March 28, 1967 R. R. BERNARD ETAL 3,311,022

GAS DRIVE FOR AUTOMATIC GUN WITH ROTATING BARREL CLUSTER

Filed Dec. 1, 1965 4 Sheets-Sheet 1

Fig. 1

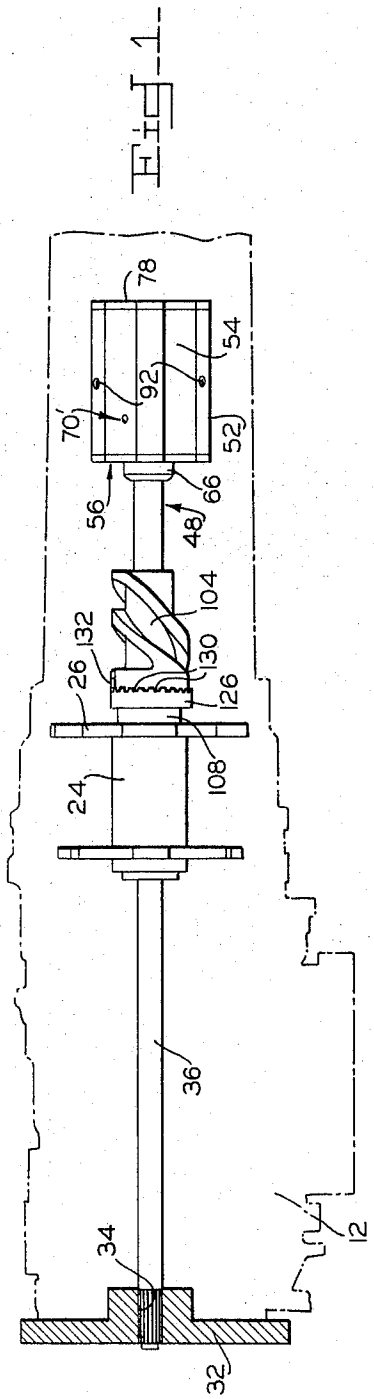

Fig. 2

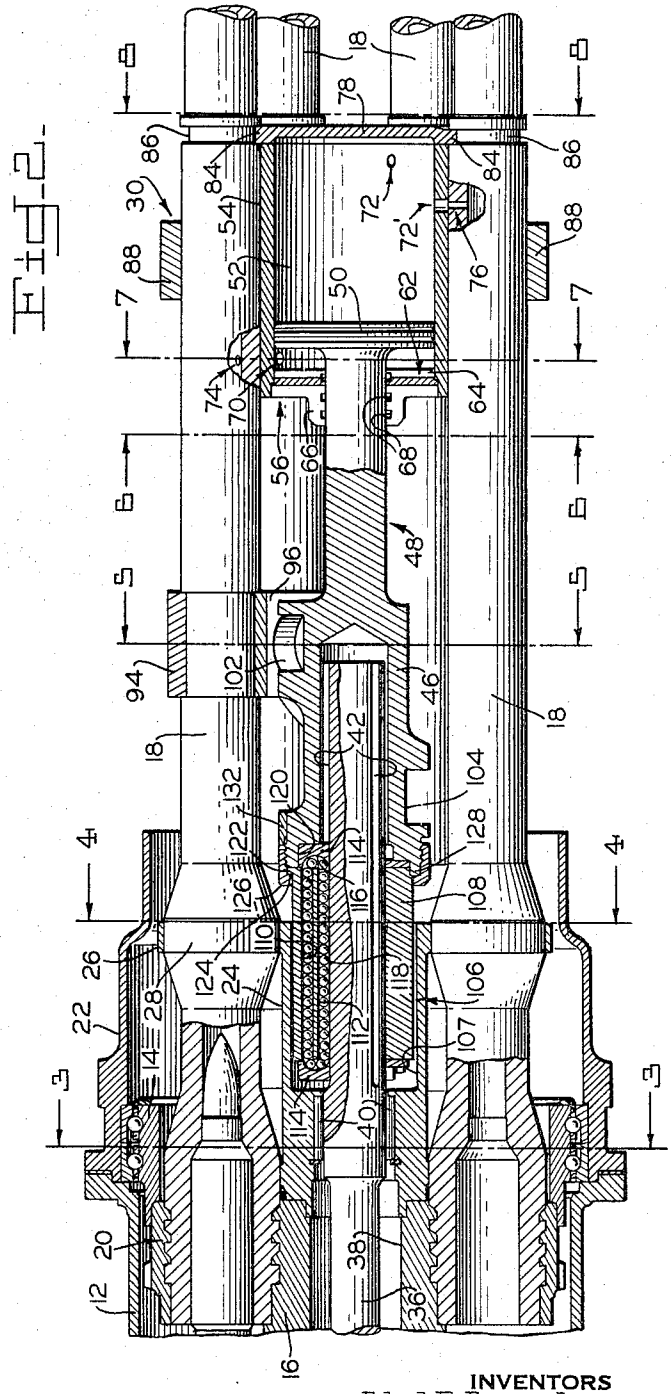

