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W. K. RICHARDSON

PROJECTILE

Filed Aug. 21, 1924

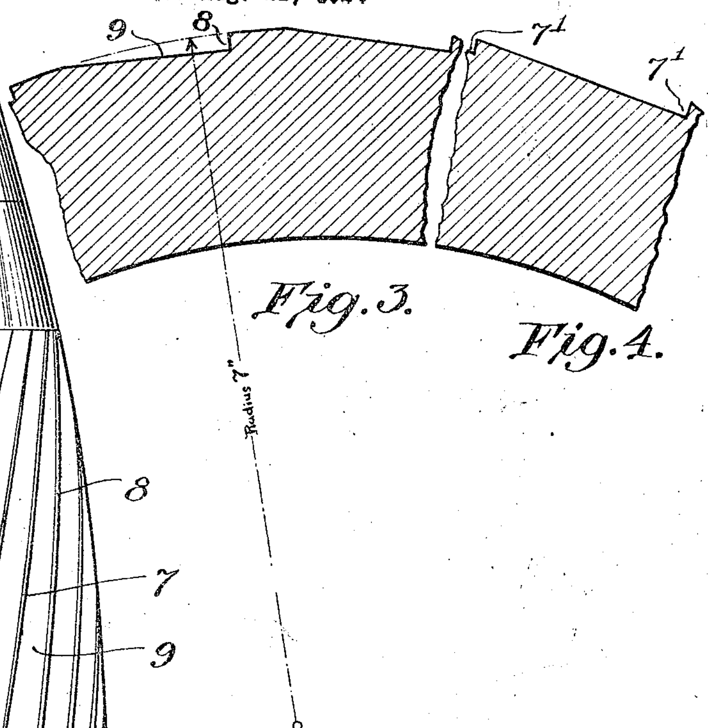


Fig. 3.

Fig. 4.

Fig. 1.

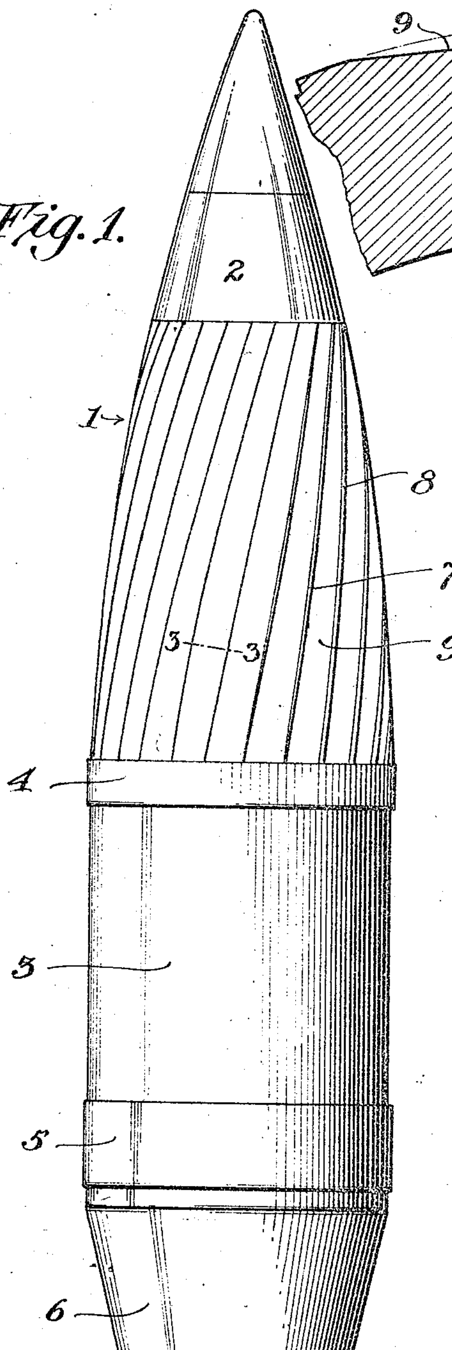
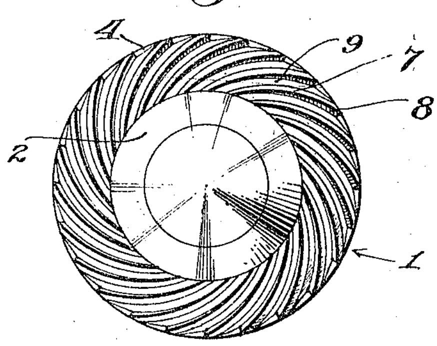


Fig. 2.



