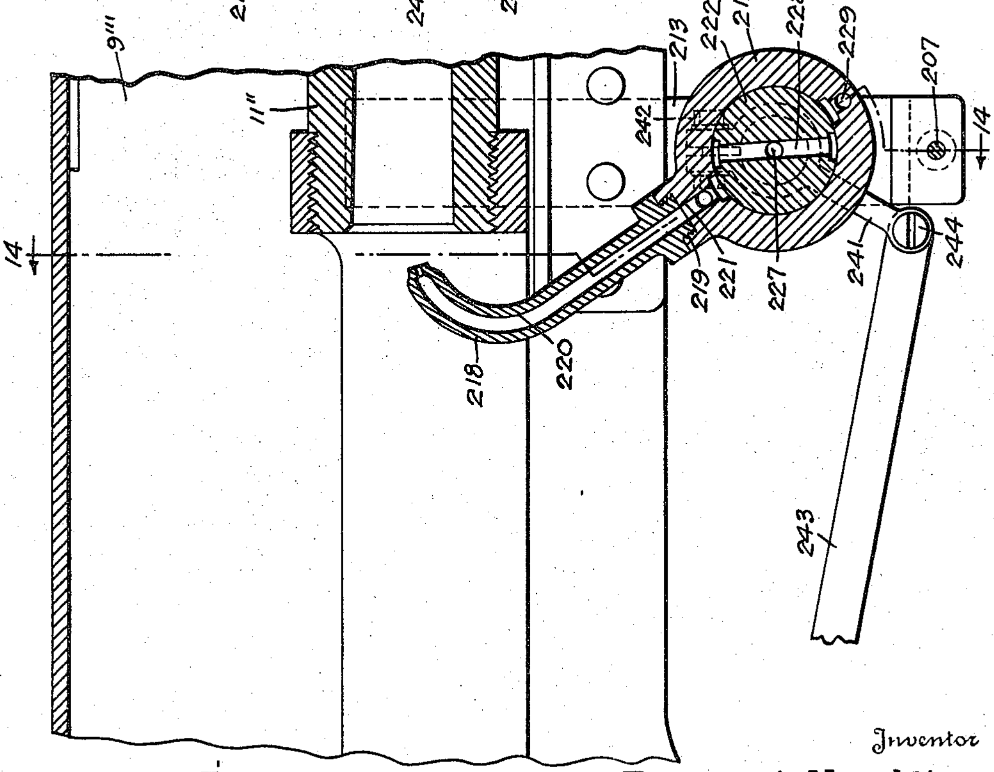


Fig. 16.

Inventor
George A. Hawkins

By G. J. Kessenich, J. H. Church & A. W. Dew.
Attorneys

United States Patent Office

2,942,524

Patented June 28, 1960

2,942,524

MACHINE GUN COOLING SYSTEM

George A. Hawkins, Lafayette, Ind., assignor, by mesne assignments, to the United States of America as represented by the Secretary of the Army

Filed Dec. 19, 1947, Ser. No. 792,722

19 Claims. (Cl. 89—14)

This invention relates to means and methods for cooling rapid-fire automatic weapons. To comply with the patent statutes the invention is shown in connection with a standard calibre .50 Browning machine gun. However, it will be readily apparent that only minor changes in size and arrangement of parts will be required to adapt it to other guns of different calibres but similar fire characteristics.

At the present time, one of the factors limiting sustained operation of rapid-fire weapons is that caused by overheating of the barrel. The barrel of a machine gun of the type disclosed, without a cooling system, will undergo a rapid rise of temperature after only a relatively short burst. For example, in the gun actually tested, without cooling, the barrel temperature increased from about 100° F. to 350° F., with a burst of only 75 rounds over a period of eleven seconds; and it required 15 minutes thereafter, for the barrel temperature to drop to approximately 225°. The possibility of sustained fire is seriously restricted when only natural cooling, that is, cooling by the ambient air, is relied upon. As a result where sustained fire under such conditions is attempted, even should the gun continue to operate, the resultant overheating limits the useful life of the barrel, and the accuracy and range of the gun.

It is accordingly an object of our invention to provide a mechanism and method for cooling rapid fire automatic guns whereby the rate of dissipation of heat from the barrel incident to sustained fire, is greatly increased.

A further object is the provision of a system whereby a cooling liquid is directly and automatically introduced into the gun in timed relation with the firing thereof whereby the heat of the liquid and its latent heat of evaporation, are utilized in the rapid extraction of heat from the barrel.

A still further object is the provision of a cooling system for guns wherein the rapid extraction and dissipation of heat takes place directly from the bore surface of the barrel and results in the possibility of more frequent bursts, greatly prolonged life of the barrel, increased average accuracy and range over the life of the barrel, and increased fire power from each battery of guns so equipped.

Another object is the provision of a cooling system for guns of the type aforesaid, which is relatively simple, reliable and easy to operate and which may be readily adapted to all conditions in which such guns are now employed.

Other objects and advantages will become apparent after a study of the following description in connection with the accompanying drawings wherein:

Fig. 1 shows a side elevation of a standard tripod-mounted calibre .50 Browning machine gun equipped with one form of my invention,

Fig. 1*a* is a perspective view of the loading and extracting mechanism of a .50 caliber Browning machine gun.