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Fig. 3

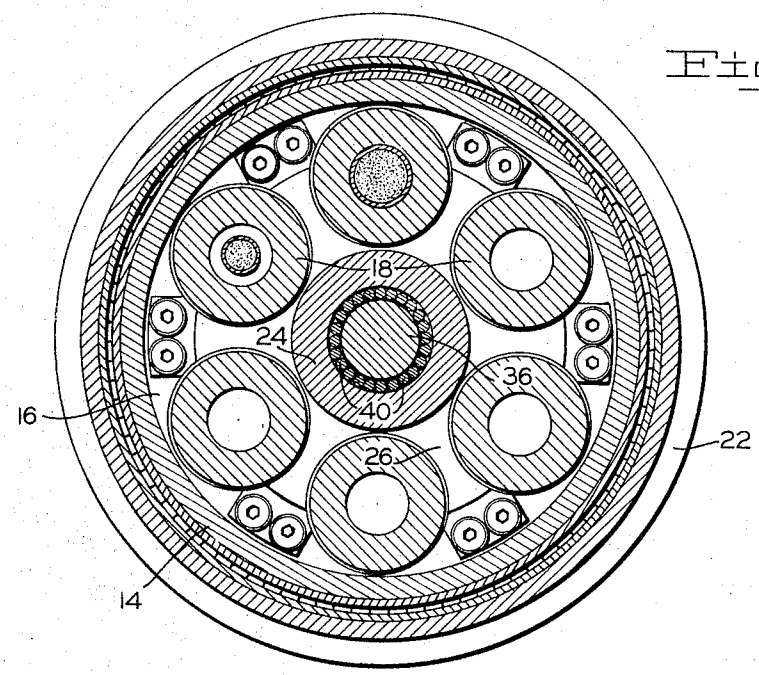

Fig. 4

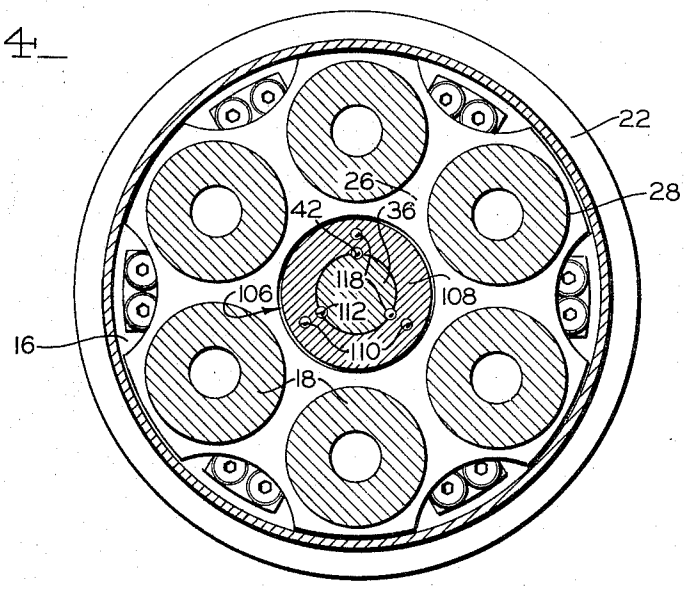

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Fig. 5

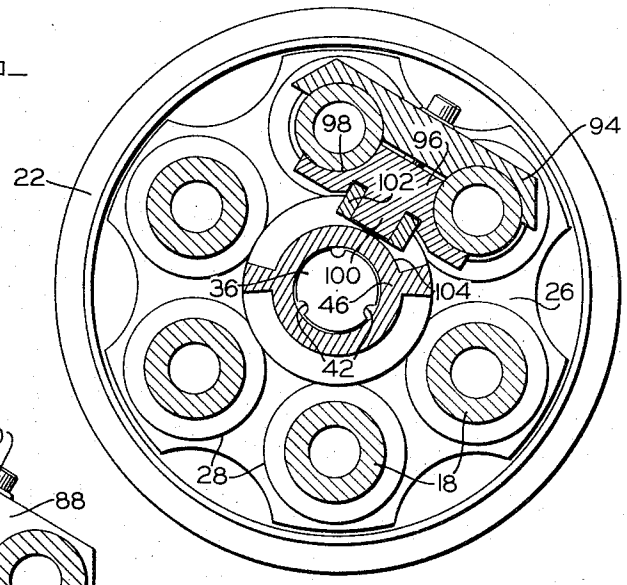