Inventor

W. K. Richardson

By Geo. E. Dow

Attorney

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UNITED STATES PATENT OFFICE.

WILLIAM K. RICHARDSON, OF WASHINGTON, DISTRICT OF COLUMBIA.

PROJECTILE.

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To all whom it may concern:

Be it known that I, William K. Richardson, a citizen of the United States, residing at Washington, in the District of Columbia, have invented certain new and useful Improvements in Projectiles, of which the following is a specification.

The object of this invention is to provide improved means to impart rotary motion to a fired projectile by means of vanes or grooves formed upon the ogival head of the projectile, or upon the windshield, or both.

This means may be employed either independent of or in conjunction with the present mode of imparting rotation to the projectile, namely, the rotating band and the [illegible].

In the accompanying drawings, Fig. 1 is a side elevation of a shell, constructed according to the invention. Fig. 2 is an end view thereof. Fig. 3 is an enlarged cross-section on the line 3—3 of Fig. 1. Fig. 4 is a similar view of a modification.

Referring to the drawings, 1 indicates the ogival head upon which his mounted the windshield 2. 3 indicates the cylinder of the shell having at its forward extremity the bourrelet 4. 5 indicates the rotating band and 6 the tapered base at the rear of the rotating band 5. 7 indicates the vanes of which there are twenty-five in the shell shown, spaced equidistant and inclined forward from the bourrelet to the windshield 5, with a right hand twist having an angle normal to the plane of flight of about 10° 44″. This angle has the effect of displacing the air tangentially at the same velocity of displacement as the radially displaced air from the ogival head of the projectile, the ogival head being struck on 7½ calibre radius. 8 indicates the face or front of the vane 7 which is perpendicular or at a 90° angle from the base or bottom 9 of the grooves forming the vane.

In the scale of construction shown for a 14″ shell, the faces 8 of the vanes are ⅛″ deep, and the bottoms 9, at the borrelet have a width of about 1$\frac{3}{32}$″, and at their forward extremity, back of the windshield 2, a width of about 1″.

The manner in which the vanes 7 impart rotation to the projectile is as follows: The projected area of the face 8 of the vanes deflect the air tangentially, which impinges upon them, in the flight of the projectile, thereby producing rotation of the shell.

For future developments of the art and to assist a designer in making and using the invention for cylindrical projectiles of all characters and calibre, I give a solution or rule for obtaining the energy required to overcome the torque of the projectile and impart a definite rotary velocity in one second of flight.

Assuming the projectile to be a 14″ shell designed as in the drawings, having factors as follows: Weight loaded, 1210 lbs.; muzzle velocity 2700 ft. per second; angle of elevation 15°; coefficient of reduction of velocity 2% per second of time. Such a projectile fired from present guns, having a twist of one turn in 25 calibres and a muzzle velocity of 2700 ft. sec., would have impressed upon it 1068368 ft. lbs. of rotary energy, and a peripheral velocity of 339.27 ft. sec.

Instead of using such a gun, my invention permits and I propose to fire my projectile from a rifled gun having one turn in 100 calibers. Therefore the peripheral rotary velocity will be 84.82 ft. sec., and the rotary energy impressed upon the fired shell will be 66773 ft. lbs. when the shell leaves the gun. There are on the projectile selected for this description, 25 vanes, each 25″ long, ⅛″ deep, angle of vanes 10′ 44″, which give a velocity of displacement of .186% of the translatory velocity of the shell. The total area of the face of the vanes equal 78.125″.

To determine the air pressure upon the vanes:—With a muzzle velocity of 2700 ft. sec.; coefficient of reduction 2%; the average velocity equals 2673 ft.; angle of elevation 15°; sine of angle equals .2588; maximum altitude 676 ft.; average density of air, .075875 lbs. per cu. ft. With such factors the pressure equals the weight of the air (.075875) multiplied by the square of the average velocity, or 7144929, divided by twice the acceleration (64.32) due to gravity, multiplied by .186 velocity of displacement, divided by 144, the number of inches in a square foot, equals 10.886 lbs. pressure per square inch. The area of vanes, 78.125″, times 10.886, pressure per inch, equals

850.46875 ft. lbs. per foot rotary travel of the vanes. Therefore for one foot of travel, at the periphery at the bourrelet, it will be 698.6 ft. lbs. (The diameter at the bourrelet is 14″; at the forward extremity of the vanes the diameter of the ogival head is 9″; therefore the average if 11.5″ and the energy developed in one foot of travel at the bourrelet will be 11.5/14 of 850.46875 or 698.6 ft. lbs.)

