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SOME ENGINEERING FEATURES
OF A
MODERN BREECH MECHANISM

Thesis for Degree of M. E.

Henry Jacob Schneider

1931

THESIS

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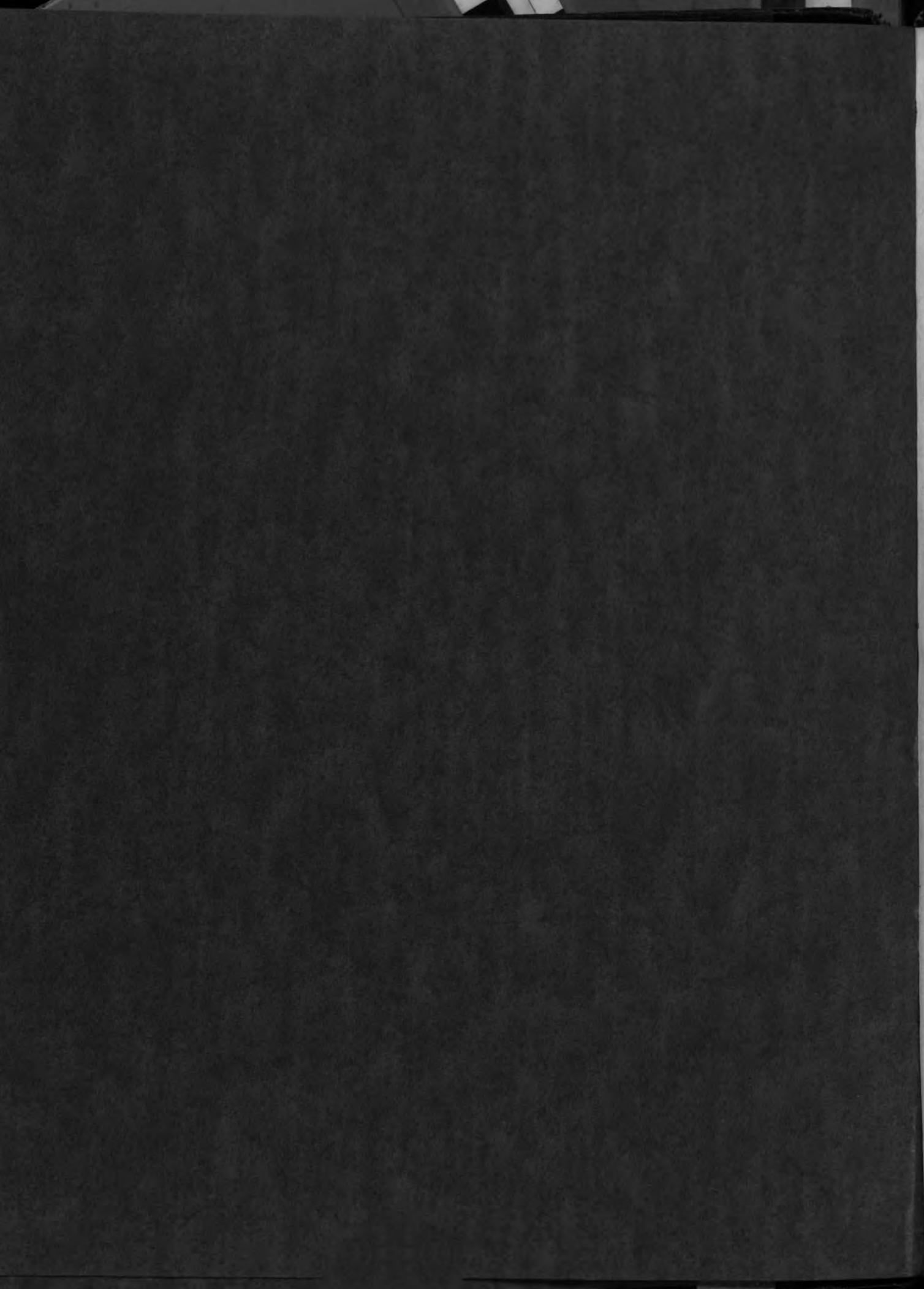


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SOME ENGINEERING FEATURES OF A MODERN BREECH MECHANISM

The term breech mechanism may be defined as an apparatus by means of which the breech end of a gun is opened in order to load the ammunition and also closed and locked when the gun is to be fired. The gun is essentially a hollow cylinder and the breech mechanism is used for opening and closing the rear end of the gun into which the projectile and powder are inserted. In the older forms of cannon the rear end was closed. These, therefore, required no breech mechanisms. This type of cannon was loaded from the muzzle end. This was a laborious and slow method. The need for greater speed in firing brought about the open ended gun with its breech mechanism. The earlier forms of breech mechanisms were very simple, inefficient and slow of operation. In great contrast to these, the heavy power operated breech mechanisms of today appear. The progress and development in this branch of ordnance is the result of years of study, research and experimentation. The modern breech

mechanism has reached a high state of perfection and has kept pace with the great progress which has been made in other lines of mechanical engineering.

In small fire arms a great variety of breech mechanisms are used and many automatic features are employed which are not suitable in larger guns. For the latter class dependability, simplicity, speed, and ease of operation are essential features. The various parts, although designed to withstand severe stresses and rough usage, must, nevertheless, be well balanced and carry no excess weight. No undue time should be required for the operation of opening and closing the mechanism. Parts requiring frequent adjustment and attention can not be utilized. The mechanism must have a positive action, be easily operated and dependable. It must be fool proof and safe in the hands of the operators. It must be easy to disassemble so that the parts may be readily inspected.

To give a detailed description of a modern breech mechanism is beyond the scope of this article. It is the intention of the writer to

present a few of the engineering problems which are encountered in the design of a modern breech mechanism of a major caliber gun.