Fig. 6

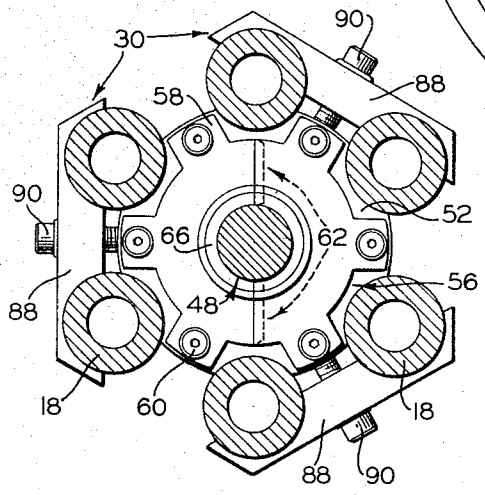


Fig. 7

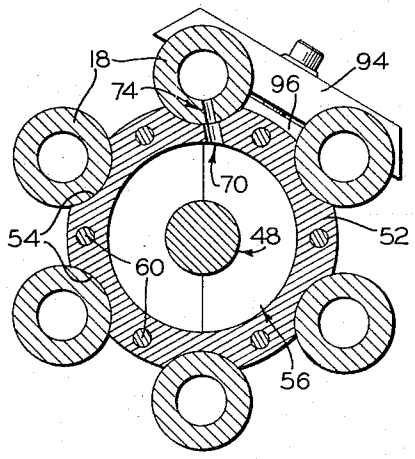
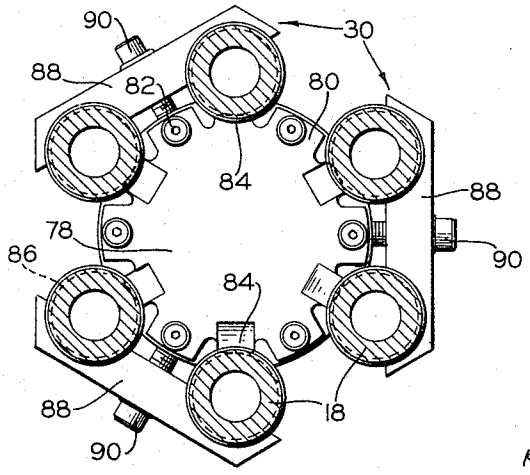


Fig. 8



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March 28, 1967 R. R. BERNARD ETAL 3,311,022

