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PICATINNY ARSENAL

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VOLUME III



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SECTION VI. ARTILLERY FUZES

2. Time Fuzes (Design and Functioning).

A time fuze is a mechanism, which, when assembled to an artillery projectile, will cause it to function at some pre-selected desired point on its trajectory prior to impact with the ground. Time fuzes of various types have been made for many years. In fact, the first missile which was provided with an interior bursting charge carried of necessity some device which would be classified as a time fuze. In the early stages of development of artillery when low muzzle velocities and short ranges only were obtained, the device could be of a very crude and simple nature.

The first device probably consisted of a slow burning match similar to the present miner's fuze. This match was inserted into the shell through a hole provided with sealing means. Ignition of the match was accomplished by the flames from the propellant charge and the time of burning was determined by the length to which the match was cut. This device later appeared in a more refined form as a wood or metal tube charged with pressed black powder. These tubes were furnished the Battery Commander with different calibrations, that is, rates of burning. These rates of burning were varied by varying the pressure applied to the powder and the composition of the powders used. Adjustment of the time of burning so as to give the burst at the desired point was accomplished by first selecting the tube of proper calibration and then cutting the tube off, drilling out the tube, or by punching a hole through the side of the tube.

In some cases, it is understood that sufficient multiplicity of fuze tubes of different times of burning were issued so that it was only necessary for the Battery Commander to select the proper tube to give the desired time of burning. Ignition was effected by the propellant powder gases and the functioning of the shell charge occurred when the tube burned through and the flame came in contact with the black powder burster charge of the shell.

With the development of breech loading, rifled guns, longer range of weapons, accuracy of flight and also time of flight

increased, the need arose for greater times of burning and greater accuracy.

The platen, plate, ring, or disc fuze and the tube fuze came into being to meet these demands. In these fuzes, the ignition is accomplished by indirect means, that is, by applying the forces developed by the acceleration of the projectile in the bore of the gun to fire a movable primer element. This primer at the end of its stroke came in contact with a firing pin and the flame from the primer charge communicated with the desired point of ignition of the train.

The lead tube fuze and platen fuze were probably developed simultaneously for a period. Fuzes of the lead tube type were used at one time in the United States service. Eventually the platen fuze reached undoubted supremacy over the lead tube type at least in popularity. It is understood that today only one European power has any interest in the lead tube fuze. The time train of the tube fuze consists of a lead tube carrying a central charge of black powder. The manufacture of this tube is accomplished by loading a short lead tube of relatively thick walls and large diameter with the powder under pressure. The tube is then drawn through a series of dies which reduces the diameter and wall thickness and reconsolidates the powder in its new distribution.

The fuze employing this lead tube consists of a body, on the exterior of which, is machined a spiral in which the lead tube is laid. This body is then covered with a thin metal shell. A fuze punch is provided which is capable of piercing the exterior shell and the lead tube. In the interior of the fuze body there is a primer contained in a movable element and passages are provided communicating from the interior of the fuze body to the space between the fuze body and the surrounding shell. Upon firing from the gun, the primer pellet is carried down against the firing pin and the flash from the primer fills the interior of the body with flame which reaches the annular cavity between the fuze body and the shell. This flame ignites the lead tube at the point at which it was pierced by the fuze punching operation. Burning then proceeds both ways from this point, but the effective portion of the burning is in the lower part of the tube which leads to a black powder magazine charge. This black powder magazine charge when fired communicates the flame to the expelling charge of the shrapnel. Obviously, this type of fuze when once punched, can be repunched only for a shorter time of burning.

It is understood that this type of fuze is still of interest to one country because their experience has been that it is more uniform in functioning. This claim can not be discussed due to lack of comparative firing data. As an obvious advantage it may be cited that the fuze can be made practically, if not absolutely, waterproof for transportation and can be retained in this condition until just before firing.

The platen or ring type of fuze is used exclusively in the United States Army today. The originator of this type of fuze is supposed to have been a man by the name of Bormann, although the first fully developed fuze was designed and patented by O. Hartmann, U. S. Patent No. 737,229 dated 8-25-03. The first fuzes of this type available to the United States Army were procured from the Erhardt Company, about 1903. Ring fuzes have been made with three rings, two rings and one ring. The three ring fuzes have been made for the purpose of obtaining greater time of burning than can be accomplished in the new conventional two ring type. Three ring and multiple groove fuzes are also used (foreign) to permit the use of faster and presumably more uniform powder. At the present time, fuzes of this type are not of interest, as it is believed that the relatively small requirements for fuzes of greater burning time can be met with mechanical fuzes. The one ring fuze has been used in certain countries on short range projectiles such as the 37 mm and 2.24 inch, but it is believed that the American service has never had a fuze of this type. A two ring fuze can be made of moderate diameter to give a burning time of 45 to 50 seconds by using slow burning powders and this time of burning is sufficient to take care of most of the Army requirements.