Fig. 2 is a vertical section to an enlarged scale, taken

in a plane indicated by the line 2—2, Fig. 1 and showing the cooling nozzle in lowermost position and the means for operating the same,

Fig. 3 is a detail elevational view of the lower portion of Fig. 2 and taken at right angles to Fig. 2 show the nozzle guide means,

Fig. 4 is a detail perspective view of the fluid control valve and solenoid operating means depicted upon Fig. 1,

Fig. 5 is a detail substantially full-size elevation of the left side of the gun as in Fig. 1, showing the control switches for energizing and de-energizing the respective solenoids,

Fig. 6 is a wiring diagram showing the control circuits for the solenoids,

Fig. 7 is a detail sectional elevation of a modification in which a single solenoid is used to actuate the nozzle and the fluid valve controlling the same,

Fig. 8 is a detail sectional view taken upon a plane indicated by line 8—8, Fig. 7,

Fig. 9 is a detail sectional view to an enlarged scale, of a modified form of Fig. 7 in which the piston of the valve moves instead of the cylinder thereof,

Fig. 10 is a side elevation of a calibre .50 Browning machine gun equipped with a pivoted type nozzle and mechanical connections for oscillating the same from the bolt mechanism of the weapon,

Fig. 11 is a plan view corresponding to Fig. 10 showing schematically the solenoid-operated control valve and circuit therefor,

Fig. 12 is a plan view, partly in section, of a modified form of switch or commutator section,

Fig. 13 is an elevation looking from the right, of the modification of Fig. 12,

Fig. 14 is a vertical section to an enlarged scale, through the receiver of a machine gun equipped with an oscillating type nozzle having its control valve formed as an integral part thereof and showing the nozzle nearing its uppermost, or ejecting position,

Fig. 15 is an elevation taken in a plane indicated by the line 15—15, Fig. 14,

Fig. 16 is a central vertical section taken upon a plane indicated by the line 16—16, Fig. 14, and

Fig. 17 is a detail elevation of the nozzle and operating connections thereto detached from the gun and as seen from the right, Fig. 14.

In Fig. 1 a standard calibre .50 Browning machine gun **1** such as that disclosed in Patent 1,628,226, granted May 10, 1927, is shown swivelled upon a tripod **2**. The tripod includes a spider **3** to which a pair of rearwardly-extending legs **4** are detachably connected. A forwardly-extending leg **5** is connected with the spider **3** by a plate **6** and an adjustable pivot **7**. A central, generally U-shaped bracket **8** rises centrally from spider **3** and is pivoted thereon for movement about a normally vertical axis. The receiver **9** of gun **1**, is journaled at its forward lower side, between the ends of the bracket **8**, for pivotal movement about a normally horizontal axis, as indicated at **10**. The gun is thus mounted for universal pivotal movement. The tripod mounting shown is purely conventional and any other well known supporting means may be substituted therefor. The gun receiver **9** has been identified. Other standard elements of this weapon may be briefly identified as **11**, barrel; **12**, barrel jacket; **13**, extractor switch; **14**, bolt stud; and **15**, receiver slot.

Fig. 1*a* shows the loading and extracting mechanism of a 0.50 caliber Browning machine gun. The operation of the parts illustrated is so well known as to need a brief description only. The loading or feeding mechanism includes the belt feed lever, belt feed pawl and the belt holding pawl whereby a live round is placed in the gun and positioned so the extractor can draw the round from the belt (not shown) and insert it into the bolt slot (not shown). As the bolt recoils the live round is pushed into the bolt slot ejecting the spent round from the receiver through an opening in the bottom thereof.

The operation of the "Browning" is well known and the foregoing brief description is given only to aid in understanding my invention hereinafter disclosed.

A U-shaped bracket 20 is rigidly secured to receiver 9 in a plane just rearwardly of the breech of barrel 11. As best shown at Fig. 2, the bracket supports a solenoid 21 between its intermediate portion 21a and the receiver. A pair of guides 22 and 23 are secured to the respective sides of bracket 20 and extend downwardly therefrom in spaced parallel relation and each depending end has a slot 24 and 25, respectively.

A plunger generally identified at 26 is mounted for reciprocation centrally within solenoid 21. This plunger is a composite element including a section of pipe 27 of magnetic material having a brass nozzle 28 threaded and brazed, as at 29, to its upper end. Nozzle 28 is closed at its upper end and is provided, closely adjacent such end, with a vent 30. This vent faces toward the breech of barrel 11 and the parts are so dimensioned that when plunger 26 is at its upper limit of travel vent 30 is closely adjacent and in alignment with the bore of the barrel. The lower end of section 27 is threaded and carries, first a lock nut 31 to adjustably limit the upper travel of plunger 26 by abutment against the bight portion of bracket 20 and, secondly, a guide 32 having a central aperture through which section 27 passes and clamped in adjusted position thereon by nuts 33 and 34. Guide 32 is generally circular and has diametrically opposite, radially extending pins 35 and 36 each having a smooth sliding fit in slots 24 and 25, respectively. A compression coil spring 37 surrounds plungers 26 and acts between guide 32 and bracket 20 to urge the plunger into its lowermost or fully retracted position. Downward movement is limited by engagement of pins 35 and 36 against the ends of the slots 24 and 25. A section of flexible hose 38 has one end connected to the lower end of a nipple 41, by clamp 39. Nipple 41 is rigidly connected with pipe section 27 as by threading and soldering. Thus, when solenoid 21 is energized, the plunger 26 is drawn upwardly until opening or vent 30 is immediately behind the bore of the barrel so that fluid ejected therefrom is sprayed into the bore to effect cooling of the bore surface, as indicated at 30a, Fig. 2.

A control valve assembly, generally indicated at 40, Figs. 1 and 4, is carried by one upright of bracket 8. Referring more particularly to Fig. 4, this assembly includes a bracket 42 having its vertical portion 42a adapted to be rigidly attached to bracket 8. A valve cylinder 43 is fixed to portion 42a by a base 44. Rod 45 is connected to a piston, not shown, within cylinder 43. This piston has a circumferential groove in such a position that, when the piston is in uppermost position, it acts to connect an inlet pipe 46 to an outlet pipe 47 while acting to cut off the flow of pressure fluid when moved downwardly a short distance depending upon the axial width of the groove or channel. It will be understood that inlet 46 is connected by flexible hose 16 and clamp 17, with any suitable source of coolant, under pressure.