To determine the acceleration:—As the shell leaves the gun at a muzzle velocity of 2700 ft. sec. the rifling of the gun having a twist of one turn in 100 calibres, there will be impressed upon the shell a rotary energy of 66773 ft. lbs. and a rotary velocity of 84.82 ft. sec. at the bourrelet. As shown above, there will be 698.6 ft. lbs. generated and impressed upon the shell in one foot of rotary travel. 698.6 divided by 66773, the rotary energy impressed upon the shell due to the rifling of the gun, equals .01004623 times 84.82 equals .887412 divided by 2 equals .4437 times 84.82 equals 37.634 ft., the acceleration for the first second of flight, plus 84.82 initial velocity equals 122.4546 ft. sec. the rotary velocity. The rotary travel will be 103.6373 ft.; energy due to velocity of 122.4546 ft. sec. equals 139174 ft. lbs.

Proof: Energies are as the square of the velocities. $84.82^2 : 66773 :: 122.4542^2 : 139174$. Further proof: 698.6 energy per ft. of travel, times 103.6373 the travel, equals 72401 ft. lbs. plus 66773, initial energy, equals 139174 ft. lbs.

Correction must be made for the efficiency of the vanes. While it is not material for the first second of flight, this efficiency gradually diminishes until there is no rotary energy derived from that portion of the vanes which have a velocity greater than .186% of the translatory velocity of the shell, because the air cannot impinge upon the vanes, for they are at an angle of 10° 44″. The average velocity of the shell for the first second of flight equals 2673′ times .186, sine of the angle, equals 500. 500^2 equals 250000, minus 103.6373^2 (rotary travel 1 sec.) 10740 equals $\frac{239260}{250000}$ of 72401 ft. lbs. equals 69290. Correcting developed first second of flight plus 66773 ft. lbs., initial energy, equals 136063 ft. lbs. true final energy; which equals to a rotary velocity of 121.083 ft. sec. True acceleration 36.263 ft. Travel 102.9515 ft. sec.

To determine the energy developed for second of flight: Take the average range, the maximum ordinate, and average altitude and from these factors determine the weight and pressure of the air and proceed to determine the energy developed, final rotary velocity, etc.

It is determined in the second second of flight there will be developed and impressed upon the shell a rotary energy of 89524.58 ft. lbs. and the shell will have a final rotary velocity 155.911 ft. sec.

The peak of efficiency of the vanes occurs in the 6th second of flight, when there will be developed 93590 ft. lbs. and the total energy will be 595589 ft. lbs. and a rotary velocity 263.3255 ft. sec.

From this point in the flight of the shell the energy developed per each second lessens, due to reduced velocity of the shell, the density of the atmosphere, and the efficiency of the vanes.

For the 8th second of flight the energy developed equals 73428 ft. lbs.

For the 10th second of flight it will be 56661 ft. lbs. and a total energy impressed upon the shell for the ten seconds of flight will be 938689 ft. lbs. and a rotary velocity 306.05 ft. sec.

The advantages derived from a shell of the form stated are an increased muzzle velocity for the same propellant charge; reduced maximum pressure in the gun; less erosion to the gun and therefore longer life; reduced longitudinal stress upon the gun; greater accuracy of fire; increased range; and the only means by which we may materially increase the muzzle velocity of our highly developed guns.