The Army has had in the past 21 second and 30 second fuzes having a flange diameter of approximately 2 3/8 inches and 31 second and 45 second fuzes with a flange diameter of approximately 3 inches. The 30 second fuze was an adaptation of the 21 second fuze manufactured by loading the 21 second rings with slow burning powder and graduating the movable ring to suit. The 45 second fuze was made from the 31 second ring by the same procedure. The original composition used for this purpose was Army black powder diluted with approximately 16% barium nitrate. When an attempt was made by the Bartlett-Hayward Company during the World War to produce the 45 second fuze they changed to a so-called coal powder in which the charcoal content of Army black powder was in part replaced by powdered semi-anthracite coal. Of late years the 30 second and 31 second fuzes have been removed from the Army list of standard items of issue.

In all of the fuzes of the two ring type, the body, upper ring, and closing cap are secured in a fixed relationship to one another. The graduated ring, which is the lower one, is movable with respect to the body and the other ring so that the burning time can be adjusted by changing its position. When fired from the gun the primer which is contained in a recess in the body and closing cap is caused to move so as to contact with the firing pin by the forces developed by acceleration in the gun. In the new designs of fuzes, the primer is held securely in the fuze body, while a plunger moves so as to strike and fire the primer. The flash from the primer is communicated to the upper ring and burning then proceeds in this ring until the flash hole to the lower ring is met. The burning then proceeds in both the upper and lower rings until the point in the body carrying the body pellet is reached and the body pellet is ignited and the magazine charge fired. In case a failure occurs in the time train rings or impact with the ground occurs before the set time is reached, functioning then occurs by reason of the impact element contained in the base of the fuze. This impact element fires the percussion primer which in turn fires the magazine charge.

These fuzes carrying the impact element in addition to the time element are called combination fuzes. The percussion element is omitted in anti-aircraft fuzes as impact burst of these fuzes would be highly undesirable under the normal conditions of anti-aircraft fire where impact occurs in friendly territory.

The time fuzes are provided with an interruption of solid metal in the graduated time train ring. When this interruption or space is in position over the body pellet, the fuze is set safe so far as the time element is concerned. This safe setting is used for transportation and also may be used to produce impact action alone. Canister effect from time fuzes assembled to shrapnel may be deliberately obtained by setting the fuze for zero time of burning and firing in this position. There actually is sufficient delay to permit the shrapnel to leave the muzzle of the gun before functioning occurs and this functioning may then occur at some point between the muzzle and approximately 50 feet in front of the muzzle. The zero setting would, of course, produce a very dangerous condition, if fired, so set, assembled to a high explosive projectile, as some of the fragments from the high explosive shell would be projected to the rear endangering the gun crew.

The mechanical time fuze is a device in which the powder train is replaced by a mechanism similar to a clock or watch mechanism. Mechanical time fuzes have been worked on for many years. It is believed that the first mechanical time fuze made available to this country was the Krupp mechanical time fuze imported about 1911. Practically all mechanical time fuzes are one of three types, the so-called Krupp type, the Schwab type or the flag type.

The Krupp type consists of a time keeping mechanism which carries on its upper face a setting disc. This setting disc is free to turn and is tied in with the cap by some means which is releasable upon firing. The setting disc carries on its periphery a notch. The setting is accomplished by moving the cap so as to change the position of the notch in the setting disc relative to the releasing device. Upon firing from the gun, the clock work mechanism is started, the setting disc is rendered immovable with respect to the main staff of the time keeping mechanism and the setting means is released. The running of the mechanism causes the notch in the disc to approach the releasing mechanism and when the notch reaches the releasing mechanism it passes into the notch and the firing pin is released. This type of fuze has been produced with main spring actuation of the mechanism, and also with centrifugal force actuation.

The standard Mechanical Time Fuze, M2, now being manufactured at Frankford Arsenal, is of the Krupp type with centrifugal actuation. The advantage of this is the fact that we do not have in stores fuzes with main springs held under constant tension.

The Schwab type of fuze has as its principal point of difference an escapement which operates in the vertical position and a somewhat unusual method of releasing the firing pin. While this mechanism employs a main spring, when stored the main spring has only a small amount of tension. The storing of energy in the main spring is accomplished in the setting of the fuze.