A strap 48 is bolted to the horizontal or shelf portion of bracket 42 and supports a second solenoid 49 provided with a plunger 50 adapted to be drawn upwardly when the solenoid is energized. The forked lower end of plunger 50 embraces one end of a lever 51 and is pivotally connected therewith by a bolt 52. The other end of lever 51, is fulcrumed on portion 42a, by means of a bracket 53 and bolt 54, in a manner obvious from inspection of Fig. 4. A coil spring 55 connected between lever 51 and bracket 42, acts to urge plunger 50 to lowermost or cut-off position. Downward movement of the plunger is limited and regulated by a stop screw 56 which engages the lever 51 and limits its clockwise movement as viewed in Fig. 4. Upward movement of plunger 50 is limited and regulated by a screw 57 positioned to abut lever 51 when the plunger has moved the piston of valve 43 to fully open position. Piston rod 45 is connected with lever 51 by a connecting rod 58 comprising a yoke 59 having a stud 60 threaded into a second yoke 61. A bolt 62 pivotally connects rods 45 and 58. A bolt 63 pivotally connects the other end of rod 58 with lever 51. Thus, as coil 49 is energized the piston of valve 43 is moved to connect inlet 46 with outlet 47 and cooling fluid is forced through hose 38 and plunger 26, and ejected from hole 30 in the form of a stream or spray.

The coils or solenoids 21 and 49, are preferably connected in series and means are provided for energizing them in timed relation with firing of the gun so that (1) the nozzle 28 is moved upwardly into fluid-ejecting position only during the short period when the bolt mechanism is in retracted position and (2) pressure fluid is ejected from the nozzle only when the nozzle is in a position such that hole 30 is in alignment with the bore of the barrel.

For the purpose of controlling the circuit in timed relation with firing of the gun, I have utilized the fact that extractor switch 13 is moved downwardly as the bolt assembly of the gun moves rearwardly subsequently to the firing of each round. A metallic stud 64, Figs. 1 and 5, is rigidly attached to switch 13 and projects freely through an aperture 65 formed in the left side of the receiver. The stud 64 forms one part of a control switch, generally identified at 66, Figs. 4 and 5. The remaining components of this switch may comprise a right-angle bracket 67 adjustably secured to the receiver 9 by screws 68 passing through horizontal slots 69'. The outstanding portion of bracket 67, carries a series of three stacked blocks of insulating material 69. A pair of spring switch blades or leaves 70 and 71 are held in upwardly-extending spaced relation by block 69 and screws 72 which pass through aligned holes in the blocks, leaves and bracket 67. The holes in bracket 67 accommodating screws 72, may be elongated vertically whereby to permit limited vertical adjustment of the switch leaves relatively to stud 64. The upper ends of leaves 70 and 71 are bent outwardly and the spacing is such that when stud 64 is moved downwardly, it contacts both leaves and thereby closes a circuit therethrough.

For a purpose subsequently described, a second or auxiliary switch is provided, indicated generally at 73, Figs. 5 and 6. This switch includes insulating blocks 74 and 75 fixed by screws 76 and 77 to the side of receiver 9, upon opposite sides of bolt slot 15. A bowed metallic spring leaf 78 is secured at its ends to the under side of block 74. Likewise a second spring leaf 79 is attached at its ends to the upper side of block 75 and in spaced relation with leaf 78. Bolt stud 14 is attached to, but electrically insulated from the gun bolt. This stud, therefore moves back along slot 15 as the fired shell is extracted from the barrel and, in so doing, rides between and electrically connects leaves 78 and 79.

Referring to the circuit diagram of Fig. 6, the leads 80 and 81 are supplied from a source of A.C. voltage which may be a standard 110 volt, 60-cycle supply. The leads 80 and 81 are connected in parallel with the primaries 82 and 83 of transformers 84 and 85. Secondary 86 of transformer 84, has one terminal connected by lead 87, with the anode of electric valve 88 which may be a grid-controlled mercury vapor tube or Thyratron, such as the FG33. Likewise, one terminal of secondary 89 of transformer 85, is connected by lead 90 with the anode of a second valve 91. The remaining terminals of secondaries 86 and 89 are connected to a common terminal 92 which is connected by lead 93 with one terminal of nozzle control coil 21. The remaining terminal of coil 21 is directly connected by lead 94 to one terminal of coil 49 whose remaining terminal is connected over lead 95 with the common cathode terminal 96 of tubes 88 and 91. Filament current for the tubes is supplied from a transformer 97 over leads 98 and 99. The primary of transformer 97 may be supplied from the same source as 82 and 83.

The grid of tube 88 is connected by lead 100 and a resistor 101, to a terminal 102 connected with switch leaf 71. The grid of tube 91 is connected over lead 103 and a resistor 104 with terminal 102. Resistors 101 and 104 are of about 500 ohms each. The terminal 96 is connected by way of lead 105, contacts 106 of relay 115, and lead 107 with the negative side of a source of D.C. potential 108, having its positive side connected to switch leaf 70. Thus, with contacts 106 closed, movement of stud 64 downwardly closes control switch 66 and applies the necessary potential to fire tubes 88 and 91 and effect simultaneous energization of coils or solenoids 21 and 49. This causes movement of nozzle or plunger element 27 upwardly to position opening 30 in alignment with the barrel bore, and connects hose 38 with inlet 46 whereby cooling liquid is sprayed into the barrel. The leaves of switch 66 are so adjusted that they are contacted by stud 64 only during the final two or two and one-half inches of travel of the bolt, at which time the bolt and empty cartridge case are out of the path of movement of nozzle 28. During the final quarter-inch of travel of the bolt, extractor switch 13 snaps upwardly to its normal position as a lug on the extractor overrides the end of the switch. This acts to open switch 66 and de-energize coils 21 and 49 whereupon spring 37 causes nozzle 28 to snap downwardly out of the path of the returning bolt, while spring 55 moves valve 43 to fluid cut-off position. The system shown is intended to use water as the principal element of the coolant at about 60 p.s.i. gage pressure.