There are two principal types of mechanisms in use today viz: the sliding block type and the interrupted screw type. In the former the breech block which closes the rear of the bore against the force of the charge, slides transversely to the axis of the bore on suitable guides. The second type employs a breech block, called a plug, having interrupted threads around its circumference which engage similar threads in the rear end of the bore of the gun. The plug moves in the prolongation of the axis. The latter type only will be treated in this article.

The screw threads are an important feature in this type of mechanism. They will be treated in detail later. A plug with a continuous thread engaging the threaded bore in the rear of the gun is not adaptable to a speedily operated breech mechanism because of the great number of revolutions necessary to engage or disengage the plug from the gun. The time required for opening and closing the mechanism would be prohibitive. The

operating time must be reduced to the minimum. This is accomplished by employing what is known as interrupted threads. Threads are not cut around the whole periphery of the plug and gun, but the circumference is made up of several threaded bands and blank bands arranged alternately and extending parallel to the axis. For example, the circular arcs of quadrants 1 and 3 will be threaded while those of quadrants 2 and 4 will have the threads removed. This is true of both the plug and the gun. By means of this arrangement only ninety degrees of rotation of the plug are required for engagement or disengagement of the threads. Thus instead of a great number of revolutions of the plug being required to release it from the gun only one-fourth of one revolution is necessary. Figures 1 and 2 illustrate this principle.

Fig. 1 shows the plug A with threads removed in quadrants 1 and 3. Fig. 2 shows the gun, B, with threads removed in quadrants 2 and 4. It will be seen that the plug, A, may be inserted in the gun, B, if the horizontal axes X-X are coincident and the Y-Y axes of figures

1 and 2 coincide. When the plug is thus inserted in the gun its entire length and thus rotated, the threads of the plug will engage those of the gun. By continuing this rotation through ninety degrees the X-X axis of the plug will coincide with the Y-Y axis of the gun, all the threads will be bearing throughout their entire length and the mechanism will be locked.

The design produces a mechanism which can be quickly opened and closed, but half of the bearing threads have been removed to provide clearance. Thus fifty percent of the original bearing surface has been sacrificed. In order to regain this the length of the plug must be doubled. This will require a very heavy plug which will be cumbersome to operate. This design is used for small mechanisms but is not practical for large sizes on account of its inefficiency and the great weight necessary to produce a plug having sufficient thread area to stand the firing loads.

A mechanism of greater efficiency is produced by reducing the length of the blank arcs, thus utilizing more of the periphery of the