The so-called flag type of mechanism is a type which has been seriously proposed on numerous occasions, but it is probably fallacious in its basic idea. This fuze consists of a mechanism which is intended to be driven by relative motion between the projectile and the central staff of the mechanism which is held immovable by air resistance acting against a flag projecting from the nose of the projectile. It is probable that the flag would produce only a small amount of slippage

which would not be definitely determined due to varying conditions of atmosphere.

There are attached prints which illustrate the different types of fuzes which have been items of issue in the Army. The principal difference between the two ring time fuze as originally obtained from the Erhardt Company and as now manufactured, is in the method of venting. The present fuze is vented through an umbrella forming a part of the cap and the gases are bled from the interior of the fuze through this umbrella. The fuzes as originally procured were exterior vented fuzes, that is, the rings were provided with sealing discs on the exterior contour at the beginning of each train. These discs were blown out by respectively the primer and the magazine charge of the graduated ring and venting was by means of the orifices thus produced. The change from the exterior vented type to the interior vented type was made in 1907. A study of the records indicates that the comparative firings made at this time to justify the change were quite limited and the basic reason for the change is not definitely known. The interior vented fuzes appear to have the disadvantage of a weakened ring which is very serious when the high loading pressures which are used are considered. The possibility of short timing of fuzes by reason of pre-ignition of the lower ring through its interior vent is also evident in the current designs. In the new designs of fuzes, the Army is reverting to the use of exterior vents.

It has been recognized that the vents of the 21 second 1907M fuze and similar fuzes provide ready access of moisture to the interior of the fuze. Attempt has been made to correct this by sealing the vents using tin foil shellecked to them. This sealing was accomplished by rolling the tin foil into the groove under the head and also by shellecking the tin foil over the vent in the upper ring. Tests were conducted using tin foil .005 and .002 inch thick. The results were as follows:

Table I

Tin Foil over Vents in Ring

Without Tin Foil

With Tin Foil
.002 Thick

23.50 sec.
23.71 "
23.65 "

23.70 sec.
23.52 "
22.74 "

Tin Foil over Vents in Cap

<u>Without</u>	<u>With Tin Foil .005 Thick</u>	<u>Without</u>	<u>With Tin Foil .002 Thick</u>
Max. 23.38 secs.	22.75 secs.	23.42 secs.	23.82 secs.
Min. 23.00 "	19.25 "	23.19 "	22.08 "
Av. 23.22 "	20.64 "	23.30 "	22.82 "
G.D. .38 "	3.50 "	.23 "	1.74 "

Based on these results the conclusion was formed that sealing of the vents was impractical and the work was abandoned.

There have been many different types of releasing mechanisms for the concussion primer, that is, the primer which initiates the burning of the time train.

Devices which are inherently safe during transportation against the shocks produced thereby are suitable for use only in the high pressure smaller caliber guns, as in other cases the forces developed upon firing are not sufficient to overcome a transportation safe device. Hence, we find that fuzes intended for use in the larger caliber guns and howitzers carry concussion plungers, which in addition to the locking means which may be released in the bore of the gun, are held during transportation by means of a removable locking pin.

A multiplicity of devices for the percussion plunger, that is the plunger which functions upon impact with the ground, has been proposed and used. The centrifugal type of plunger used in the Army fuzes since its inception in about 1907 has been used in numerous American fuzes, both combination time, and straight percussion types, since that time.

The possibility of parts turning relative to one another while in the bore of the gun due to angular acceleration has been a subject of discussion for many years, and in the early history of time fuzes, it was the tendency to blame any malfunctioning of the fuze upon the fact that the graduated ring had turned while in the bore of the gun and devices were incorporated in certain foreign fuzes to prevent this occurrence. It is quite certain that the time train rings of time fuzes do not turn while in the bore of the gun. It has been demonstrated both experimentally by firing at Sandy Hook Proving Ground and by calculations, that the frictional forces resulting from linear acceleration will

oppose any forces due to angular acceleration to the point where turning is impossible. The theoretical results calculated upon the basis of firing the Mk. II Time Fuze with aluminum rings in the 3 inch A. A. Gun, Model 1917, are as follows:

Position in Gun	Setback Force	Setback Force	Frictional Moment of	Angular Setback	
Bore	Lower	Upper	Lower Ring	in./lbs.	
	Ring lbs.	Ring lbs.	in./lbs.		
14 inches	1039	1381	904	37.9	38.0
28 "	1009	1343	878	47.8	36.9
55 "	853	1136	721	53.7	31.2
83 "	739	983	643	57.9	27.0
109 "	658	877	573	61.1	24.1
123 "	626	834	545	61.0	23.0
137.28 (muzzle)	614	818	535	33.6	22.5

✧ When fired in gun having increasing twist of rifling
1 in 50 to 1 in 25.