In the gun shown, the switch stud 64 moves downwardly for an instant as the bolt returns to firing position and the extractor moves up on the extractor cam preparatory to feeding in a new cartridge. The duration of this movement is very brief but is long enough to again energize coil 21 and force injector 28 up against the bottom of the bolt as it moves into forward limiting position. To obviate this undesirable second energization of the coils, I have provided auxiliary switch 73. From Figs. 5 and 6 it will be noted that block 75 carries a pair of insulated terminals 109 and 110 and that spring 78 is connected by lead 111 with terminal 109, while spring 79 is connected by lead 112 with terminal 110. Terminal 109 is connected by a lead 113 with the coil 114 of relay 115. The remaining terminal of coil 114 is connected by lead 116 to a source of potential, not shown. The circuit may be completed by a lead 117 extending from the aforesaid source to terminal 110.

It will be noted that switch leaves 78 and 79 are so positioned relatively to slot 15 and the travel of bolt stud 14, that the latter electrically connects the leaves only when the stud is in its forward position of travel. When so connected, the coil 114 is energized to attract the armature of relay 115 and open the common lead 105 forming a part of the grid circuits of both tubes 88 and 91. Since it is desired to energize coils 21 and 49 only when the bolt stud 14 is at the rearward portion of its travel, auxiliary switch 73 is open at such time, relay 115 is de-energized, and closure of control switch 66 is effective to fire the tubes. However, as stud 14 reaches the forward portion of its travel it acts to close switch 73 and thus open the grid circuit at 106. Consequently when undesired closure of switch 66 takes place due to the momentary movement of switch 13 as aforesaid, such closure is ineffective to close the grid circuit and coils 21 and 49 remain de-energized. Hence the nozzle 28 and valve 43 are actuated only when the breech of the barrel is open and unobstructed.

At Fig. 7 is shown a simplified form of the invention wherein the coolant control valve and injection nozzle are combined into a unitary structure and are actuated by a single coil. Referring in detail to this figure, the numeral 9' identifies the receiver of a gun, which may be of the same standard type as the one shown at Fig. 2. An elongated U-shaped bracket 118 has its upper ends rigidly attached to opposite sides of the receiver as indicated at 119 and 120. A solenoid 121 is mounted between the sides of bracket 118 to fit snugly against the under side of the receiver and is supplied by current from a plug 122, and socket 123 fixed to one side of the bracket.

A valve cylinder 124 fits smoothly between the sides of bracket 118, Fig. 8, and is guided for reciprocation thereon by pairs of lugs such as 125 and 126, each pair engaging opposite edges of the bracket. At its top, the cylinder has a projection 127 within which is threaded the lower end of plunger or nozzle element 128 comprising a pipe section 129 of magnetic material and a nozzle section 130 united in aligned relation with section 129 by threading and/or welding. Section 130 which may be of brass has an outlet opening 131 adjacent its upper closed end and so positioned that when the composite nozzle and cylinder are moved to uppermost position, opening 131 lies substantially in the bore axis of the barrel, as indicated at 131*a*, Fig. 7. This position may be determined by engagement of flange 129*a* on section 129, against the underside of coil 121.

Cylinder 124 is formed with an internal circumferential groove 132 adjacent its lower end. A passageway 133 places this groove in communication with the bore of section 129. In order to equalize fluid pressures upon the two sides of piston 134, a passageway 139 is provided in the cylinder wall connecting the cylinder ends.

A stem 135 is fixed to piston 134 and has an axial passageway 136 communicating with radial bores 137, 138 (see Figure 8). Stem 135 projects through a gland 140 in the lower end of cylinder 124. The stem is threaded at its lower end. This end passes through an aperture in the horizontal portion 118*a* of bracket 118 and is adjustably fixed to the bracket by nuts 141 and 142. The end of a flexible hose 143 is clamped to stem 135 by a clamp 144. This hose corresponds with hose 16, Fig. 1. A coil spring 145 acts between the lower side of coil 121 and the top of cylinder 124 to urge the latter into lowermost, or cut-off position.

Coil 121 may be energized by the same circuit connections and mechanism as are used to energize coils 21 and 49, shown at Fig. 6 and previously described. Hence it is deemed unnecessary to repeat the description. It is desired to point out however, that energization of the coil 121 may be controlled by other parts of the gun moving in timed relation with the firing thereof, so long as such parts have a definite relation or position with respect to the receiver at the instant that the breech is free of obstructions.

The operation of this form of the invention will be obvious. As coil 121 is energized, plunger 128 is drawn upwardly and ejection begins as soon as groove or channel 132 begins to overlap the radial bores in piston 134 and thereafter continues as long as the solenoid is energized. As soon as the solenoid is de-energized, spring 145 acts to restore the plunger and cylinder to retracted cut-off position. By adjustment of nuts 141 and 142, the time of ejection and cut-off may be precisely varied with relation to the movement of that part of the gun used to control energization of coil 121. By making bracket 118 in the form of a cylindrical casing, this modification may be completely enclosed so that there are no external moving parts. In such case lugs 125 and 126 will ride in axially-extending grooves in the inner wall of the casing.