GAS DRIVE FOR AUTOMATIC GUN WITH ROTATING BARREL CLUSTER

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Fig. 9

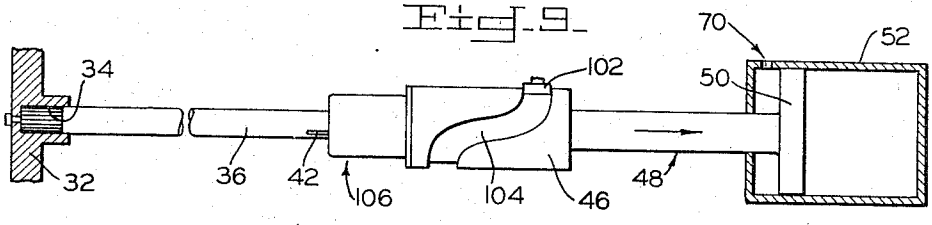


Fig. 9a

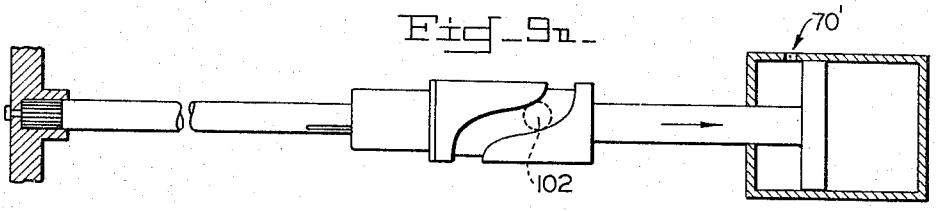


Fig. 9b

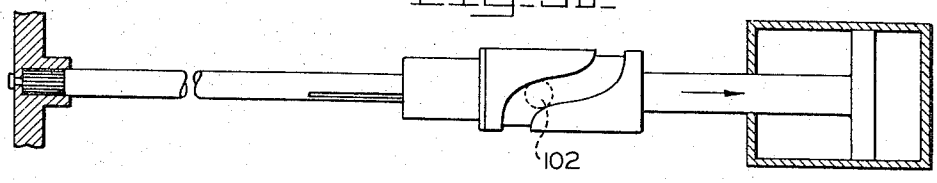


Fig. 9c

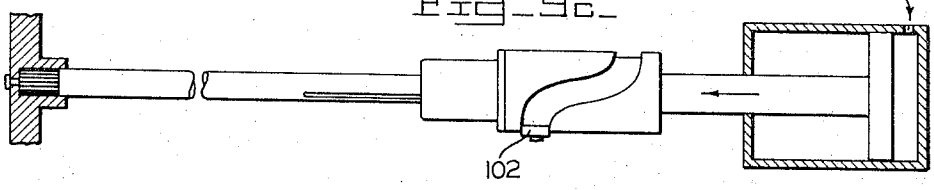


Fig. 9d

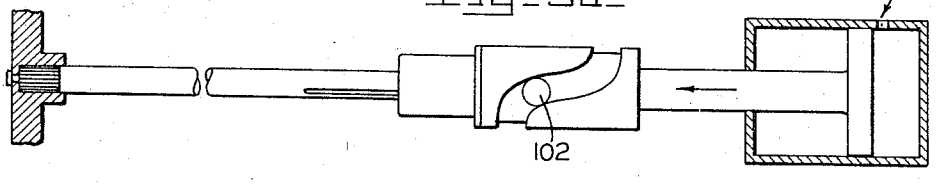
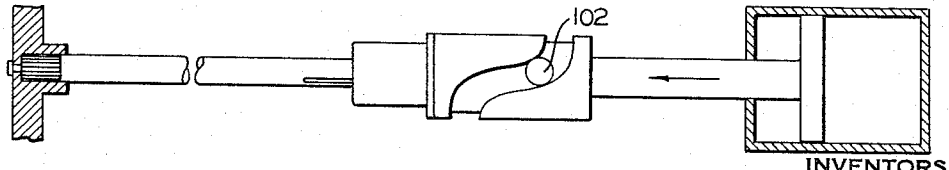


Fig. 9e



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United States Patent Office 3,311,022
Patented Mar. 28, 1967

3,311,022

GAS DRIVE FOR AUTOMATIC GUN WITH ROTATING BARREL CLUSTER

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Filed Dec. 1, 1965, Ser. No. 511,306
7 Claims. (Cl. 89—126)

This invention relates to automatic guns with a plurality of barrels which are radially mounted for rotation about a common central axis and is more particularly directed to means for utilizing the gases generated by the firing of the ammunition to power the required rotation of the barrels.

One of the few guns in current military use capable of providing the sustained high rate of fire required of modern aircraft armament is a mechanized version of the well-known "Gatling" mechanism wherein a plurality of barrels are mounted in a circular group or cluster which can be rotated about a common central axis for successive passage through a fixed firing station. While a separate electric or hydraulic motor operated by the power system of the aircraft has heretofore been utilized to rotate the barrel cluster, experience has shown that an external motor is not completely satisfactory in all respects. For example, it has been found that whenever the gun is being subjected to initial acceleration, the resulting drain on the power system of the aircraft is frequently of sufficient magnitude to adversely affect the proper functioning of other equally vital accessories. Furthermore, in many aircraft installations the additional weight and size of the external driving motor results in a corresponding decrease in the quantity of the ammunition which can be carried or stored in the immediate vicinity of the gun.

It has been proposed, therefore, that the gases generated during the discharge of the ammunition be harnessed to impart rotation directly to the barrel cluster. However, prior are attempts to provide a self-powered gas drive for this type of high rate gun have not been satisfactory from a military standpoint primarily due to the relatively complex and heavy linkage structures which resulted from the fact that each barrel in the cluster was furnished with an individual motor unit. Obviously, any increase in the weight of the rotating parts complicates the task of accelerating such parts to the angular velocity required to provide the desired firing rate within a given interval of time. In fact, even the best of the starter mechanisms in current use have not been able to accelerate the rotating barrels and the ammunition feed mechanism associated therewith to the required high operating speed and within the relatively short time dictated by military necessity.

Furthermore, where the gun is intended to be carried in an inclosed pod attached to the exterior of the aircraft, the addition of a separate motor unit to each barrel increases the external silhouette of the gun beyond the limited space available within the interior of such pod.

It is, therefore, a general object of this invention to provide a simple, lightweight, and reliable gas drive adapted to power the operation of a high rate of fire multibarreled gun.