✧ When fired in gun having uniform twist of rifling
1 in 40.

It will be noted that a factor of approximately 20 to 1 is operating against the ring turning while in the bore of the gun, that is, that this ratio exists between the frictional moment, preventing motion and the "angular setback", tending to produce motion. The figures given are based upon the assumption that the upper ring will exert setback against the lower ring, an assumption which is undoubtedly always met in the fuze. While the fuze rings upon which the calculations were based, were made from aluminum and the service fuzes have rings made from brass, this does not affect the ratio of the forces acting since the change in weight without change in contour would have equal effect on both of the critical forces.

Similar calculations made for the closing cap of the fuze indicates that with the increasing twist of rifling and assuming that the cap would bear only on the stem threads, turning of the cap would be possible. This is due to the small diameter of contact and the resulting preponderant angular torque. This point

has never been checked by experimental firings. A physical check is practically impossible due to the fact that fuzes could not be recovered from such a firing except in damaged condition which would affect the accuracy of the data obtained.

Some of the factors which will affect the time of burning of a powder train fuze are the following:

a. Strength of primer. The effect of this factor would be at the moment of initiation only due to the possibility of blasting the time train ring.

b. Composition of the powder. If a powder which is slower burning than Standard Army Black Powder is desired, the composition is usually varied by adding excess sulphur, inert materials, barium nitrate or powdered coal, all of which serve as deterrents. The use of sulphur as a deterrent has been found to be unsatisfactory, and at the present time, coal, barium nitrate, and oak charcoal are the only important retarding agents.

c. Pressure of air surrounding the fuze vents.

d. Temperature of air surrounding the fuze.

e. Rotational rate of fuze.

It will be noted that the velocity of the projectile is not included as one of the factors effecting the rate of burning. Velocity is, of course, an affecting factor, but appears as a dynamic pressure factor which is combined in the general expression of pressure of air surrounding the fuze vents. This is not of nearly as great magnitude as might be expected, according to the work of Bairstow, Fowler and Hartree as published under the title of "The Pressure Distribution on the Head of a Shell Moving at High Velocities." The distribution of dynamic pressure along the contour of the shell was found by their experiments to fall away very rapidly from the point directly on the nose of the shell, so that at the vent location this pressure is only a small fraction of that existing on a flat plate exposed to air moving at shell velocity. The total external pressure on the vents is the summation of the dynamic pressure at this point plus the static pressure or barometer pressure at the same point.

Discussion of the various factors and their effect, will follow. The strength of the primer has its effect only due to the mechanical removal of powder grains by the blast of the primer.

This effect is minimized by the proper design of primer. An attempt is being made to produce a primer which will give a maximum temperature effect with minimum blasting effect.

The effect of composition of powder does not belong in this lecture and is mentioned only incidentally. The blending of powder is a large subject in itself and is undoubtedly adequately covered in other lectures.

As stated following the listing of the factors affecting the rate of burning, the pressure at the vents of the fuze is composed of two factors, that is, dynamic pressure and atmospheric pressure. The effect of atmospheric pressure has been studied quite completely by burning fuzes under varying pressures while at rest and also while under a nominal rotation. As might be expected, the rate of burning under varying atmospheric pressure follows a curve of the general character

$$T = T_0 \frac{P_0^x}{P^x}$$

T_0 equals the time of burning at normal pressure (P_0), T equals time at pressure P . The determination of x has been made experimentally with the indication that x is very close to .5. Where x equals .5 the formula may be written

5.48

$$T = T_0 \sqrt{P} \quad ; \quad T_0 = \frac{T \sqrt{P}}{5.48} \quad \text{or}$$

$$\text{in the form } T_0 = T \left(1 + \frac{P-30}{60} \right)$$

will give practically the same results, with P expressed in inches of mercury. This formula is used in the static testing of fuzes to reduce the times of burning obtained to times of burning at normal atmospheric pressure (30 inches Hg).

Chart No. 1 shows the variation in rate of burning of time fuzes when rotated at 11,750 R.P.M. with variation in atmospheric pressure. This chart employs rate of burning. This rate of burning can be employed to convert to time of burning by dividing the normal time of burning, that is, the time of burning at 30 inches barometer by the factor, rate of burning. The data given below is from the experiments of Prof. Goudie and is self explanatory.