Fig. 9 shows a modification corresponding generally to the species of Figs. 7 and 8, in which the piston of the valve is connected with the nozzle. In this form, a cylinder 146, has an internal circumferential channel 147 in communication with the radial bore 148 of a nipple 149. The cylinder is closed at its lower end by a threaded cap 150 having a central guide 150*a*. A passageway 151 connects the two ends of the cylinder to equalize pressures on the two sides of piston **152**. This piston has a circumferential groove **153** which communicates by radial bores **154** with a bore **155** in a stem **156** rigidly attached to the piston and extending upwardly through a gland **157** in the closed end of cylinder **146**. The lower end of piston **152**, as viewed in Fig. 9, has a second stem **158** extending axially therefrom and extending with a smooth fit into the bore in guide **150***a*. Stem **156** may form the armature of a coil similar to **121** and has a nozzle element secured to its upper end for reciprocation in the manner illustrated in Fig. 7. In this respect, stem **156** is analogous to pipe section **129** of Fig. 7. The relation of the parts is such that groove **153** is aligned with channel **147** when the ejection opening of the nozzle unitary with stem **156**, is directed along the bore of the barrel.

In Figs. 10 to 15, inclusive, I have shown a modification wherein the nozzle is pivotally mounted and is oscillated into ejection position by a mechanical connection with the bolt assembly of the gun. Figs. 10 and 11 show a form wherein the coolant control valve is separate from the nozzle. Figs. 12 through 15 show a form in which the nozzle and valve are combined in a unitary structure.

Referring to Figs. 10 and 11, the form of the invention there shown is applied to a standard Browning machine gun of the same type as that shown in Fig. 1. Consequently it will be sufficient to identify barrel **11′**; jacket **12′** and receiver **9″**. A hollow shaft **159**, extends between and is journaled as by means of bearings **160** and **161**, in the side walls of receiver **9″** on an axis below and substantially in the plane of the breech end of barrel **11′**. One end of shaft **159** is closed by a cap **162**, while the other end is connected, by clamp **163**, with a flexible hose **164**.

A curved or hooked nozzle **165** is fixed to the central portion of shaft **159** and has its passageway **166** in communication with that of the shaft. The shaft is so positioned that in one limiting position, the nozzle tip is aligned with the bore of barrel **11′** in position to direct a stream of coolant thereinto, while in the other limiting position the nozzle is entirely below and clear of the barrel.

A short lever **167** is fixed to the lower end of shaft **159**, as viewed in Fig. 11, and has its end pivotally connected by bolt **168**, to one end of a link **169**. The other end of link **169** is pivoted by bolt **170** to a lever or rocker arm **171** fulcrumed at **172** to a plate **173** bolted to the side of the receiver just forwardly of slot **15′**. The end of arm **171** remote from pivot **170**, has a slot **174** in which rides a stud **14′** attached to the bolt assembly of the gun. As a result of these connections, reciprocation of stud **14′** causes a synchronous rocking of shaft **159** through an angle of approximately 90°. In the position shown at Fig. 10, the bolt is in its limiting position of rearward translation and arm **171** is consequently in its limiting position of counterclockwise movement and has pivoted shaft **159** and nozzle **165** counterclockwise, into injecting position. As bolt stud **14′** moves forwardly, arm **171** and nozzle **165** are pivoted clockwise until the nozzle is entirely clear of the breech. The curved forward portion **174***a* of slot **174** acts to slow down pivotal movement of arm **171** for a given travel of stud **14′** as the latter approaches fulcrum **172**, and limits further angular movement of shaft **159** after the latter has moved to a position in which it has turned nozzle **165** out of the way of the bolt.

The other end of hose **164**, is connected by clamp **175** with the discharge nipple of an electro-magnetically operated valve **176** whose inlet **177** is connected by hose **178** and clamp **179** with a source of cooling fluid under pressure. A valve element **180** has a stem **181** of magnetic material forming the armature of an electro-magnet **182**. This magnet is mounted with a sleeve **183** threaded into the valve housing and provided with a gland **184**. A coil spring **185** acts to urge the valve element onto its seat **186** in a manner obvious from inspection of Fig. 11.

The circuit for energizing coil **182** in timed relation with loading and firing of the gun comprises a commutator-type switch including a part fixed to shaft **159**. The switch element consists of a disc of dielectric material **187** having a conducting insert **188**. A brush or spring contact blade or segment **189** is fixed at one end to an insulating block **190** which, in turn, is attached to a bracket **191** bolted to the side of receiver **9″**. The free end of blade **189** bears resiliently upon disc **187** as the latter oscillates with shaft **159**. Disc **187** may be fixed to shaft **159** by means such as a set screw, not shown, so that it can be fixed thereon in any desired position of rotative adjustment. This adjustment is effected so that blade **189** contacts insert **188** at the instant the nozzle **165** reaches injection position behind the breech of barrel **11′**.

The switch thus provided is included in a circuit for energizing valve coil **182** and shown schematically upon Fig. 11. This circuit may be traced from one pole of source **192** of current by way of lead **193** to one terminal of coil **182** and from the other terminal of said coil by lead **194**, to blade **189**, thence to segment **188** and by lead **195** to source **192**. Thus, as bolt stud **14′** approaches its limit of rearward travel, at the instant when the breech is clear of the bolt and the extracted cartridge casing, nozzle **165** reaches its injection position, segment **188** moves beneath the end of blade **189**, and the circuit is closed to energize coil **182**. Energization of coil **182** raises valve element **180** from its seat, against the thrust of spring **185**, and coolant is forced from the source connected to hose **178**, through hose **164**, hollow shaft **159** and nozzle **165**, into the barrel. As the bolt moves forwardly, the nozzle is pivoted downwardly out of its path, the circuit is broken, and spring **185** closes the valve to cut off further injection.