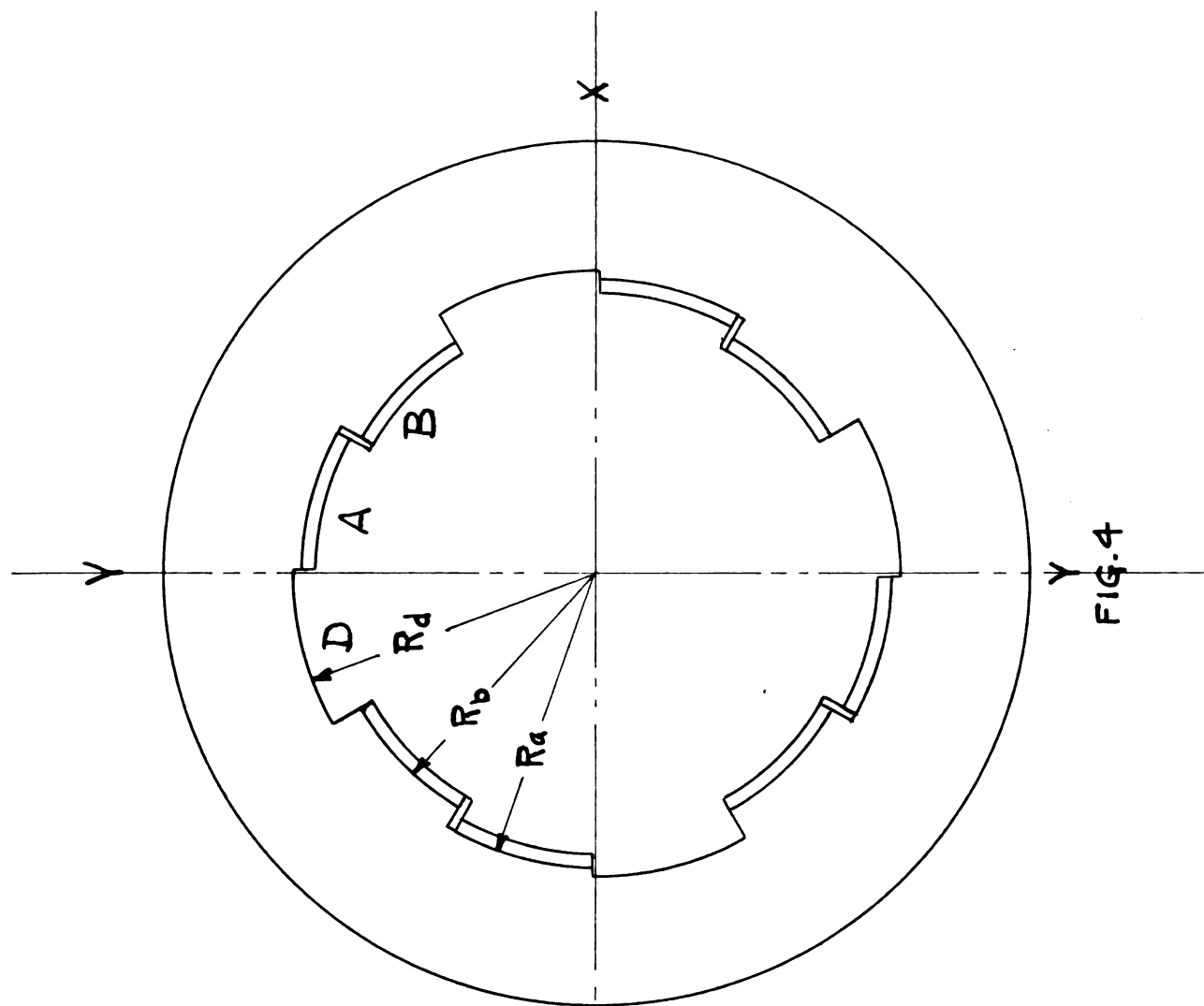


FIG. 4

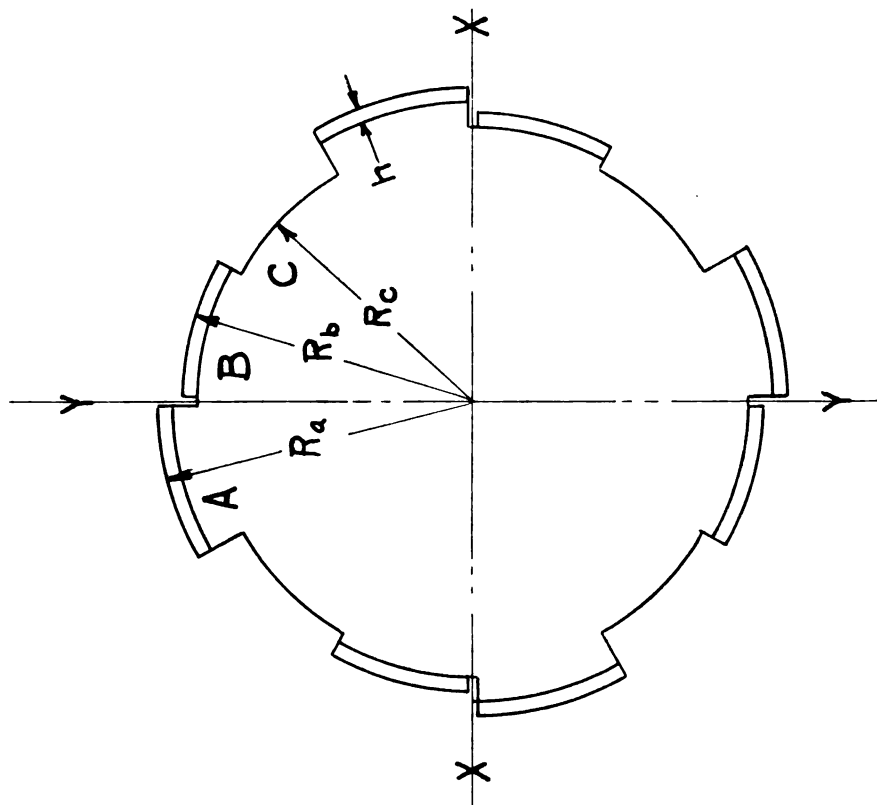


FIG. 3

plug for threads. This is accomplished by the use of stepped threads. The plug and the bore at the rear of the gun are slotted to form numerous sections, let us say, for example, twelve sectors. These twelve sectors will consist of four groups, each containing one blank sector and two threaded sectors one of which is of a little greater radius than the other. The blank sector is made a little wider than the threaded sectors to permit clearance for the withdrawal of the plug.

Virtually each quadrant is divided into threaded sectors A and B and a blank sector C as shown in Fig. 3 which represents the plug. Fig. 4 represents the gun. Threaded sector A has a radius = R_a , threaded sector B has a radius R_b and blank sector C a radius R_c . Let the thread depth be represented by h . Now R_b is made less than R_a by an amount a little greater than h , the depth of the thread, and R_c is smaller than R_b by the same amount.

The bore at the rear end of the gun is machined in the same manner except the blank sector, D, is cut to a radius a little greater than

R_a. By this arrangement it is necessary to rotate the plug only 30° to engage or disengage the threads. The plug A can be inserted in the gun B if the X-X axes remain coincident and the Y-Y axis of the plug coincides with the Y-Y axis of the gun. Thus sector A of the plug enters into the blank sector D of the gun, the sector B of the plug enters into sector A of the gun and sector C of the plug enters into sector B of the gun. When the plug is thus inserted in the gun its entire length and rotated thirty degrees all of the threads will be bearing throughout their entire length and the mechanisms will be locked.

The improvement of this design over the previous design is obvious. Only 30° of rotation are necessary instead of 90°. The total width of the blank sector has been reduced from 2 x 90° = 180° to 4 x 30° = 120°. In other words, 360° - 120° = 240°, approximately, or 2/3 of the circumference of the plug is threaded and provides bearing area to carry the firing load.

The efficiency of this plug, disregarding all clearance cuts, is approximately

$$\frac{360^{\circ} - 120^{\circ}}{360^{\circ}} = \frac{240^{\circ}}{360^{\circ}} = .66 \frac{2}{3}$$

while that of the first design was approximately

$$\frac{360^{\circ} - 180^{\circ}}{360^{\circ}} = \frac{180^{\circ}}{360^{\circ}} = .50$$

This type of mechanism may be further improved by carrying this same idea of reducing the width of the blank sector still farther and by increasing the number of stepped sectors. For example, let the face of the plug and gun be divided into three groups, each containing one blank sector and three stepped threaded sectors of different radii. The blank should be a little wider than the threaded steps to permit clearance for withdrawing the plug from the gun. This arrangement is shown in Figs. 5 and 6, Fig. 5 representing the plug and Fig. 6 the gun.