Another object of the present invention is to provide a gas drive as aforesaid which does not require that each barrel be provided with its own drive unit.

A further object of this invention is the provision of a gas drive as aforesaid in which a single piston and cylinder unit is utilized to receive the discharge gases directly from the barrels without the necessity for any intermediate valve structure.

It is an additional object of this invention to provide a gas drive as aforesaid wherein the gas cylinder is attached to the barrels for rotation therewith while the piston is independently mounted for reciprocating longitudinal movement.

An important object of the present invention is the provision of a gas drive as aforesaid which can be mounted entirely within the opening provided by the circular grouping of the barrels without any increase in the external silhouette of the gun.

A final object of this invention is to provide a gas drive wherein a double-acting piston is adapted to be continuously reciprocated in direct response to the discharge gases being ported from the barrels.

It has been found that the foregoing objects can be attained by replacing the external type of drive motor now in use with a single piston and cylinder unit centrally mounted within the opening formed by the circular grouping of the six barrels with which the gun is equipped. Four of the barrels are each provided with a gas port in an arrangement which leaves each third barrel unported. The cylinder is clamped to the barrels and is provided with four gas passages disposed in pairs adjacent the front and rear endwalls thereof and spaced so that each passage is in direct communication with a respective gas port in the barrels.

The piston is formed with an elongated rod portion which projects rearwardly from the cylinder into slidable telescopic engagement with the splined forward end of a shaft anchored at the opposite end thereof to the backplate of the gun housing. A helical cam track surrounds the rear end of the gas piston and is engageable with a cam follower fixedly mounted to a pair of the barrels.

Thus, as the discharge gases are sequentially diverted into the cylinder against the front or rear face of the piston, the latter is reciprocated to actuate the cam follower and thereby rotate the barrels through one complete revolution. The foregoing arrangement provides a simple yet positive means for utilizing a portion of the energy derived from the discharge of the ammunition to furnish the power required to cycle the gun at a steady firing rate once the barrels have been mechanically accelerated to the desired rate by suitable mechanism. Accordingly, except for the relatively insignificant electrical energy required to detonate the ammunition primers, the gun is essentially a self-powered unit of far less complexity and weight than a gun with a separate external motor attached thereto.

Further objects and advantages of the present invention will be apparent from the following specification and the accompanying drawings which are for the purpose of illustration only and wherein:

FIG. 1 shows the gun configuration in phantom outline with the gas drive unit being drawn in full;

FIG. 2 is an enlarged longitudinal elevation of a portion of the barrel cluster with the gas piston in partial cross-section to show the mounting details thereof;

FIGS. 3 thru 8 are sectional views of the gun taken along the respective lines shown in FIG. 2 to illustrate the internal structure of the gas drive unit; and

FIGS. 9 thru 9*e* are a series of schematic views depicting the movements of the gas piston and cam follower through one complete firing cycle of the gun.

As shown in FIG. 2 of the drawings and more fully detailed in U.S. Patent No. 2,849,921, the gun to which the present invention is particularly applicable essentially comprises a stationary housing **12** provided with a suitable ball bearing ring **14** in the interior thereof which serves to support the forward end of a rotor **16** in which the breech ends of a plurality of barrels **18** are radially fixed at equally spaced intervals by a suitable interrupted locking lug arrangement **20**. Although the present inven-

tion is illustrated as applicable to a gun having six barrels, it should be understood that the invention is equally operative regardless of the particular number of barrels utilized in the gun. Housing 12 is forwardly extended as indicated at 22 to seat a cylindrical rear barrel support port 24 bolted to the front end of rotor 16 and provided with a perforated support plate 26 at the front end thereof to accommodate the enlarged exterior peripheral portion 28 formed on each barrel 18 slightly forward of the chamber portion thereof. In view of their length, barrels 18 are additionally supported by a muzzle clamp (not shown) and a more intermediate clamping arrangement 30 to be described hereinafter in more detail.

In order to incorporate the gas drive of the present invention without altering the exterior configuration of the gun, the backplate 32 of housing 12 is provided with a centrally located splined hole 34 in which the rear end of a longitudinal shaft 36 is fixedly secured. As best indicated at 38 in FIG. 2, rotor 16 is axially bored for the passage of shaft 36 therethrough and rear barrel support 24 is coaxially bored to seat a set of annular roller bearings 40 which provide rotatable support to shaft 36. Forwardly of bearings 40, shaft 36 is longitudinally splined as indicated at 42 and is slidably received in the enlarged hollow rear end 46 of a reciprocating piston 48. The front end of piston 48 terminates in an enlarged cylindrical head 50 slidably engagable in a stationary gas cylinder 52 which is in turn fixedly clamped in the area defined by the circular arrangement of barrels 18. Gas cylinder 52 is exteriorly scalloped to form a plurality of identical arcuate recesses 54 as best shown in FIG. 7 into which the peripheral undersides of barrels 18 in the vicinity of clamping arrangement 30 are snugly fitted. Each recess 54 is numerically keyed to receive a correspondingly numbered barrel 18 for a purpose to be hereinafter described.