At Figs. 12 and 13, I have shown a modified form of commutator or switch element which may replace element **187** in the species shown at Figs. 10 and 11. In these figures, **159′** identifies a hollow shaft which may be a duplicate of shaft **159**, Figs 10 and 11. A flanged collar **196** has a smooth fit on shaft **159′** and may be secured thereon in adjusted position by a set screw **197**. A disc **198** of dielectric material is mounted on collar **196** and secured to the flange thereof by one or more screws **199**. A second dielectric disc **200** is mounted on collar **196** and is adjustably fixed to disc **198** by screws **201** and **202** which pass loosely through respective arcuate slots **203** and **204** in disc **200** and are threaded into apertures in disc **198**. The disc **198** has a conducting segment **205** fixed in its periphery. A like segment **206** is fixed to the periphery of disc **200**. The contact blade has its end extending over and in contact with the periphery of both discs, as indicated at **189′**, Fig. 12. Segments **205** and **206** are electrically connected in any suitable manner as by having their adjacent ends in contact, or by a branch connection to each from a common lead **195′**.

Thus, the total angle of rotation of the commutator during which the valve circuit remains closed, may be varied by loosening screws **201** and **202**, and angularly shifting disc **200** relatively to disc **198**, to thereby vary the angular spacing of the remote edges of the segments **205** and **206**. Furthermore, by loosening set screw **197**, the two discs and collar may be angularly adjusted as a unit to vary the instant at which injection begins. In this way, the period of injection and its timing relatively to the nozzle, may be varied to give the most efficient cooling.

In Figs. 14 to 17, inclusive, I have shown a rotary or oscillating type injection nozzle in which the control valve is structurally integrated with the nozzle itself.

Referring in detail to these figures, the receiver 9''' has a frame or bracket comprising two sections 213 and 214, attached to respective sides of the receiver, as indicated at 208 and 209, and secured together at their lower portion by a bolt 207. Section 213 has a bearing aperture 210 in alignment with a similar aperture 211 in section 214.

The casing 212 of a valve comprises a body portion having a reduced central projection 212a journaled in aperture 210. The other end of casing 212 is closed by a cap 215 secured in place by screws 216 and having a reduced central projection journaled in aperture 211. The casing is thereby mounted for pivotal movement about an axis 217, Fig. 14.

A nozzle 218 has the same general form as 165, Figs. 10 and 11, and is rigidly attached to casing 212 to extend radially thereof, as by a threaded connection 219, Figs. 14 and 16. The passageway 220 in nozzle 218 communicates with the interior of the casing through a radial aperture 221 in the casing wall.

The piston element of the valve comprises a core 222 having a smooth fit with casing 212 and provided at one end with an axial stem 223 journaled within the bore in projection 212a, and at its other end with a hollow stem 224 having a smooth fit within the central hole in cap 215. A packing gland 225 acts to prevent the escape of fluid under pressure between the bearing surfaces of cap 215 and stem 224. The end of stem 224 is threaded, as at 226, to provide for connection thereto of a source of coolant under pressure.

The axial passageway 227 in stem 224 and core 222, communicates with a diametrical bore 288 in the core. Bore 228 is slightly enlarged at its ends as clearly indicated upon Figs. 14 and 16. To provide a balance of lateral forces with consequent ease of operation of the valve, a passageway 229, Fig. 14, is provided in the wall of casing 212, extending from an interior opening in the wall thereof diametrically opposite aperture 221, extending to and opening into said aperture. To balance axial thrusts on valve core 222 passageways 230 and 231, Fig. 14, are provided therein, leading from bore 228 to the respective ends of the core.

Core 222 and the parts attached thereto, including stem 224, are adjustably fixed to the gun by means of a split collar 232 adapted to be clamped to stem 224 by bolt 233 in a desired position of rotary adjustment. An arm 234 extends from collar 232 and projects between the confronting ends of adjusting screws 235 and 236, threaded through respective lugs 237 and 238 on bracket section 214. After a relatively coarse adjustment of core 222 about axis 217 the bolt 233 is tightened and a final adjustment effected by turning of screws 235 and 236 after which they are locked in position by nuts 239.

A stud 240 is secured to projection 212a. See Figs. 14 and 17. A lever 241 has its end formed as a split collar 241a adapted to be clamped in adjusted position to stud 240, by bolt 242. An operating link 243 is pivotally connected with lever 241, by bolt 244. This link may correspond to link 169, Figs. 10 and 11, and be similarly operated by mechanical connection with the bolt action of the gun. Alternatively, the link may be actuated by a solenoid such as 21, Fig. 1, which may be similarly energized, as in that figure. A spring 245 has one end fixed to casing 212 and its other end to bracket 213, to urge the casing and nozzle into retracted position.

Figs. 14, 15 and 16 show the position of the parts as the nozzle is approaching its limiting position of injection. During firing, the coolant in bore 228 is at all times under pressure. Injection begins the instant that the leading edge of the openings of passageways 228 and 229 through the wall of casing 222, begins to align with passageway 228, and continues until such passageways pass out of alignment as the nozzle moves in the reverse direction. In order to give rapid injection and cut-off, the openings of these passageways through the walls of casing 212 and core 222 are somewhat enlarged with straight edges extending in the direction of axis 217, as clearly shown upon Figs. 14 and 16. Injection and cut-off may be timed relatively to the position of nozzle 218, by adjustment of screws 235 and 236. The angular movement of nozzle 218 during which injection takes place is determined by the circumferential dimension of the ends of bore 228. Because of the fact that the control valve is an integral part of the nozzle operating mechanism, the amount of coolant and its momentum between valve and nozzle is a minimum. Consequently, injection and cut-off are sharp and the amount of coolant spattered into the gun mechanism, is small. While water is the coolant at present preferred other liquids may be used such as n-octyl alcohol, benzyl alcohol, diethylene glycol, glyceral, ethylene glycol and ethyl alcohol. Where water is used, various well-known anti-corrosive compounds may be added to prevent corrosion when coolant is spattered into the operating mechanism of the gun.

I have shown the system as operating from the breech end of the weapon. It is also contemplated that the cooling nozzle and its moving means may be attached to the muzzle of the weapon and operated in timed relation with firing, as disclosed, to align the projecting opening therein, into alignment with the bore of the barrel, to eject coolant thereinto. In fact, from a purely technical point of view, muzzle injection has been found practical, and may, in some cases at least, be preferable to breech injection, since it enables a somewhat greater period of injection between rounds. Where muzzle injection is employed, the supply tube may be fixed to the barrel to extend therealong, and means will be provided to balance all acceleration forces having components normal to the bore axis.