Table II

Effect of Speed of Rotation on Burning Time
No. 80 fuze

<u>Rotational Speed</u>	<u>Time in Seconds</u>			
	Mt.	Max.	Min.	GD
0	21.83	22.2	21.2	1.00
10,600	22.25	22.59	21.60	1.01
16,480	23.32	23.78	23.10	.68
18,400	25.18	26.20	24.14	2.06
20,410	25.79	28.50	23.70	4.80
24,100	29.21	32.00	27.00	5.00

Table III

Effect of change in Pressure under varying rotational speeds.

Vacuum Ins.	Atmos. Press.	<u>Times at Speeds - RPM</u>				
		0	10,000	14,000	18,000	22,000
0	1.0	22.50	22.75	23.25	23.75	24.75
5	.83	25.25	26.75	26.75	27.50	29.00
10	.66	29.25	31.50	31.75	33.50	36.00
15	.50	34.25	39.00	40.25	43.00	43.75
20	.33	44.00	51.50	54.50	56.00	57.25

Table IV.

Effect of Varying Temperatures on Burning Time

No.80(Degrees Fahn.	-58°	-22°	32°	50°	77°	122°	158°	212°
(Mean Time	23.77	23.34	22.71	22.88	22.28	22.06	21.82	21.04
Fuze (Mean Diff.	.17	.20	.14	.10	.35	.08	.18	.34
No.85(MT	23.96	24.19	23.40	24.15	23.16	22.72	22.15	22.20
Fuze (MD	.17	.20	.20	.13	.06	.13	.35	.16

The figures of Tables II and III are plotted on Chart 2, forming a part of this lecture.

The British No. 80 fuze referred to in the tables given above is a 22 second fuze with exterior vents. The British No. 85 fuze is a 21.2 second fuze and is identical with the 21 second 1907M Fuze except for the size of the body thread.

The effect of temperature has been studied to a considerable extent. The results have been published by the British in a publication comprising the work of Professor Goudie. The conclusion from this work was that a flight time correction due to temperature could be made on the basis of the formula $T = .00053$ second per degree Fahrenheit per second of mean time of burning, where T is the correction to be applied to the observed time. This correction is negative for temperature below the standard temperature and positive for temperatures above the standard temperature.

A general formula for temperature correction has been proposed as follows: $r = r_0 \times (1 \pm Bt)$, where r equals rate of burning at temperature, t, above standard, r_0 equals rate of burning at standard temperature. T = variation from standard temperature in degrees of Fahrenheit. Values of B were determined experimentally by Professor Goudie to be as follows:

.00073 for British No. 85 Fuze having a normal time of burning of 23.4 seconds.
 .00040 for British No. 80 Fuze having a normal time of burning of 22.7 seconds.
 .00014 for British No. 84 Fuze having a normal time of burning of 30.1 seconds.

The actual changes per degree Fahrenheit in the time of burning for the three fuzes listed above are:

.017 second
 .009 "
 .004 "

when the fuzes are set at full time of burning. This temperature correction is probably independent of other factors such as spin, pressure at the vents, etc.

It may be presumed from the wide variation in the value of B that the results of these experiments are not very reliable. In fact, the results are given with considerable reservation by Professor Goudie, as he recognized that heating of the fuze parts by the combustion of the powder might have an overpowering effect on the primary temperature of the fuze. Temperature corrections are in general ignored in American practice.

The effect of rotation alone on the time of flight is very nicely illustrated by the summary forming a part of Aberdeen Proving Ground Firing Record No. 6693, in which rounds were fired

under similar conditions from the 3 inch A. A. Gun, Model 1917, with tubes having a twist of rifling 1 in 40 and 1 in 25 at the muzzle. The corresponding rotations under the conditions of firing were 16,800 R. P. M. and 26,900 R. P. M.

The results of this firing were as follows:

Table V									
Gun	Muzzle		Elev. Dog.	Fuze No. Set. Sec.	Rds. Cons.	Mean Time of flight sec.	Disper-		No. of
	Twist	Fuze Lot					sion Max.	Sec. All.	
1-40	8060-3	2800	60	10	5	9.15	.25	.90	0
1-25	"	"	"	"	5	11.15	1.55	.90	0
1-40	"	"	45	15	5	14.38	.21	1.15	0
1-25	"	"	"	"	4	16.55	1.08	1.15	1
1-40	"	"	70	"	5	16.29	1.38	-	0
1-25	"	"	"	"	4	20.69	3.18	-	1
1-40	"	"	30	20	5	18.70	.26	1.40	0
1-25	"	"	"	"	3a	22.25	.70	1.40	1

a = One time of flight very erratic. Not considered.