A circular closure cap 56 is circumferentially provided with equally spaced radial projections 58 for mounting suitable bolts 60 which are utilized to fixedly secure cap 56 to the rear face of gas cylinder 52 for retaining gas piston head 50 therein. Cap 56 is formed by a pair of symmetrical halves whose mating edges are provided with a tongue and groove connection 62 for sealing the interior of gas cylinder 52 against the leakage of gas. Cap halves are also contoured to form a diametrically reduced front end 64 fitting snugly into gas cylinder 52 and a rearwardly projecting central extension 66 of lesser diameter which, as best shown in FIG. 2, is provided with a plurality of longitudinally spaced annular grooves 68 along the interior surface thereof for contact with the exterior periphery of piston 48 to complete the sealing of gas cylinder 52.

A rearward and a forward pair of gas passages 70, 70' and 72, 72', respectively, are drilled into gas cylinder 52 to communicate with the interior thereof and each passage is angularly spaced from the other passage in the same pair by 60° while the pairs are similarly spaced from one another by 120°. Such arrangement is necessary to align with gas ports 74, 76 which are provided only in four of the six barrels so that every third barrel is left unported. In addition, each gas passage in each pair is longitudinally displaced from the other passage in the same pair but such displacement is limited so that no more than two successive passages on each side of piston head 50 will be uncovered thereby at any given interval during the reciprocation thereof. In order to avoid the possibility of creating localized stresses in the rod portion of piston 48 as a result of the direct impingement thereon of the extremely hot gases produced by the discharge of the ammunition, each of gas passages 70 and 70' are inclined at a slight angle to the vertical. As best shown in FIG. 7, the barrel gas ports 74 corresponding to inclined gas passages 70 and 70' are similarly angled to retain the required coaxial alignment therebetween. Thus, as the gases are

directed into the gas cylinder area behind piston head 50, the swirling action imparted thereto by passages 70 and 70' effectively prohibits direct impingement against the exterior periphery of piston 48.

The forward end of gas cylinder 52 is closed by a circular cap 78 whose periphery, like that of rearward cap 56, is provided with projections 80 for mounting the attaching bolts 82. However, the equal spacing between bolts 82 does not apply to all six since one is slightly offset to ensure that cap 78 will always be assembled to gas cylinder 52 in the same radial orientation relative to the gas passages therein. In addition, the periphery of cap 78 is provided with outwardly extending rectangular tongues 84 disposed intermediate projections 80, such tongues being numerically keyed in correspondence with scalloped recesses 54 and barrels 18 to insure that any replacement of these parts will invariably provide the identical relationship between gas passages 70, 70' and 72, 72' in gas cylinder 52 and gas ports 74, 76 in barrels 18. In order to ensure the necessary correspondence between scalloped recesses 54 and barrels 18, the thickness of each tongue 84 increases in increments of .010" in counterclockwise succession. Gas cylinder 52 is oriented during assembly so that the thickest one of tongues 84 will extend upwardly in the twelve o'clock firing position. Each barrel 18 is provided with an annular groove 86 about the exterior periphery thereof which is dimensioned to mate with one of the tongues 84 on closure cap 78 and thereby restrict the original assembly and subsequent replacement of barrels 18 in the gun to a predetermined sequence.

Any whipping or radial movement of barrels 18 away from contact with scalloped recesses 54 is prevented by clamping arrangement 30 which consists of a trio of clamps 88 (FIGS. 6 and 8), each of sufficient length and contour to fit over a pair of adjacent barrels 18. Clamps 88 are secured to gas cylinder 52 by suitable cap screws 90 which pass through clamps 88 and engage in threaded holes 92 provided in the exterior periphery of gas cylinder 52.

Rearwardly of clamps 88, a similarly shaped clamp 94 is bolted to a follower 96 which is arcuately recessed along the outer side thereof as indicated at 98 in FIG. 5 to fit snugly against the undersides of a pair of adjacent barrels 18. The inner side of clamp 94 is provided with a projecting central stud 100 for mounting a roller 102 thereon which is slidingly engageable in a helical cam track 104 surrounding the enlarged rear end 46 of piston 48.