For example, in the form shown at Figs. 1 to 6, inclusive, bracket 20 and parts carried thereby, may be clamped to the muzzle of the gun with pipe 38 in the form of a small metallic tube, extending along the barrel from valve 40. The remaining parts may be mounted exactly as shown upon Figs. 1 to 6. When rotary valve means are employed, as in the species of Figs. 14 to 17, for muzzle injection, it will be advantageous to mount the valve on the barrel at the muzzle, and to oscillate casing 212 in timed relation with firing, by a solenoid or coil operating means carried directly by bracket 213 and operating upon an armature fixed to arm 241 and extending through the necessary arc concentric of axis 217.

It is also contemplated that nozzles may be mounted at the breech and muzzle and controlled for simultaneous injection into the barrel at both points.

Numerous other changes and modifications will be obvious or readily occur to those skilled in the art, after a study of the present disclosure. Hence I do not wish to be limited to the precise details of constructions shown and such constructions should be taken as illustrative, rather than in a limiting sense. It is my intention and desire to reserve all modifications and substitutions of equivalents within the scope of the subjoined claims.

Having now fully disclosed the invention, what I claim and desire to secure by Letters Patent is:

1. In a cooling system for a rapid fire automatic gun having a barrel, a nozzle carried by said gun and movable from a first position in which its vent is directed into the bore of said barrel adjacent the breech thereof, to a second position in which said nozzle is out of alignment with said barrel, means operated in timed relation with firing of said gun to move said nozzle between said first and second positions and valve means responsive to firing of said gun to connect said nozzle to a source of coolant under pressure only when said nozzle is in said first position.

2. In a cooling system for a rapid fire automatic gun having a part moved in timed relation with firing thereof, nozzle means, means mounting said nozzle means for

movement laterally of said barrel so that a coolant ejection opening in said nozzle means is moved into and out of alignment with the bore of the barrel of said gun, conduit means including a valve, adapted to connect said nozzle means with a source of coolant under pressure, and means responsive to movement of said part to so move said nozzle means and operate said valve in timed relation with the firing of said gun.

3. In a cooling system for a rapid fire gun having a barrel and loading and extracting means including a part movable in timed relation with said loading and extracting means, a nozzle, first means mounting said nozzle on said gun for reciprocation radially of said barrel closely adjacent one end thereof, conduit means, including a valve adapted to connect said nozzle to a source of coolant under pressure, a first coil adapted, when energized, to move said nozzle so that a coolant ejection opening therein is aligned with the bore of said barrel, a second coil adapted, when energized, to open said valve, circuit means including switch means for energizing said coils, and means operated by said part for closing and opening said switch means in predetermined timed relation with operation of said loading and extracting means.

4. In a cooling system for a rapid-fire gun having a barrel and loading and extracting means including a reciprocable bolt assembly and an element oscillating twice in response to each complete reciprocation of said bolt assembly, a hollow plunger, means carried by said gun mounting said plunger for reciprocation radially of said barrel so that a vent opening therein is in and out of alignment with the bore of said barrel adjacent the breech thereof, a first coil surrounding said plunger and energizable to move said opening in one direction into alignment with said bore, spring means urging said plunger in the other direction, coolant conduit means adapted to connect said plunger with a source of coolant under pressure, said conduit means including a valve, a second coil, means responsive to energization of said coil for opening said valve, spring means urging said valve to closed position, a circuit including said coils, and the anode-cathode of an electron discharge tube having a control grid, a second circuit including (1) the grid of said tube, (2) switch means closed by a first oscillation of said element and (3) a relay, and a circuit including switch means closed by movement of said bolt assembly to open said relay to prevent closure of said grid circuit by a second oscillation of said element.

5. In an automatic rapid fire gun having a barrel, nozzle means mounted on said gun and movable from a first position in alignment with the bore of said barrel adjacent one end thereof, to a second position out of alignment therewith, operating means moving said nozzle means between said first and second positions, in timed relation with firing of the gun, and valve means responsive to movement of said nozzle means to said first position, for connecting said nozzle means to a source of coolant under pressure.

6. In a rapid fire gun having a barrel, a nozzle mounted upon said gun and having a coolant ejecting opening therein, means operated in timed relation with firing of said gun to move said nozzle so that said opening is in and out of aligned relation with the bore of said barrel, and means coupling said nozzle to a source of coolant under pressure only when said opening is in said aligned relation.

7. In a cooling system for a rapid fire gun having a barrel and automatically operating loading and extracting mechanism, a nozzle, means mounting said nozzle for movement into and out of alignment with said barrel at the breech thereof, means including a valve adapted to connect said nozzle with a source of coolant under pressure, and means responsive to movement of said mechanism to move said nozzle into aligned position with said barrel and simultaneously to open said valve, whereby coolant is injected into said barrel.

8. In a direct injection cooling system for an automatic gun, a coil, nozzle means forming an armature for said coil, bracket means adapted to mount said coil and plunger on said gun so that said nozzle means is in a first position free of the breech of said barrel when said coil is deenergized and in a second position, with its vent aligned with said barrel, when said coil is energized, two-part valve means mounted on said bracket means, one said part being directly attached to said nozzle means and the other said part being fixed to said bracket means, spring means urging said nozzle means to said first position, and connections adapted to connect said valve means to a source of coolant under pressure, said valve being opened only by movement of said nozzle means to said second position.