Each group or sector of 120° consists of three stepped threaded sectors A, B and C and one blank sector D. The radius R_b of the threaded sector B is again made less than R_a , the radius of the threaded sector A, by an amount a little greater than the depth of the thread h . The radius R_c of sector C is made less than R_b by the same amount. R_d , the radius of the blank

sector D is similarly less than R_0 . The bore at the rear end of the gun is machined in the same manner except that the blank sector E is slotted out to a radius a little greater than R_0 to provide clearance for the plug. The plug A can now be inserted into the gun B as in Figs. 3 and 4 above if the X-X axis and the Y-Y axis of the plug coincide respectively with the X-X axis and the Y-Y axis of the gun. Thus again the threaded sector A of the plug enters into the blank sector, E, of the gun; the threaded sector, B, of the plug enters into the threaded sector, A, of the gun and the threaded sector, C, of the plug enters into the threaded sector, B, of the gun and finally blank sector, D, of the plug enters into the threaded sector, C, of gun. When the plug is thus inserted its entire length and rotated in a clockwise direction the threads of the various steps of the plug will engage the corresponding stepped threads in the gun. When the plug has been rotated about 30° , all of the threads will be bearing throughout their entire length and the mechanism will be locked.

Let us compare this design with the preceding one. Here we have the face of the plug divided into three parts of the 120° each. Each one of these parts is divided into four sectors of approximately 30° each. The total width of the blank is $3 \times 30^\circ = 90^\circ$ approximately $360^\circ - 90^\circ = 270^\circ$ approximately or about $\frac{3}{4}$ of the circumference of the plug is threaded while $\frac{1}{4}$ is blank. The efficiency is $\frac{360^\circ - 90^\circ}{360^\circ} = .75$ which is an improvement of 25% over the preceding one.

By increasing the number of stepped sectors, the lengths of the threaded ones become shorter. Thus by continuing this process the blank arcs will become very short resulting in a plug of maximum threaded circumference and a consequent reduction in the length of the plug. This means that a lighter, more efficient and more easily operated mechanism can be produced. Practical considerations, however, will determine the maximum number of threaded steps which can be used in any design of a breech mechanism.

The machine operations necessary for cutting the threads on these stepped arcs are laborious and costly. It is clear that in order to insure

an even distribution of load the workmanship on the threads of both plug and gun must be very accurate and in order to maintain this distribution the material must be of uniform quality and hardness throughout. The cost of fabricating a stepped thread mounts rapidly as the number of steps is increased. There is a practical limit beyond which the refinement of increasing the number of threaded steps should not be carried.

Clearance Cuts.

Thus far we have considered only the engagement of the plug threads and the amount of rotation of the plug which is necessary to free it from the gun. In order to open the end of the gun so that ammunition may be inserted, the plug must be moved out of the way after it has been disengaged from the gun. In this type of mechanism this is accomplished by supporting the plug on a sort of hinge which is commonly called a carrier. This carrier which pivots about a bracket bolted to the outside of the gun is provided with a spindle upon which the plug is mounted so that the plug can be rotated and its threads be disen-

gaged from the threads of the gun. When thus freed the plug can be swung out of the gun by means of the carrier, leaving the end of the gun open for inserting the ammunition.

The path of the plug when swinging out of the gun necessitates the removal of some of the metal from both the plug and the gun in order to provide clearance. In order to sacrifice as little metal as possible, these swing clearances are calculated very accurately. Much study and careful planning are required to establish the most satisfactory locations of the stepped threads and blanks in relation to the center of the hinge in order to keep the clearance cuts down to the minimum. When metal must be sacrificed for clearance, investigations are made to insure that only the least desirable metal is removed. For example, clearance cuts, if possible, should be made on the blanks rather than on the threads.

The location of the hinge center is important. It has a decided bearing on the nature of the clearance cuts.

