

REMINGTON ARMS COMPANY, INC.

ENGINEERING DEPARTMENT



COMPUTATION SHEET

SHEET No. 1

TITLE OF PROJ.

Article for Product Engineering

PROJ. No.

SUBJECT

Design of M721

WORKS

M H Ward

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9-20

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The problem of gun design for the commercial trade can be condensed to this general statement: "Design for ease of manufacture, low cost and resultant low selling price, while retaining approved features and as possible introducing new features to improve consumer acceptance." An attempt will be made to show how this statement was applied in the design of the Model 721, a Remington High Power Bolt Action Rifle including some of the engineering problems involved.

TP#1 On the 1920s following the first world war the high power bolt action rifle became popular as a sporting rifle due to the close association of our service personnel with the 1903 Springfield and the 1917 Enfield. As

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a result of this popularity Remington introduced a sporting bolt action high power based on the 1917 Enfield and called the Model 30.

This model was redesigned and improved in 1938 and was called the Model 700. The limitations of the original military action, mainly ^{high} manufacturing costs, were not eliminated. The relatively high cost and resultant high selling price limited the volume. Thus the need for a new design.

EASE OF MANUFACTURE & LOW COST

The bolt action rifle is basically one of the most simple to produce. However, tradition and Paul Mauser's Model '98 action have influenced previous designs to the point that manufacturing cost was given very little consideration. As an example, the receiver and bolt of the 1917 Enfield took over 250 operations

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to compute. The
total on the m7-x1 receiver & bolt is less
than 75% of that number.

Blanked, formed or drawn parts were
used very little in gun manufacture until
the last war, when speed and conservation of
material became very important. There are
reports of this type in the m7-x1 where of
which detract from the function or appearance,
but contribute appreciably to moderate
selling price.

Of the total of 58 parts in this rifle
20 are blanked & formed, 25 are completed on
high production automatic machines such as
screen machines & spring makers, and 9 have
secondary operations after being partially
completed on automatic machines. Only
four parts, the receiver, barrel, stock, &

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front might have a major portion of their operations on low production machines such as milling machines & lathes.

In order to keep the investment in inventory and parts in process as low as possible it was necessary to make all parts interchangeable except those few which are (applicable) to individual calibers. For example, all parts in the M 721 are interchangeable between calibers except the barrel and the bolt head. There are three calibers supplied in M 721 at present. The .270 Win is exactly the same as the 30-06 except for the internal dimensions of the barrel. The 300 H&H Magnum is identical with the 30-06 except for the barrel chamber and bolt head. Where 58 parts are needed for any one caliber, only 61 separate parts are necessary for the three calibers.

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DESIGN FEATURES

Several desirable features were incorporated in the new model which are not new, but had not been previously featured in their entirety in any single design. These features are:

- ① A bolt handle design which allows low mounting of a telescope sight without interference. Placing the telescope line of sight ~~so~~ close to the metallic line of sight is desirable to alleviate the necessity for changing the stock when metallic and glass sights are used alternately. Telescope sights are ordinarily from $\frac{3}{4}$ " to $1\frac{1}{4}$ " in diameter. With the metallic sight line $\frac{1}{8}$ " above the receiver there is necessarily from $\frac{1}{4}$ " to $\frac{1}{2}$ " difference between the glass and metallic sight line.

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② For those shooters who object to the difference between telescope & metallic lining of sight a stock is available which provides a $\frac{1}{2}$ " higher comb & heel.

③ A trigger mechanism providing a pull approximately .015" in length with out preliminary take up or overtravel or backlash. This allows the shooter to discharge the arm with proper control without disturbing the alignment of sights and target. This was previously available only on match rifles. This is possible ^{at the present price} because, out side of blanking and forming, there are only 3 drilling operations, 3 grinding operations, and delivering on all the trigger parts.

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④ Short firing pin travel (.290") giving a lock time of about .003 seconds (only 40% of the 1903 Springfield lock time) yet providing definitely superior ignition characteristics. This superiority can be accounted for by the positive seating of the cartridge in the chamber by the spring urged ejector. This makes it unnecessary for the firing pin to overcome the inertia of the whole cartridge and its total energy is used for indentation of the primer. The result is that variation in cartridge length has no effect on the ignition, each primer is debited the full energy of the firing pin blow.

⑤ The safety can be operated equally well by either right or left hander.