In order to minimize the sliding friction between the splined end of shaft 36 and the hollow interior of piston 48, a ball spline assembly 106 is secured to the rear end of piston 48 and extends into a counterbored opening 107 in barrel support 24 to surround shaft 36. Assembly 106 consists of a hollow cylindrical carrier 108 provided with three radially disposed equidistant longitudinal tunnels 110 therethrough, each in parallel alignment with an arcuate groove 112 extending longitudinally along the interior wall surface of carrier 108. Carrier 108 is in turn fixedly capped at the opposite ends thereof with diametrically reduced circular end plates 114 containing elongated recesses 116 which are radially disposed to connect the open ends of tunnels 110 and grooves 112 and form a continuous race for a row of balls 118.

Piston 48 is counterbored at the extreme rear end thereof as indicated at 120 in FIG. 2 to seat plate 114 projecting from the front end of carrier 108. A circular flange 122 at the front end of carrier 108 provides a stop shoulder 124 for a collar 126 which serves to threadably connect ball spline assembly 106 to piston 48. The rear face of piston 48 is provided with a plurality of radially disposed projections 128 which engage in correspondingly located recesses in the front face of ball spline carrier 108 to prevent any rotational displacement therebetween. In addition, the front end face of collar 126 is circum-

ferentially provided with rectangular slots **130** (FIG. 1) and a key **132** is adjustably mounted on the enlarged rear end **46** of piston **48** to engage in one of slots **130** and prevent collar **126** from unloosening in its retention of ball spline assembly **106**.

Once the gun has been accelerated to the required operating speed by suitable mechanical or electrical means (not shown), the discharge of the chambered ammunition creates high pressure gases which pass through the barrel **18** being fired for entry into gas cylinder **52**. Although the acceleration of barrels **18** to operating speed renders it impossible to predict the longitudinal position of piston head **50** in gas cylinder **52** at the instant firing of the gun is initiated, it will be assumed for clarity of explanation that piston head **50** has reached the end of its rearward stroke and is disposed slightly forward of gas passage **70** as shown in FIG. 9. As the discharge gases entering gas cylinder **52** expand, piston head **50** is forced forwardly to uncover gas passage **70'** as shown in FIG. 9*a*. The corresponding travel of piston **48** causes cam track **104** thereon to act on follower roller **102** and rotate the barrel cluster and gas cylinder **52** secured thereto so that the next successive barrel **18** is advanced into firing position. Thereupon, additional discharge gases are introduced into gas cylinder **52** through gas passage **70'** to continue the forward travel of piston head **50** to the position shown in FIG. 9*b*. As gas enters cylinder **52** through passage **70'**, the amount of gas which escapes through passage **70** is relatively negligible due to the rapid expansion against piston head **50**.

Although the next successive barrel **18** to be rotated to the firing position is unported, the residual energy of the gases then in gas cylinder **52** is sufficient to complete the forward stroke of piston head **50**. At this point, follower roller **102** has reached its rearwardmost position in cam track **104** and begins to actuate piston **48** in the opposite direction. Since no discharge gas is being introduced into gas cylinder **52** at this time, piston head **50** is not subjected to the timing problems which otherwise would be encountered by admitting gas into cylinder **52** at the critical period in which piston head **50** is reversing the direction of travel thereof. Instead, the passage of gas through gas passage **72** does not take place until after piston head **50** has begun the rearward stroke thereof as shown in FIG. 9*c*. The rearward stroke of piston **48** is continued as gas passage **72'** is rotated into position to direct additional discharge gases against piston head **50** as shown in FIG. 9*d*. The next barrel **18** to be fired is unported and the further introduction of gas into gas cylinder **52** does not take place until piston head **50** has reached the position shown in FIG. 9 thereby completing one cycle of operation.

During the reciprocation of piston **48**, each set of balls **118** in assembly **106** rides along the grooves formed in shaft **36** by longitudinal splines **42** so that frictional resistance to the movement of piston **48** is minimized by the rolling action of balls **118** in the continuous tracks formed by tunnels **110** and the passages created by the opposition of arcuate grooves **112** and splines **42**.

Thus, there is here provided a simple and reliable gas drive system for a multibarrel gun which utilizes the power of the expanding discharge gases to reciprocate a piston provided with a helical cam track for imparting rotation directly to the cluster of barrels. This simple and highly successful method of operating a multibarrel gun is primarily due to the unique combination wherein a double-acting piston is slidably disposed in a gas cylinder fixedly secured between the cluster of barrels for corresponding rotation therewith.