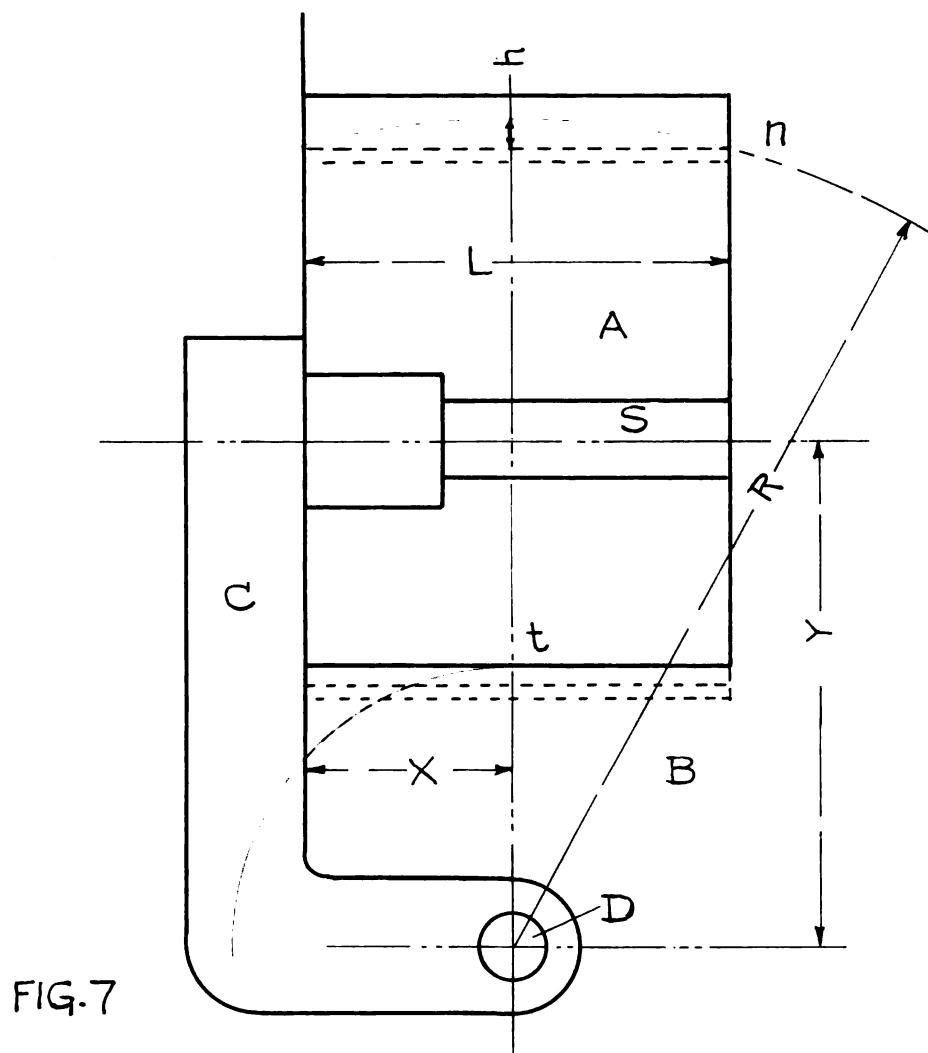


Fig. 7 shows a sectional view through the breech end of a gun, plug and carrier. A represents the plug which is mounted axially on the spindle, S, of the carrier, C. The carrier is hinged to the gun at D. Y is the distance from the center of the hinge to the center line

of the gun. X is the distance from the center of the hinge to the rear face of the gun. L represents the length of the plug. By making the distance Y large, the radius to the extreme point of the plug, such as $\underline{n}$, will be long, producing a somewhat flat arc and a shallow depth of clearance cut at $\underline{h}$. The distance Y , however, must not be made too long lest a long and weak carrier, which is easily deflected will be the result. Furthermore, the plug will swing on a long arm requiring much space at the end of the gun when the mechanism is in the open position.

The dimension X is also important. If X approaches the length, $\underline{L}$, then the depth of the cut at $\underline{h}$ approaches zero. At the same time, however, the clearance cut in the gun which is required by the point, $\underline{t}$, becomes deeper. Here again the importance of keeping the length of the plug at a minimum becomes evident. The shorter the plug is made, the smaller the clearance cuts become. Much thought and study should be devoted to the determination of the location of the hinge center because of its influence on the clearance cuts.

Determination of Swing Clearances.

Having established the location of the hinge center, the next problem is to determine the clearance cuts which are necessary in order that the plug may swing clear of the gun. In determining the amount and location of the clearance cuts, the chief aim is to reduce to a minimum the cutting away of any threaded section. Studies and layouts are made to determine the least objectionable location of these cuts, whether the metal be removed from the plug or the gun. Sometimes a compromise is made and metal is removed from each member. Here again considerations of the nature and difficulty of the machine operations involved are of utmost importance, lest, in the effort to gain efficiency an impossible or impracticable condition will be produced for the machinist. Often the advantage gained in maintaining a certain dimension is not justified by the complications and added cost which are involved.

Let us now consider the plug A and its motion in swinging out of the gun, B. Fig. 8 shows the end view of the plug and gun and a vertical sec-