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shooters. The position is such that low mounted telescopes do not interfere with its operation. With normal use its operation to the "off" position is effortless.

new features are incorporated which are available in no other sporting bird action rifle at the present time. These are:

① Strength characteristics which have defied all efforts to make the action fail under over load conditions. The reason for this, of course, is that the design is based on sound engineering principles.

② A new manual extractor entirely contained in the bolt head, contributing to low cost, and giving better extraction characteristics than the old hook type.

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(3) A barrel & bolt design which completely encloses the cartridge case in steel, making the strength of the action independent of the strength of the cartridge case. This system also allows an arrangement for handling the gas from a blow or a pierced primer without injuring the shooter.

(4) A weight very close to 7# complete, approximately one pound lighter than previous high power bolt action rifles, yet stronger & safer from the standpoint of cartridge or gun failure.

ENGINEERING PROBLEMS

1. Barrel Strength

The exterior dimensions of a shoulder arm are limited by the

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appearance, the weight, and the required handling qualities. The usual practice is to fix these dimensions first then modify if necessary to meet strength requirements. On high power rifle it is often necessary to heat treat several of the parts in order to provide adequate strength. The barrel is one of these parts.

As the most economical way to heat treat steel is in furnace size lots, the cartridge with the highest strength requirements is used for calculating the necessary properties of the barrel steel for all cartridges in any one model. On the No. 9A

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This cartridge is the .300 H & H
 magnum. (300 stands for bore, H & H
 for Holland & Holland & magnum
 a large glass of liquor, in other words
 a big shot).

The highest pressure in a shoulder
 rifle occurs while the bullet is moving
 its first few inches of travel. Therefore,
 the chamber portion of the barrel must
 be the strongest. Ordinarily some
 derivation of James' thick wall tubing
 formula is used for calculating stress
 in gun barrels. For tangential stress -

$$S = \frac{P(R_1^2 + \frac{R_1^2 R_2^2}{R^2})}{R_2^2 - R_1^2}$$

Where

S = Stress

P = Unit pressure in tube

R₁ = Internal radiusR₂ = External radius

R = Radius at which stress is taken.

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Substituting in this formula the average tangential stress 1 inch in front of the receiver using 84,000 p.s.i. internal pressure is 65,000 p.s.i. From this calculation and others a minimum yield strength of 80,000 p.s.i. was established. In addition an alloy is used which will give at least 50% reduction of area and 20% elongation to prevent fragmentation in case the shooter gets an obstruction in his barrel. An obstruction will wreck even the strongest of barrels.

(12) ACTION STRENGTH

Due to the strict control of the loads used in a high power rifle the factor of safety used in the design of barrels and actions is generally not over 1.3. However in the loaded position it

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it is possible to get a larger factor of
 safety with the new design. The
 largest load applied to the bolt face
 occurs with the 300 magnum proof.
 This load is in the neighborhood of
 $84000 \text{ psi} \times .21 \text{ sq in} = 17,500 \text{ pounds}$
 maximum force. The smallest area
 in tension is .48 sq in, in shear is
 .43 sq in, & in compression is .14 sq in.
 The highest probable stress then is
 $17,500 / .14 = 125,000 \text{ psi}$. The
 receiver & bolt are austempered
 to a yield strength of 190,000 average.
 An alloy was selected which has
 excellent impact properties, averaging
 Izod 35 at the selected hardness.

③ IGNITION CHARACTERISTICS

Using the proven sensitivity
 specifications set up by the Service

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Arms and Ammunition Manufacturers
Institute the minimum energy of
firing pin blow for proper ignition
in a fire arm has been established.
The conventional method for measuring
the sensitivity of primers uses the
drop test machine. A steel ball of known
weight is dropped on a light firing pin
which strikes the primer. Samples
of 25 to 100 primers are tested at each of
several heights of fall and the fraction
of primers that fire at each height is
recorded. The controlling factor, under any
given set of conditions, which determines
whether or not a primer fires is the
energy with which it is struck by
the firing pin. The drop test sets

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recorded in terms of height of fall is readily expressed in convenient energy units of inch-ounces from the product of the height of fall in inches and the weight of the falling ball in ounces.

All that remains is to determine the variables introduced by a gun mechanism and field conditions. These are, under ordinary conditions, friction, backspace (the space from the face of the bolt to the surface in the chamber which supports the cartridge longitudinally), eccentricity of blow, and temperature. These factors have been isolated and reasonable limits set relative to their effect on the ignition.