We will now proceed to analyze the advantages claimed by use of this invention. First a greater muzzle velocity: It it evident that if that portion of energy of the propellant charge required to impart rotation to the shell is utilized to assist in producing acceleration of the shell in its travel thru the gun, there will be increased muzzle velocity in proportion to the square root of the energy expended, which is of three distinct characters:—1st. Energy required to produce rotation; friction of the load upon the rifles of the gun; friction of the rotating base of the shell upon the dense gases, and stripping of the rotating band by the lands of the gun, which represent the energy required for the flow of the copper band under pressure. 2nd. Reduced maximum pressure. As the resistance to the generated gases on detonation are reduced so is the pressure, and a higher initial velocity is obtained and maintained thruout the gun, with more uniform pressure, but without a higher terminal pressure, for the reduced load governs both the pressure and the velocity. 3rd. Erosion of the gun is directly as the density of the gases confined at that point, which is determined by the pressure and the temperature. Therefore, when we reduce the maximum pressure we at the same time reduce the temperature, and by so doing increase the life of the gun. 4th. Greater accuracy of fire. When we reduce the twist of the gun from one turn in 25 calibres to one turn in 100 calibres, we prevent vibration of the shell in its movement thru the gun, and we also reduce the friction of the bursting charge upon the interior walls of the shell and thereby eliminate one of the causes of the premature explosion in the gun. The vanes upon the ogival head of the shell will prevent the drift of the shell. In present constructed shells, the drift is approximately as the range, due to the shell rolling upon the denser air on its lower side due to the acceleration of fall. With this "turbine" head shell, the greater reaction of the air upon the vanes on the lower side counteracts the drift. As the greatest rotary velocity will be attained after the shell has passed the crown of the trajectory or maximum ordinate, the gyroscopic influence offers resistance to the resultant of forces, i. e., motion of translation of the shell and the fall, due to gravity, the air pressure of each controlling the angle of fall. By slower obeying the air pressure due to acceleration of fall the range is materially increased, due to two causes, first, the area of cross-section of the longitudinal axis of the shell when at right angles to the plane of gravity offer the greatest resistance to the force of gravity, thru displacement of the air. Therefore acceleration of fall is reduced and the increased time of flight will represent that increase in range.

It may appear on superficial consideration of the subject matter presented in relation to this invention that: While the vanes of the ogival head will produce rotation of the shell i. e., reduce the range in proportion as the muzzle velocity is to the muzzle velocity less the energy impressed upon vanes by the impinging air. This is not the fact, for we have not increased the area of cross-section of the ogival head, nor displaced any of the air in the path of the shell at a higher velocity of displacement. The long point of a shell when ungrooved displaces the air radially at low velocity and performs no other function. The turbine head of the shell, grooved as in this invention, displaces air at the same velocity, but that portion of the air which impinges upon the vanes is displaced tangentially and not radially and thru reaction performs a useful function—imparts rotation to the shell.

The art has arrived at the limit of muzzle velocity in our present constructed guns due to rifling of the guns. With reduced twist (one turn in 100 calibers) the rotating band may be reduced in both width and thickness, and the rifles shallower, for but $\frac{1}{16}$ of the energy is impressed upon the shell to produce rotation, compared to one turn in 25 calibers, the prevailing custom. The yaw is reduced and the intensity of vibration is reduced as the square of the tolerance. The great pressure in the first few feet of movement of an old or known shell, required to force the band against the lands of the gun to produce flow of the copper band, retards movement of the shell in the first few feet of its travel and high maximum pressure results, producing high temperature and loss of energy. It is a well-known principle of physics that work performed of whatever kind by a given source of energy reduces that initial energy directly as the resistance overcome; therefore, the energy which is employed to form the rotating band to the lands and rifling of the gun can perform no other function dynamically.

One of the important principles to be deduced from the foregoing disclosure, and observed in making a most efficient shell, is that the curvature of the spiral of the vanes equals the curvature of the ogival head, or, stated in another way, their projected area or face should be the same angle to the plane of the flight of the shell as the angle of the ogival head. Thereby they produce the same velocity of displacement of the air as the ogival head and produce the desired turning effect without changing the ballistic coefficient of the shell. By the "projected area" is meant that surface of the vanes which extends radially to the surface of the ogival head and at a right angle to the plane of flight. Thus, the "projected area" in the 14″ shell herein illustrated equals the product of the 25 vanes multiplied by their length 25″, multiplied by ⅛″ their depth, multiplied by .186 the sine of the angle, amounting to 14.53125″, the projected area of the vanes.

The projected area of the vanes in turbine head shells for all calibers should equal .0053 of the cube of their calibre in inches. Comparatively, their projected area should be approximately as their weights.

