10/26/48

<u>ARTICLE FOR "PRODUCT ENGINEERING"</u>

<u>DESIGN OF MODEL 721</u>

In the 1920's, following the first world war, the high power bolt action rifle became popular as a Sporting Rifle. No doubt this was influenced by the close association of our service personnel with the 1903 Springfield and the 1917 Enfield, and as a result of this popularity, Remington introduced a Sporting Bolt Action High Power Rifle based on the 1917 Enfield and designated as the Model 30. In 1940 this rifle was redesigned and improved and called the Model 720. However, the relatively high cost and resultant high selling price limited the volume. Thus the need for a new design.

The objective of good gun design can be condensed to this general statement applicable to many products, "Design for reliability and ease of manufacture with re-sultant low cost and selling price, while retaining approved features and if 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 721-722 Remington High Power Bolt Action Rifle, including some of the engineering problems involved.

<u>EASE OF MANUFACTURE AND LOW COST</u>

The bolt action rifle is basically one of the most simple to produce. However, tradition as well as Paul Mauser's M/'98 Action have influenced previous

R2501531

-2-

designs to the extent that manufacturing cost was given very little consideration.

As an example, the receiver and bolt of the 1917 Enfield took over 250 operations to

complete. The total on the M/721 Receiver and Bolt is less than 25% of that number.

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

20 parts of this type in the M/721 none of which detract from the function or

appearance, but contribute appreciably to moderate selling price.

Of the total of 58 parts in the rifle, 20 are formed, 25 are completed

on high production automatic machines such as screw machines and spring winders,

and 9 have secondary operations after being partially completed on automatic

machines. Only four parts, the Receiver, Barrel, Stock and Front Sight have a major

portion of their operations on production machines such as milling machines and 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 the M/721 at present. The rifle for the 270 Win-

chester caliber is exactly the same as for the 30-06 except for the internal

R2501532

- 3 -

dimensions of the Barrel. The rifle for the 300 H&H Magnum caliber is identical with the 30-06 except for the Barrel chamber and Bolt Head. Whereas 48 parts are needed for any one caliber, only 61 separate parts are necessary for the three calibers.

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 close to the line of the open sight is desirable to alleviate the necessity for changing the Stock when "iron" and telescopic sights are used alternately. Telescope sights are ordinarily from 3/4" to 1-1/4" in diameter. With the metal sight line 1/8" above the Receiver, there is necessarily from 1/4" to 1/2" difference between the telescope and metal sight line.

2. For those shooters who object to the difference between telescope and metallic line of sight, a Stock is available which provides a 1/2" higher comb and heel.

-4-

3. A trigger mechanism providing a pull approximately .05" in length without

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,

however, this feature is available on the Model 721 by designing for a

minimum number of required operations. In fact after forming there are only

3 drilling operations and 3 grinding operations on all of the trigger parts.

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 with 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 in-

dentation of the primer. The result is that normal variation in cartridge

length has no effect on the ignition, each primer is delivered the full

energy of the firing pin blow.

5. The Safety can be operated equally well by either right or left handed

shooters, and its position is such that low mounted telescopes do not

-5-

interfere with its operation. With normal care its operation to the "off"

position is noiseless.

New features are incorporated which are available in no other sporting bolt

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 and novel Extractor entirely contained in the Bolt Head gives better

extraction characteristics than the old hook type.

3. A Barrel and Bolt design which completely encloses the cartridge case in

steel makes the strength of the action independent of the strength of the

cartridge case.

4. A weight very close to 7 lbs. complete, approximately one pound lighter

than previous high power bolt action rifles, yet stronger and 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 appearance,

the weight, and the required handling qualities. To meet the strength

-6-

requirements in high power rifles without an adverse effect on appearance, weight and handling characteristics, it is often necessary to heat treat several of the parts. 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 physical properties of the barrel steel for all cartridges in any one model. In the M/721 this cartridge is the 300 H&H Magnum (300 stands for bore, H&H for Holland and Holland, and 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 derivations of Tame's thick wall tubing formula is used for calculating stress in gun barrels.

For tangential stress -
$$S = P \frac{\left(R_1^2 + \frac{R_1^2 R_2^2}{R^2} \right)}{R_2^2 - R_1^2}$$

Where

S = Stress
P = Unit pressure in tube
R_1 = Internal radius
R_2 = External radius
R = Radius at which stress is taken

-7-

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.

2. Action Strength

Due to the strict control of the loads used in a high pressure rifle,
the factor of safety used in the design of barrels and actions is generally
not over 1.3. However, in the M/721 design it was possible to get a larger
factor of safety. The greatest load applied to the bolt face occurs with
the 300 Magnum proof. This load is in the neighborhood of 84,000 p.s.i. x
.21 sq. in.= 17,500 pounds maximum force. The smallest area in tension is
.48 sq. in., in shear is .43 sq. in., and in compression is .14 sq. in.
The highest probable stress then is 17,500/.14 = 125,000 p.s.i. The
Receiver and Bolt are austempered to a yield strength of 190,000 average.
An alloy was selected which has excellent impact properties, averaging
Izod 25 at the selected hardness.

-8-

3. Ignition Characteristics

Using the primer sensitivity specifications set up by the Small Arms
and Ammunition Manufacturers Institute, the minimum energy of firing pin
blow for proper ignition in a firearm 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 data 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 under field conditions. These are usually
friction, head space (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 evaluated and reasonable

-10-

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 extra effort involved is in the trial and error choice of wire diameter and spring diameter. The wire diameter is therefore set a .055" and the O.D. at .400". This choice leaves space on both inside and outside for winding tolerance. Having set the wire diameter the maximum number of coils can be determined from the maximum solid height. 2.30 ÷ .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.

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 = Torsional Modulus of rigidity which for steel wire averages 11,500,000.
D = Mean spring diameter (O.D. - d)
d = Wire diameter.
P = Spring load in lbs.

-11-

Substituting

$$\frac{P}{F} = \frac{11.5 \times 10^6 (9.1 \times 10^{-6})}{8 (.0411)37}$$

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

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

$$\frac{19.6}{L-3.493} = 8.6 \qquad \text{Where L = Free length.}$$

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

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 x 8.6 = 1.2#.

From the stress formula

$$S = \frac{8 \ PD}{\Pi \ d^3} = \frac{2.55 \ PD}{d_3} \ K \qquad \text{the average working stress is}$$

$$(K = \text{concentration correction} = 1 + \frac{.5d}{D})$$

$$\frac{2.55 \ (5.94-3.493) \ 8.6 \ (.345)}{.000166}(1.08) = 120,000 \text{ p.s.i.}$$

With a solid height of .055 x 39 = 2.145 the solid stress is

$$\frac{2.55 \ (5.94-2.145) \ 8.6 \ (.345)}{.000166}(1.08) = 187,000 \text{ p.s.i.}$$

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

From the proceeding information it is possible to calculate the lock time.

From the fundamental equations $E = 1/2 \ MV^2$, $E = PS$ and $t = \frac{S}{V}$, lock time

-12-

$t = \sqrt{\frac{2MS}{P}}$, where M = mass of Firing Pin plus 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 $t = \sqrt{\frac{2(.145).290}{21(32.2)12}}$ = .0032 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 introduces greater possibility for human error in

placing the shot at the target.

M.H.Walker/mc
10/28/48