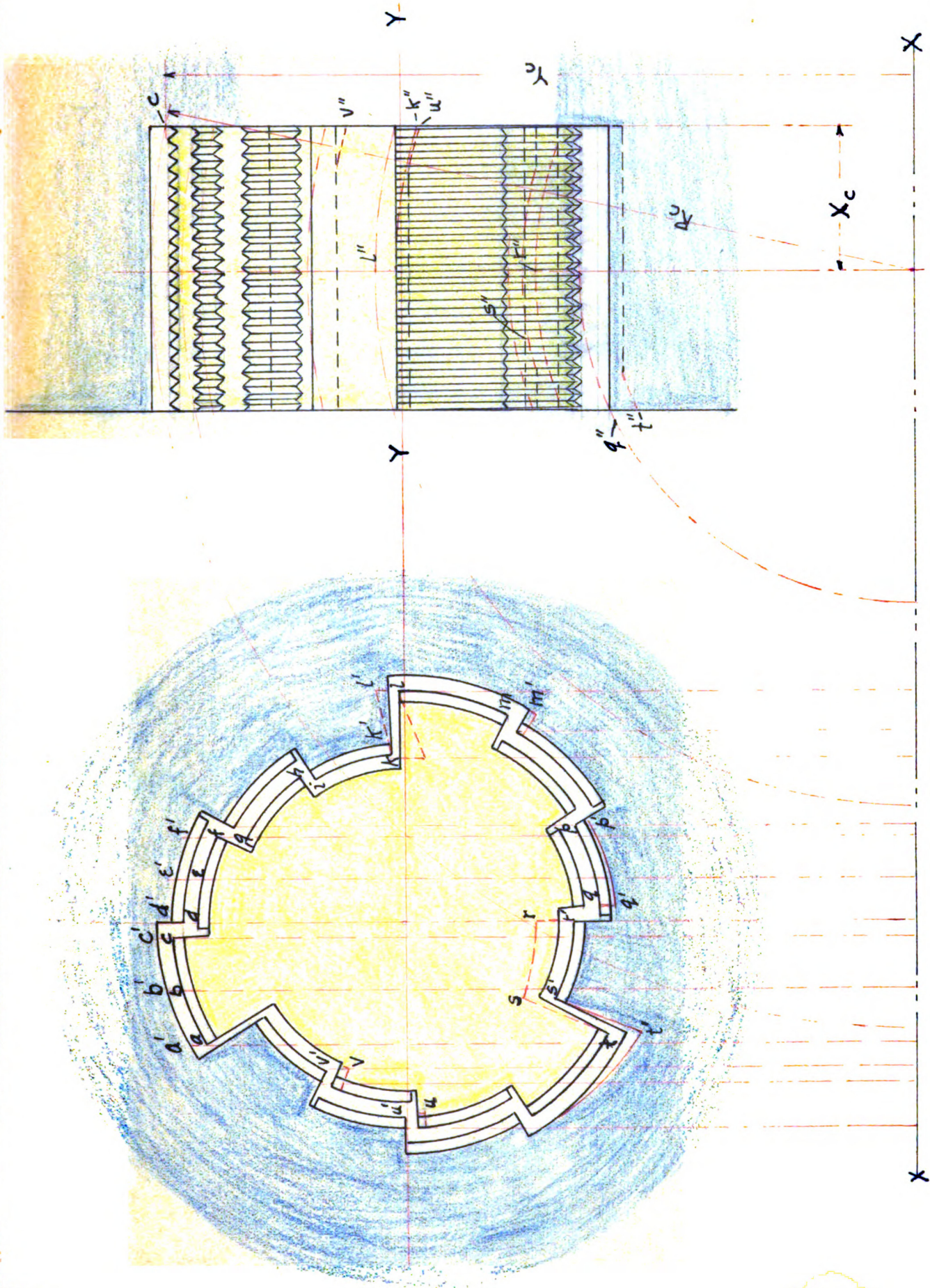
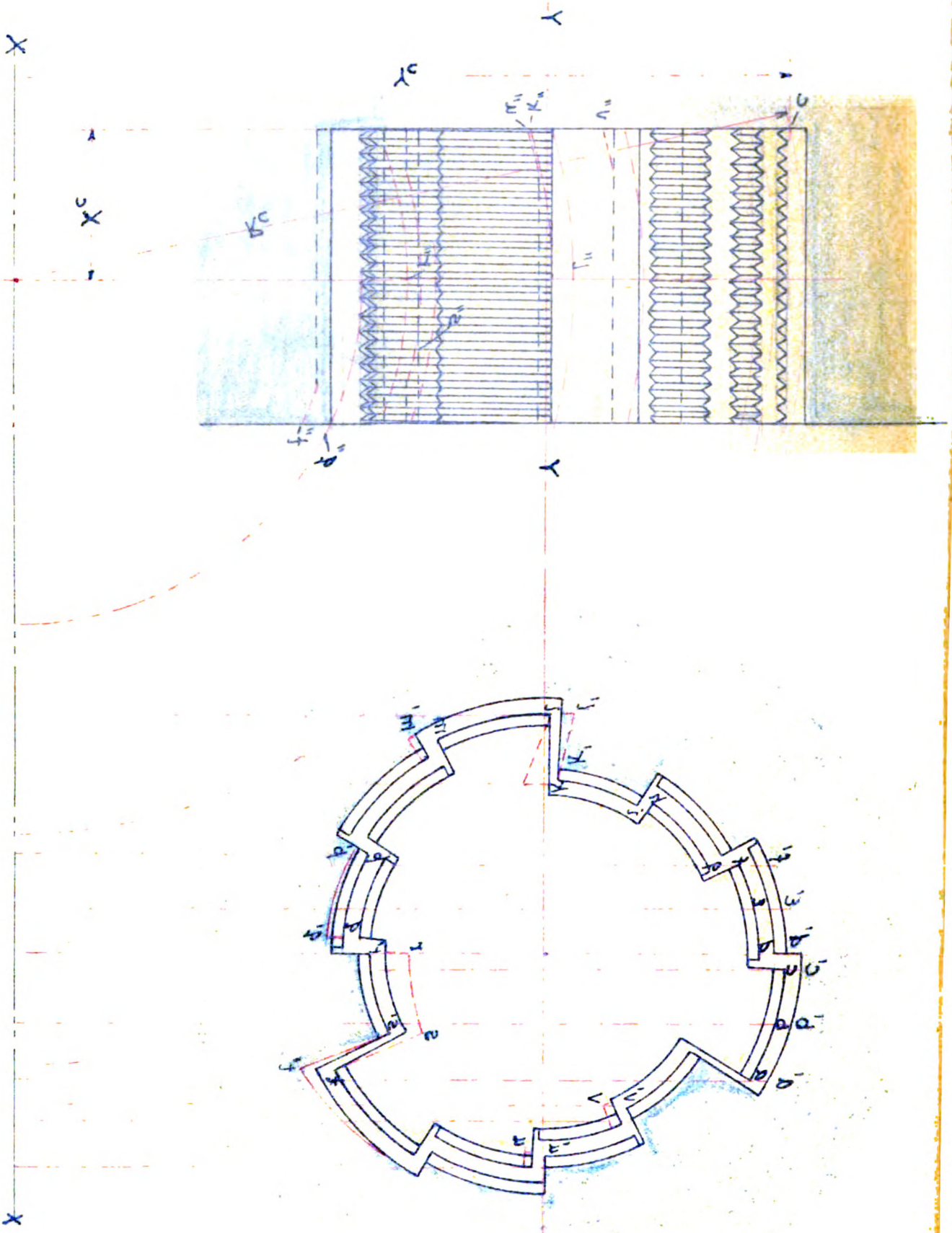


FIG-8

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tion through the gun. X-X is the hinge axis about which the plug and carrier swing and Y-Y the axis upon which the plug rotates to engage and disengage the threads of the gun. The plug is shown in the unlocked position i.e. it has been rotated so that the threads are disengaged and it is now ready to be swung out of the gun. The paths described by the points a, b, c, d, etc., on the plug will be considered as the plug is swung about the axis X-X in the act of opening the mechanism. The plug must have an unobstructed movement. Therefore, the path of every critical point of the plug must be investigated so that the interference, if any, may be removed.