A blow approximating 85 inch-ounces is required to cause ignition.

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ignition variables in the gun. Knowing this and the length of travel of the firing pin the figure can be substituted in the equation:

$$E = F \frac{M_f}{M_f + 3M_s} D$$

Where

E = Energy delivered in inch-ounces.

F = Average force of main spring (in pounds) between cocked & fired load.

M_f = Weight of firing pin assembly

M_s = Weight of spring

D = Distance firing pin travels from cocked to fired position (in inches).

Substituting

$$85 = F \frac{61.5}{61.5 + 4.2} \cdot 290$$

$$F = 313.03 = 19.6^{\text{th}} \text{ Avg Force.}$$

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With the average load requirements and the space in which the spring must operate a relatively precise design can be accomplished. On the next the main spring must work in a .45" dia hole and over a .783" dia firing pin. The cocked length of the spring is 3.348 and the fired length is 3.638. The maximum solid height of the spring can be no more than 2.30" as the spring must be compressed to this height during assembly.

A certain amount of experience in spring design, although not absolutely necessary, reduces the time and effort involved. A good rule in designing gun springs is to use all the space available for spring energy keeping the tolerances and the stress within reasonable limits. The

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extra effort involved is in the trial and error choice of wire diameter and spring diameter. Dispensing with the trial and error part, the wire diameter is set at .055" and the o.p. at 400. This choice leaves space on both inside and outside for winding tolerance. Leaving set the wire diameter the maximum number of coils can be determined from the maximum solid height.

$2.30 \div .055 = 41+$, the extra wire diameter produced in winding complete coils reduces this to 40+. Leaving a coil for clearance brings the total coils to 39. Then to prevent excessive buckling and consequent friction the end coils are squared and ground, leaving 37 active coils. The necessary lengths are then determined from the constant $\frac{P}{F}$, pounds load per inch deflection.

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The usual formula for deflection is:

$$F = \frac{8PD^3N}{Gd^4} \quad \text{OR} \quad \frac{P}{F} = \frac{Gd^4}{8D^3N}$$

where

F = Deflection in inches

N = Number of active coils

G = Shear modulus of rigidity
which for steel wire averages 11.5×10^6

D = Mean spring diameter (O.D. - d)

d = Wire diameter

P = Spring load in lbs.

Substituting

$$\frac{P}{F} = \frac{11.5 \times 10^6 (31 \times 10^{-6})}{8 (0.411)^3}$$

$$\frac{P}{F} = 8.6$$

Since a minimum approximating 19.6#
is desired at a length of 3.493:

$$\frac{19.6}{L - 3.493} = 8.6 \quad \text{Where } L = \text{FREE LENGTH}$$

$$L = 5.773 \text{ inches}$$

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If reasonable cost of manufacture is expected, the spring manufacturer should have at least 10% tolerance on the load. With a minimum free length of say 5.80" and a working load of 20#, the average free length was set at 5.94" giving a tolerance of $\pm .14 \times 8.6 = 1.2\%$.

From the stress formula

$$S = \frac{8PD}{\pi d^3} K = \frac{2.55PD}{\pi d^3} K \text{ The working stress is } \frac{2.55(5.94 - 3.493) 8.6(3.45)(1.02)}{.000166} = 120,000 \text{ psi}$$

(K = Concentration Correction = $1 + \frac{.5d}{D}$)

With a solid height of $.055 \times 39 = 2.145$ the solid stress is

$$\frac{2.55(5.94 - 2.145) 8.6(3.45)(1.02)}{.000166} = 187,000 \text{ psi}$$

This is on the high side, but acceptable with good quality music wire.

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From the preceding information it is possible to calculate the lock time. From the fundamental equations $E = \frac{1}{2} MV^2$, $E = P \cdot s \cdot d \cdot t = \frac{S}{t}$, lock time $t = \sqrt{\frac{2MS}{P}}$, where M = mass of firing pin plus $\frac{1}{3}$ the mass of the main spring, S = distance the firing pin travels in feet, and P = Average force exerted by the spring. Substituting

$$t = \frac{\sqrt{2(145)(.290)}}{21(32.2)(12)} = .0037 \text{ seconds. By}$$

measurement this was found to be very close to actual. Lock time is important because it indicates the possible movement of the arm, in the hands of a shooter, between trigger release and ignition of the charge, i.e., greater lock time indicates greater probability for human error in placing the shot at the target.