The results of this firing are plotted on Chart No. 3 as part of this lecture. It will be noted that the effect of increased elevation becomes more noticeable under increased rotation. This is further illustrated by Chart No. 4 forming part of this lecture showing the difference in time of burning between rounds fired in 3 inch A. A. Guns, Model 1917, of the two different types of rifling. It will be noted that when fired at 1,500 mils. gun elevation, the increase in time of burning between the two rotational speeds is over 5 seconds at full setting, whereas, at 200 mils., the difference in time of burning is less than 1.5 seconds.

The effect of angle of elevation alone is illustrated by Chart No. 5 as part of this lecture which shows the results of firing Mk. I Shrapnel in the 3 inch A. A. Gun probably with a tube having rifling 1 in 25 at the muzzle. This information on the rifling is given with reservation as it is not definitely known. It will be noted that at 70 degrees elevation the time of burning corresponding to full setting for a nominal 24 seconds fuze becomes approximately 29 seconds and that this increases to over 30 seconds for a 90 degree elevation.

It may be seen from the data given that the conditions under which a fuze is tested are of great importance in interpreting the results. The graduations of the 21 second fuze Model 1907M are not equidistant as they are based upon the results of

an extensive firing test of the fuze in the 3 inch Field Gun at a muzzle velocity of 1700 f/s and a muzzle R. P. M. of 13,650, with the elevation of the gun to give normal heights of burst of the shrapnel at the set time. If fired at any other velocity or different rotational speed or both and at different elevations than that for which the graduations were determined, the burning rate will be varied to some extent. As an instance of this, the fuzes when fired from the same weapon at 1793 f/s gave flight time as follows:

- a. At 20.9 seconds setting, burning time 20.12 seconds.
- b. At 16.9 seconds setting, burning time 15.91 seconds.
- c. At 11 seconds setting, burning time 11.31 seconds.

The elevations used in this firing were those used in the calibration firings at 1700 f/s. Therefore, it becomes necessary to define very definitely the conditions under which fuzes are to be tested ballistically for the conditions to be fair to the contractor. In the new designs of fuzes, no consideration is given to calibrating the time settings, the graduations being chosen arbitrarily and spaced equidistant from each other.

The flight time requirements for the 21 second 1907M fuzes have been redefined in recent years based upon results of firing in the 75 m/m Gun, Model 1897. The conditions of firing and the results required are as follows: Firings to be conducted from the 75 m/m Gun, Model 1897, with muzzle velocity of 1755 f/s.

Table VI

<u>Fuze Setting</u>	<u>Elevation of Gun</u>	<u>Mean Time</u>
5	5° 00'	4.80 $\pm$.201
10	9° 30'	9.87 $\pm$.308
15	14° 00'	14.88 $\pm$.414
20.4	19° 00'	20.73 $\pm$.537

The allowable dispersion is given as .4 second plus 1% of the fuze setting.

The American practice in accepting Army time fuzes is to judge the acceptability of the product entirely on the basis of mean time and total dispersion, the latter being the extreme variation between any two shots in a group fired under the same conditions. This may result in the rejection of a lot of fuzes due to one erratic fuze among the samples selected for test.

Placing entire reliance upon maximum dispersion in determining the satisfactoriness of a lot of fuzes has not been universally followed by other nations. It can be cited that the British employ a practice of permitting the omission of one shot from a group with adjustment in the permissible dispersion. As an instance of this, the practice in accepting the British No. 80 Fuze was to require the following:

MD (mean difference) of 20 fuzes, .14 second max., set full.

MD (mean difference) of 20 fuzes, .12 second max., set 14.5 seconds.

GD (greatest difference) .75 second max., set full.

GD₁ (greatest difference omitting one fuze) .60 second max., set full.

GD₁ (greatest difference omitting one fuze) .50 second max., set 14.5 secs.

GD (greatest difference) .60 second max., set 14.5 secs.

This tabulation illustrates two practices not in accordance with American practice. The MD, that is, the average deviation from the mean is given consideration and secondly, specific provision is made for omitting one fuze, provided the balance of the fuzes will show sufficiently small dispersion to come within a narrower range. The MD is considered in most physical observations to be of great importance as it is a measure of frequency as well as the extent of deviations, whereas the greatest difference or maximum dispersion is admittedly subject to considerable variations by reason of accidental selection of samples.

An additional difference in the method of testing British fuzes consisted in conducting the static fuze test with the fuze spinning at 2,500 RPM instead of with the fuze not spinning. When tested under these conditions, the No. 80 fuze must function at 22.0 $\pm$.2 seconds. Barometer correction is made on the basis of .023 of the mean time for every inch of barometer readings above or below 30 inches, being plus when above and minus when below. This correction factor of .023 gives a considerably greater correction than the square root law given in a previous portion of this lecture

The United States Navy in fuze tests has recognized the importance of the mean dispersion figure. At one time the Navy required that on flat trajectories the 21 second fuze should meet the following requirements:

GD should be less than .12 second plus .03 times T.