Furthermore, the highly reliable operation achieved by this type of piston-cylinder combination stems from the fact that every third barrel is unported and is specifically arranged to be fired during the interval in which the gas piston is reversing its direction of travel. As a result, the possibility of premature entry of the discharge gases in opposition to the direction of travel of the piston head is positively avoided without the necessity for the expensive dimensional control of the various gas drive components which otherwise would be required.

The present invention has been described in detail above for the purpose of illustration only and is not intended to be limited by this description or otherwise except as defined by the scope of the appended claims.

We claim:

1. In an automatic gun having a plurality of barrels radially grouped for rotation about a common axis, a self-powered gas drive comprising a gas cylinder fixedly secured to the barrels for rotation therewith within the central opening defined by the radial grouping thereof, a longitudinal shaft fixed to the rear end of the gun for axial passage therethrough into the area adjacent the breech ends of the barrels, a gas piston slidably mounted on the forward end of said shaft and having an enlarged head extending into said gas cylinder, a plurality of gas passages formed in said gas cylinder for successively directing the discharge gases exiting from the barrels against opposite faces of said piston head for imparting longitudinal reciprocation thereto, and cam means on said gas piston for converting the longitudinal reciprocation thereof to rotation of the barrels.

2. The combination defined in claim **1** wherein said cam means on said gas piston comprises a helical cam track surrounding the exterior periphery thereof and engageable with a follower fixed to the barrels.

3. The combination defined in claim **1** including ball spline means slidably mounted on said shaft and secured to the rear end of said gas piston for minimizing the frictional resistance encountered during the reciprocation of said gas piston on said shaft.

4. In an automatic gun having a plurality of barrels radially grouped for rotation about a common axis and successive passage through a fixed firing station, a self-powered gas drive responsive to the discharge gases produced by the firing of the barrels, comprising a gas cylinder fixedly secured to the barrels for rotation therewith within the central opening defined by the radial grouping thereof, a longitudinal shaft fixedly secured to the rear end of the gun for axial passage therethrough into the area adjacent the breech ends of the barrels, a gas piston slidably mounted on the front end of said shaft and having an enlarged head slidably fitted within said gas cylinder, a plurality of gas passages radially formed into said gas cylinder in a forwardly and a rearwardly disposed set with each passage in each set being equally and successively displaced from the preceding passage in that set along the circumferential and the longitudinal axis, gas port means in the barrels in individual registry with said gas passages in said gas cylinder, said sets of gas passages being respectively positioned to direct discharge gases against the front and rear faces of said piston head to impart continuous longitudinal reciprocation thereto, a helical cam track surrounding the exterior periphery of said piston, and a follower secured to the barrels in position to engage in said cam track whereby the longitudinal reciprocation of said piston actuates said follower to impart rotation to the barrels.

5. The combination defined in claim **4** wherein the number of barrels is six and said gas passages are disposed in two pairs of two each so that said gas port means in the barrels can be limited to every third barrel in order to prevent the introduction of discharge gases into said gas cylinder during the intervals in which said gas piston head is reversing the direction of travel thereof.

6. In an automatic gun having a housing, a rotor mounted in the housing, and six barrels with the breech ends thereof fixedly mounted in the rotor in a predetermined circular group at equally spaced intervals, the improvement of a self-powered gas drive comprising a gas cylinder disposed intermediate the breach and muzzle

ends of the barrels in the opening defined by the circular grouping thereof, clamp means for securing said gas cylinder to the barrels for joint rotation therewith, a longitudinal shaft fixed to the rear end of the housing for axial passage through the rotor and into the area adjacent the breech ends of the barrels, a gas piston having a hollow rear end slidably engageable with the forward end of said shaft, an enlarged head at the front end of said piston slidably engageable in said gas cylinder, first and second pairs of gas passages radially formed in said gas cylinder respectively adjacent the front and rear ends thereof, gas port means in four of the barrels positioned for individual registry with each of said gas passages in said gas cylinder whereby every third barrel is unported, said gas passages being positioned to successively direct the discharge gases in adjacent barrels against the front and rear faces of said piston head in turn except for the intervals in which the direction of movement thereof is undergoing reversal, a helical cam track surrounding the exterior periphery of said piston, and a follower clamped to adjacent barrels for slidable engagement in said cam track whereby the reciprocation imparted to said gas piston by the discharge gases directed thereagainst actuates said follower to rotate the barrels.

7. The combination defined in claim 6 wherein the predetermined circular mounting of the barrels is achieved by six tongues projecting radially from the front end of said gas cylinder to respectively extend into correspondingly located annular grooves in the barrels, the thickness of said tongues and the mating width of said annular grooves in the barrels varying in successive equal increments.

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