The radius of point a = $R_a = \sqrt{X_a^2 + Y_a^2}$ where X_a is the horizontal distance of point a from the axis X-X and Y_a , the vertical distance from this axis. The radius of point b = $R_b = \sqrt{X_b^2 + Y_b^2}$; X_b , Y_b being the horizontal and vertical distances of point b from the axis. The radius of point c = $R_c = \sqrt{X_c^2 + Y_c^2}$ and so on for all other critical points of the plug. Thus by making the vertical distances of the points a' b' c' in the gun from the axis X-X a

little greater in length than the radii R_a , R_b , R_c , the depth of the clearance cut in the gun for the free passage of arc a b c of the plug is defined. In like manner the clearance necessary for the arc d e f and g h i, etc., are determined. It should be pointed out here, that due consideration must be given to the determination of the difference in the radii of the successive threaded steps. The radius of the arc d e f should be made shorter than that of the arc a b c by an amount which will enable the arc d e f of the plug to swing unobstructed in the arc d' e' f' of the gun when the plug revolves about axis X-X. If this is done none of the threads of these arcs will be sacrificed for clearance. If, on the contrary, the difference in the successive steps is not made sufficiently large, a condition may arise in which the plug will be free in the gun when the threads are disengaged but when swung about the axis X-X the length of the radii R_d , R_e , R_f , etc., of the plug may be sufficient to cause interference with the gun. In this event either some of the threads must be cut away near the forward face

of the plug so as to reduce the radii R_d , R_e , R_f or some of the threads will be sacrificed in the arc d e f of the gun. In this manner the paths of the limiting points of the plug must be analyzed and sufficient clearance provided. Whether these clearance cuts will be made on the plug or in the gun or on both will depend upon which arrangement will cause the least loss in thread area.

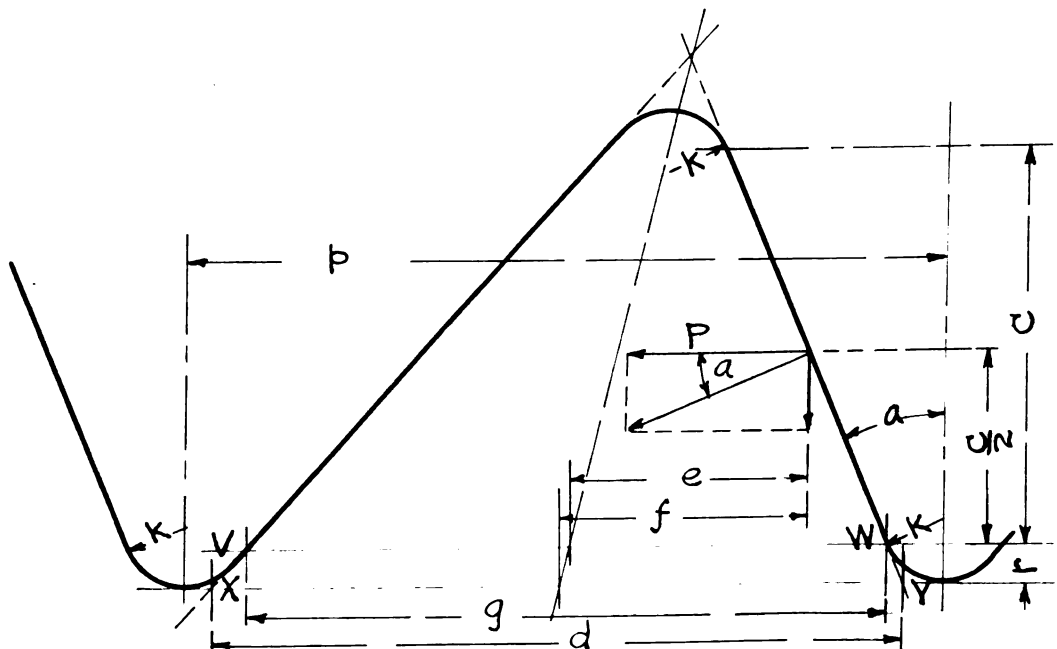
Referring again to Fig. 8 note that the clearance cuts are shown in red. The arcs a b c, d e f and g h of the plug clear the gun as shown. The difference in height of the successive stepped sectors was made sufficiently large so that no clearance cuts are needed at these points. The forward edge of the radial surface of the plug k l interferes with the gun at k' l' when the plug is swung on the axis X-X. A cut is made in both the gun and the plug in order to leave the thread area intact. The cut in the gun is shown at l'' and in the plug at k''. In swinging the point, m, of the plug necessitates the cut in the gun which is shown at m'. The arc p q requires a cut in the gun at p' q' and the point, t,

a cut at t' . These cuts are shown at q'' and t'' in the sectional view. Clearance cuts are also required at the points u and v . Metal is removed at the forward end of the plug as shown at u'' and v'' in the sectional view.

When all of the clearance cuts have been determined, the total length of thread which has been lost is computed and this amount is deducted from the total length of thread on the plug before clearance cuts were made. Thus the effective thread area is determined and calculations for strength are made.

Screw Threads

The form of screw thread best adapted for this type of mechanism is the buttress thread in which the pressure or bearing side of the thread makes the more acute angle with the normal to the pitch line. A normal section of the thread is shown in Fig. 9 below.



p represents the pitch of the thread in inches;
 c , the effective height; k the radius at top
and bottom of the threads; d , the thickness at
the bottom of the thread. If we let L denote
the length of the plug then $L \div p$ will equal the
number of threads in the length of the plug.
Compute the length of one thread around the per-
iphery of the plug by taking the sum of the lengths
of a single thread on each step, measured at the
pitch line of the thread. If this length of
thread be designated by t , then the total length
of active thread will be t multiplied by the
number of threads or $t \left(\frac{L}{p} \right) = \frac{Lt}{p}$.

Now if P = the total pressure in pounds which
is exerted on the plug then $P \div$ the length of
thread $= P \div \frac{Lt}{p} = \frac{Pp}{Lt}$ will represent the load
exerted on each inch of thread length.