MD should be less than .014 plus .006 times T.

For a 21 second time of burning the figure for GD would be .75 second and for MD .14 second. When the same fuze was fired at angles of elevation corresponding to the Anti-Aircraft Fuze, the GD figure was given as 2 seconds and MD as .4 second for full time setting.

The American Army requirements for maximum dispersion of black powder time fuzes may be summarized as follows:

45 Second Fuze - .3 plus 3% of fuze setting.

21 Second A. A. Fuze, .3 plus $5\frac{1}{4}\%$ fuze setting.

21 Second, 1907M Fuze, .4 plus 1% of fuze setting.

The 45 second fuze is calibrated statically to give a burning time of 45.25 ± 1.00 secs. The 21 second A. A. Fuze is calibrated to give a static burning time of $22.5 \pm .4$ secs., and the 1907M Fuze is calibrated for $23 \pm .4$ seconds static time.

The manufacture of Anti-Aircraft fuzes was started at this Arsenal, with little realization of the difficulties which were to arise. So far as was known this phase of the manufacture did not differ from the manufacture of combination fuzes in any material respect. The powder which had been procured commercially and used with satisfactory ballistic results in the combination fuzes was applied to the loading of anti-aircraft fuzes. It was known that performance in the anti-aircraft guns equal to that obtained in the field guns could not be expected, due to the firing conditions of greater angle of elevation and greater spin, but it was considered that the more generous allowance for dispersion would enable fuzes manufactured in accordance with practices previously successful to pass ballistic tests.

The practice used by the Scovill Manufacturing Company for wartime manufacture of loading anti-aircraft fuzes with blends of the same powders used for the combination fuzes but blended to give a slightly greater burning rate was therefore used in the preliminary loading. When these fuzes were tested ballistically a very unsatisfactory performance resulted.

Just at this time a rotating machine capable of rotating time fuzes at speeds up to 25,000 R.P.M. was being installed. This machine now forms part of the equipment of the experimental fuze plant. The first use made of this machine was in investigative work on the anti-aircraft fuzes. It was found that excessive dispersion and failures could be induced in this machine by rotating fuzes at rates equivalent to that obtained in the 3" gun with 1/25 twist of rifling, simulating exactly the performance obtained in the ballistic tests.

Experiments with powders of various types gave rise to the conclusion that the failures were due to the use of powders containing excessive quantities of sulphur which gave a soft, viscous slag. This slag acted in some way not well understood, to cause failures of the type known as "tailing out" and to cause excessive dispersion in these fuzes which burned to completion.

The occurrence of this difficulty, and its subsequent investigation, gave an opportunity to try exterior vented fuzes. The tests on the rotating machine indicated that while the change from interior to exterior vents was not a cure-all, it did result in improved performance of fuzes loaded with the proper type of powder. By the proper type of powder is meant one which contains sulphur or other low melting constituents in amounts not exceeding 10%, and which gives the desired time of burning in the fuze. Subsequent ballistic tests, so far conducted to only a small extent, tend to verify the conclusion arrived at as a result of static rotational tests, that the exterior vents are superior to the interior vents.

It is necessary to admit, however, that the performance of these fuzes in the 3" gun with 1/25 twist of rifling is still far from equal to that which may be expected from Mechanical fuzes, and the problem of the development of an entirely satisfactory powder time fuze for this gun is still open. In the 3" gun with 1/40 twist of rifling quite good results have been obtained. This is consistent with the earlier results in these two guns, as given previously, on pages 15 and 16 of this lecture.

It is probably well known that the continued use of shrapnel, for combat use, is subject to some doubt. Since the time fuze has always been associated with shrapnel for field artillery use, it might be thought that the time fuze for this use is in an equally precarious position. This is not so, since they will continue to be used with high explosive shell, and just how they fit into the picture has been thoroughly considered in Technical Staff studies. The various uses proposed are summarized at the end of

this lecture. The development of new time fuzes, and their relation to the fuzing system as a whole, will be discussed in the lecture on Point Detonating Fuzes.

The following information may be of general interest. The information is given on the drawings for the fuze or may be figured therefrom, but it may be found useful to have information of this type summarized in one place.