I would suggest as a scheme of design for any calibre shell, the ogival head of which is struck on from 6 to 7½ calibre radius, that the number of vanes be 1.8 times the calibre of the shell, 1.8 times the calibre for their length, and .008″ for each inch of calibre for the depth of the vane. Thus for a 6″ shell the number of vanes would be 11, their length 11″, and their depth (.008 times 6) .048″, sine of angle .186 equals 1.0788″ projected area. The correct projected area for a 6″ shell, weight 100 lbs. is 1.1488″. Thus 6″^{3} equals 216 times .0053″ equals 1.1448″, the required projected area to impart a rotary velocity equal to rifled guns having one twist in 25 calibers, by the time the fired shell has reached the crown of its trajectory or maximum ordinate, the gun having at least 5° of elevation.

It is not to be understood that the angle formed by surfaces 8 and 9 cannot be an obtuse angle, that is, an angle greater than 90°, such as shown in Fig. 4, 7′, for such an angle should be employed if a higher rotary velocity than that now employed be desired, because if the shell is of great sectional density, the angle of the vanes to the plane of flight must necessarily be increased and clearance for the deflected air from the surfaces 8 is thus provided for. But in such construction, the ballistic coeffiecient of the shell is changed because the air will be displaced at a greater velocity than by a similar ogival head ungrooved. A greater angle than that shown in Fig. 4, 7′, is obtained by further spacing of the groove and a greater depth to the vane may be employed. The greater depth compensating for less vanes and not changing the total projected area required.

The depth of the vanes is a matter of design; likewise their number; but their combined projected area is a definite quantity, sufficient to produce the desired result, depending on the weight, the calibre, the muzzle velocity, and the desired rotary velocity of the shell. Also, the vanes should be upon the ogival head, instead of elsewhere, because when so located they do not absorb potential energy of the shell and are most efficient. Grooves on a cylindrical surface absorb potential energy of the shell, hence the grooves should not extend rearward of the bourrelet, and the best result is attained with grooves (or vanes) as above described, located on the ogival head of a "stream line" shell having a long point struck on a radius of from 6 to 10 calibers, a relatively short cylinder length, and a tapered base, such as that disclosed in my U. S. Patent No. 1145115.

I claim:

1. A projectile having an ogival head, and a plurality of vanes on the head curved and inclined at substantially the same angle to the longitudinal axis of the projectile as that of the ogive of the head.

2. A projectile having an ogival head, and a plurality of spiral vanes on said head having substantially the same angle to the longitudinal axis of the projectile as that of the ogival head.

3. A projectile having in combination an ogival head, and vanes thereon consisting of two surfaces forming at least a right angle, the number of said vanes, their length, and angle with respect to the longitudinal axis, and depth, being such as to produce a total projected area on all shots and shells approximately proportional to their weight.

4. A projectile as stated in claim 3, the curvature of the grooves with respect to the longitudinal axis of the projectile being substantially the same as the curvature of the ogival head.

5. A projectile having a long ogival head, a relative short cylinder length, and a tapered base, the head alone having a plurality of curved vanes thereon consisting of two surfaces, one surface being radial and forming a projected area for impingement of the air due to the translatory motion of the shell.

6. A projectile having an ogival head, and vanes thereon to displace the air tangentially in the flight of the projectile, said vanes being at an angle to displace the air at substantially the same velocity as that displaced radially by the head.

7. A projectile as stated in claim 2, the projected area of the vanes being substantially equal to .0053 of the cube of the calibre.

8. A projectile having an ogival head and spiral vanes thereon, the projected area of the vanes being substantially equal to .0053 of the cube of the calibre.

9. A projectile having an ogival head, and curved vanes thereon the projected area of which is approximately proportional to the weight, calibre, muzzle velocity and desired rotary velocity of the projectile.

10. A projectile having an ogival head, and vanes on the head, one surface of said vanes being radial to the central axis of the shell and having an angle to the plane of flight equal to that of the ogival head.

11. A shell having an ogival head, and vanes on the head, one surface of said vanes being radial to the central axis of the shell and the projected area of said surface being approximately equal to 1.2 inches for each 100 lbs. weight of the shell.

12. A shell having an ogival head, and vanes on the head having two surfaces, the projected area of said surfaces aggregating in inches approximately .0053 of the cube of the calibre of the shell in inches.

13. A projectile having in combination an ogival head and vanes thereon consisting of two surfaces forming at least a right angle, the number of said vanes, their length and depth being such as to produce a total projected area in all calibre shells approximately proportional to the cube of their calibres.

In testimony whereof, I affix my signature in the presence of two witnesses.

WILLIAM K. RICHARDSON.

Witnesses:

C. W. Fowler,

J. Vincent Martin.