The bearing pressure per square inch of
thread will then be

$\frac{Pp}{Lt} \div c = \frac{Pp}{Ltc}$ where c = the effective height of
the thread

Stress in the Threads

Considering a section of thread one inch in

length let us analyze the stresses in section X-Y.

The bending due to a counter-clockwise moment, M , will be

$$M = \frac{Sbh^2}{6} \text{ or } \frac{Pb}{Lt} \left(\frac{c}{2} + r \right) = \frac{Sbh^2}{6}, \text{ now}$$

d , the thickness of the tooth, $= h$ and $b = 1$.

$$\text{therefore } \frac{Pb(c+2r)}{2Lt} = \frac{Sd^2}{6} \text{ or the stress per sq.in.}$$

$$S = \frac{3Pb(c+2r)}{Lt d^2}$$

The bending due to a clockwise moment will be

$$M = \frac{Sbh^2}{6} = \frac{Sd^2}{6} = \frac{Pb(tana)f}{Lt}$$

$$\text{the stress per sq. in., } S, = \frac{6Pb(tana)f}{Lt d^2}$$

$$\text{Compression will be } \frac{Pb(tana)}{Lt d}$$

The resultant compression at x will then be

$$\frac{3Pb(c+2r)}{Lt d^2} - \frac{6Pb(tana)f}{Lt d^2} + \frac{Pb(tana)}{Lt d}$$

The resultant tension at y will be

$$\frac{3Pb(c+2r)}{Lt d^2} - \frac{6Pb(tana)f}{Lt d^2} - \frac{Pb(tana)}{Lt d}$$

The shear will be

$$\frac{Pb}{Lt} \div d = \frac{Pb}{Lt d}$$

Stress in Threads - Section V-W

Bending due to counter-clockwise moment will be

$$M_1 = \frac{Sbh^2}{6} = \frac{Pbc}{2Lt}$$

the stress per sq. in., $S_1 = \frac{6Pbc}{2Ltq^2} = \frac{3Pbc}{Ltq^2}$
 Where $b = 1''$ and $h = g$

Bending due to clockwise moment will be

$$M = \frac{Sbh^2}{6} = \frac{Pp(\tan a)e}{Lt}$$

the stress per sq. in., $S_2 = \frac{6Pp(\tan a)e}{Ltq^2}$

Compression will be $\frac{Pp(\tan a)}{Ltq}$

The resultant compression at v will be

$$\frac{3Pbc}{Ltq^2} - \frac{6Pp(\tan a)e}{Ltq^2} + \frac{Pp(\tan a)}{Ltq}$$

The resultant tension at w will be

$$\frac{3Pbc}{Ltq^2} - \frac{6Pp(\tan a)e}{Ltq^2} - \frac{Pp(\tan a)}{Ltq}$$

The shear will be

$$\frac{Pp}{Lt} \div q = \frac{Pp}{Ltq}$$

**Stresses in Threads - Assuming the Load
Equally Distributed.**

	Section X-Y		Section V-W	
	At X	At Y	At V	At W
Tension, c'lockwise		$\frac{3Pp(c+2r)}{Ltd^2}$		$\frac{3Ppc}{Ltq^2}$
Compression, c'lockwise	$\frac{3Pp(c+2r)}{Ltd^2}$		$\frac{3Ppc}{Ltq^2}$	
Tension clockwise	$\frac{6Pp(tana)f}{Ltd^2}$		$\frac{6Pp(tana)e}{Ltq^2}$	
Compression clockwise		$\frac{6Pp(tana)f}{Ltd^2}$		$\frac{6Pp(tana)e}{Ltq^2}$
Compression radial	$\frac{Pp(tana)}{Ltd}$	$\frac{Pp(tana)}{Ltd}$	$\frac{Pp(tana)}{Ltq}$	$\frac{Pp(tana)}{Ltq}$

**Resultant compression
at X =**

$$\frac{3Pp(c+2r)}{Ltd^2} - \frac{6Pp(tana)f}{Ltd^2} + \frac{Pp(tana)}{Ltd} =$$

$$\frac{Pp}{Ltd} \left[\frac{3(c+2r)}{d} - \frac{6(tana)f}{d} + tana \right]$$

**Resultant tension
at Y =**

$$\frac{3Pp(c+2r)}{Ltd^2} - \frac{6Pp(tana)f}{Ltd^2} - \frac{Pp(tana)}{Ltd} =$$

$$\frac{Pp}{Ltd} \left[\frac{3(c+2r)}{d} - \frac{6(tana)f}{d} - tana \right]$$

Resultant compression
at V =

$$\frac{3Ppc}{Ltq^2} - \frac{6Pp(\tan a)e}{Ltq^2} + \frac{Pp(\tan a)}{Ltq} =$$

$$\frac{Pp}{Ltq} \left[\frac{3c}{q} - \frac{6(\tan a)e}{q} + \tan a \right]$$

Resultant tension
at W =

$$\frac{3Ppc}{Ltq^2} - \frac{6Pp(\tan a)e}{Ltq^2} - \frac{Pp(\tan a)}{Ltq} =$$

$$\frac{Pp}{Ltq} \left[\frac{3c}{q} - \frac{6(\tan a)e}{q} + \tan a \right]$$

Shear at X and Y = $\frac{Pp}{Ltd}$

Shear at V and W = $\frac{Pp}{Ltq}$

Bearing Pressure = $\frac{Pp}{Lt}$

If these values show that the metal is stressed beyond the safe limit of the material then the shape of the thread must be changed to provide greater strength. If, for example, the bearing stress is found excessive then the depth of the thread may be increased. This will add to the bearing area and reduce the unit bearing stress. If the shape of the thread can not be

changed to provide greater strength than the plug must be redesigned and more thread area added. This may be accomplished by changing either the length or the diameter of the plug. In this manner several sets of calculations and studies must be made, as a rule, before a satisfactory breech mechanism is designed.

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