9. In a direct-injection cooling system for a gun having a barrel, a nozzle, a two part valve, having a first part in direct connection and coolant-conducting relation with said nozzle, means adapted to mount said nozzle and first part for movement as a unit into and out of coolant injecting position with respect to said barrel, said second valve part being fixedly carried by said means and adapted for connection with a source of coolant under pressure, said valve parts connecting said source to said nozzle only when said nozzle is in coolant-injecting position with respect to said barrel, and means adapted to move said nozzle and first part to and from coolant injecting position, in timed relation with firing of said gun.

10. In a direct-injection cooling system for a rapid fire gun having a barrel, a solenoid, a hollow plunger for said solenoid having a coolant ejection opening adjacent one end thereof, a valve cylinder directly connected with the other end of said plunger, a piston for said cylinder and having a stem provided with an axial passageway in communication with a radial bore in said piston and adapted for connection with a source of pressure coolant, bracket means adapted to mount said solenoid, cylinder and piston on said gun adjacent one end of said barrel, means guiding said plunger and cylinder for reciprocation transversely of the bore of said barrel between a first position in which said opening is adjacent and directed along the bore of said barrel, and a second position in which said plunger is clear of said barrel, there being an opening in the wall of said cylinder adapted to align with the bore in said piston only when said plunger and cylinder are in said first position.

11. In a direct injection cooling system for a rapid fire gun having a barrel and extractor means, a hollow shaft journaled on said gun adjacent one end of said barrel transversely of the bore thereof, a nozzle fixed with said shaft and having its vent in communication with the interior of said shaft, means responsive to movement of said extractor means for pivoting said shaft between a first position wherein said nozzle has its vent aligned with said barrel bore, and a second position in which said nozzle is clear of said barrel, conduit means adapted to connect said shaft with a source of coolant under pressure, said conduit means including a valve, and means responsive to movement of said shaft between said first and second positions to open and close said valve.

12. In a direct injection cooling system for a rapid-fire gun having a barrel and a reciprocable bolt mechanism, a hollow shaft, a nozzle extending from said shaft transversely thereof and having a vent in communication with the interior of said shaft, means mounting said shaft on said gun at the breech thereof for oscillation on an axis transversely of and offset from the bore of said barrel, said shaft being pivotable between a first position wherein said vent is directed into said bore, and a second position wherein said nozzle is entirely offset from said bore, conduit means adapted to connect said shaft with a source of coolant under pressure, said conduit means including a valve, and means operated by and in response to reciprocation of said bolt mechanism to oscillate said shaft and nozzle in timed relation therewith and to open said

valve only when said shaft is substantially in said first position.

13. In a direct injection cooling system for a rapid-fire gun having a barrel and bolt mechanism for loading and extracting cartridges, a nozzle having an injection vent, means mounting said nozzle on said gun for oscillation about an axis transversely of and offset from the bore of said barrel, said nozzle being pivotable between a first position in which said vent is directed into said bore, and a second positoin in which said nozzle is clear of said bore, conduit means adapted to connect said nozzle with a source of coolant under pressure, said conduit means including a valve, and means responsive to movement of said bolt mechanism for oscillating said nozzle between said positions and for opening said valve mechanism only when said nozzle is substantially in said first position, to thereby inject coolant into said bore.

14. The system recited on claim 13, said last-named means including a switch having a part pivotable with said nozzle, a solenoid for opening said valve, a circuit including said switch element and solenoid, said switch operating to close said circuit when said nozzle is substantially in said first position, and spring means urging said valve to closed position.

15. The system recited in claim 13, said last-named means including a switch having a part moved by and in response to oscillation of said nozzle and a second part carried by said gun, conduit means adapted to connect said nozzle with a source of coolant under pressure, and including a valve, a solenoid associated with said valve to open the same in energization, spring means urging said valve to closed position, an electrical circuit including said switch and solenoid, and mechanical means responsive to movement of said bolt mechanism for oscillating said nozzle and switch part to close said circuit and open said valve only when said nozzle has moved substantially into said first position.

16. In a direct injection liquid cooling system for an automatic gun having a barrel and a bolt movable from a first position closing the breech of said barrel to a second loading position clear of the breech of said barrel, an injection nozzle, means carried by said gun and mounting said nozzle for reciprocation from a first position clear of the gun barrel, to a second position to direct a stream of liquid thereinto, a solenoid fixed to the gun, an armature for said solenoid connected with said nozzle, a conduit from a source of liquid under pressure to said nozzle, a valve in said conduit, and means moving said nozzle from first to second position and simultaneously opening said valve, said means including an electric circuit for said solenoid and a switch actuated in response to movement of the bolt to predetermined position.

17. In combination, a gun, a carriage in which said gun is mounted for movements in recoil and counterrecoil, a nozzle carried by said carriage for introducing a cooling medium into the gun, means connecting said nozzle to said carriage for lateral swinging movements into and out of alinement with the bore of the gun, and means operative in response to movement of the gun for swinging said nozzle into alinement with the bore of the gun.

18. In combination, a gun, a carriage in which said gun is mounted for movements in recoil and counterrecoil, a nozzle carried by said carriage for introducing a cooling medium into the gun, means connecting said nozzle to said carriage for lateral swinging movements into and out of alinement with the bore of the gun, means operative in response to movement of the gun for swinging said nozzle into alinement with the bore of the gun, and means operative in response to such movement of the nozzle for supplying cooling medium therefrom into the gun.

19. In combination with a gun of the type in which ammunition is automatically loaded from a magazine associated therewith at the conclusion of each firing operation, a nozzle through which cooling medium is introduced into the bore of the gun, means mounting said nozzle for lateral movements into and out of alinement with the bore of the gun rearwardly of the breach end of the gun while the gun is in battery, means operative in response to movement of the gun for swinging said nozzle into alinement with the bore of the gun, means operative in response to such movement of the nozzle for supplying cooling medium therefrom into the gun, and means operative in response to loading of the gun for swinging said nozzle into an inoperative position out of alinement with the bore of the gun.

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