See Table

	21 Second 1907 and <u>A. A. Fuze</u>	45 Second 1907M <u>Fuze</u>
Wt. of Fuze.....	1.25 lbs.	2.0 lbs.
Wt. of Pdr. in Magazine Charge.....	95 grs.	95 grs.
Wt. of Pdr. in Upper Ring.....	54.5 "	65 "
Wt. of Pdr. in Upper Ring Pellet.....	1.6 "	3 "
Wt. of Pdr. in Lower Ring.....	61.75"	77 "
Wt. of Pdr. in Body Pellet.....	2.5 "	2.5 "
Wt. of Pdr. in Lower Ring Pellet.....	1.95"	2.0 "
Wt. of Pdr. in Lower Ring Loose Charge..	.50"	.5 "
Wt. of Pdr. in Concussion Plunger.....	1.50"	1.5 "
Wt. of Pdr. in Percussion Primer.....	2.00"	2.0 "
Total Wt. of Pdr. in Fuze.....	221.30" =	.0316 248 lbs. .0354

Plus necessary allowance for wastage.

Wt. of Percussion Plunger	444 grs.	444 grs.
Wt. of Concussion Plunger	128 "	310 "
Resistance to arm was	69 to 77 lbs.	
now	80 to 110 "	28 to 33 lbs.
Width of grooves	.13 inch	.14 inch
Diameter of grooves at mean line	1.53 & 1.78 "	1.9 & 2.2 inch
Depth of grooves	.18 inch	.20 inch
Length of grooves	4.186 & 4.812	5.335 & 6.176 =
	8.998" total	11.511" total
Time of burning sec./cm =	.994 at mean time	1.548 sec./cm

Threads to engage with		
shrapnel	1.7 - 14 thds./in.	1.7 - 14 thds/in.
Area of grooves =	.552 and .635 sq.	.759 and .877
	inch	sq. inch
Function statically from a height		
of drop of 10 feet, on a steel	Data not available	
plate		
Percussion plunger arms at.	2000 $\pm$ 300 RPM	2000 $\pm$ 300 RPM

The American Army requirements for the mechanical time fuze are as follows:

- a. 80% must function.
- b. GD must be less than .3 second plus 1.1% of the set time.
- c. Calibration error, that is, deviation of average from set time must be less than one-half of the allowable GD.

Recognizing the effect of atmospheric pressure on the functioning of time fuzes, numerous proposals have been made to design fuzes so that the effect of atmospheric pressure may be neutralized. One specific instance of this is shown in the so-called Miller patent in which a device is claimed to use the law of flow through an orifice that "the rate of flow through an orifice will not further decrease after the pressure on the discharge side becomes less than 53% of that on the high pressure side." This, of course, requires that the fuze be entirely sealed except for the particular vent through which the combustion gases are intended to escape. This gives rise to mechanical difficulties of considerable importance. It probably has small practical value as it merely means that the pressure on the interior will reach some maximum value and not drop below that pressure. This interior pressure would depend upon the size of the orifice as the area of the desirable vent appears in the formula governing the flow of gas. Incidentally, the point at which the atmospheric pressure reaches the critical value of the relation to the pressure at sea level is about 17,000 ft. above sea level.

The Technical Staff studies previously referred to has been made in an attempt to correlate the requirements of the using Service and to prescribe the fewest number of types which would effectively meet the requirements. It has been concluded that the following types of fire will be encountered:

- a. High burst ranging at the longer ranges.
- b. High burst ranging at the shorter ranges.
- c. Time fire with H.E. Shell.
- d. Time fire with shrapnel.
- e. Anti-Aircraft fire with H.E. Shell.
- f. Anti-Aircraft fire with shrapnel.

The relative importance of accuracy, length of burning time, etc., is not a suitable subject for discussion at this time, but it may be stated that these wide variations in types of fire give only one requirement for an extremely long time of burning and it is estimated that this requirement will be for a fuze having a burning time of approximately 75 to 80 seconds. It is probable that this requirement will necessarily be filled by a mechanical fuze. The other requirements for fuzes that will burn in the neighborhood of 25 to 30 seconds can be met in powder train time fuzes.

SECTION VII. MANUFACTURE OF METAL COMPONENTS FOR ARTILLERY AMMUNITION.

1. Metal Components Department

Section I

History and Purpose.

Metal components of ammunition were first manufactured at this Arsenal during the World War, but due to the limited facilities of the shops then in existence, only small scale production was attained. Prior to this time Frankford Arsenal was charged with this work.

About 1920 the Metal Components Department was formed and the equipment augmented in order to manufacture a small lot of shell bodies. This order was followed by one for experimental fuzes. The present shop was built after the Lake Denmark explosion in 1926, machinery and equipment were installed, and has been manufacturing ever since.

Section II

Functions and Responsibilities.

The functions and responsibilities of the Metal Components Department are:

To manufacture or modify the metal parts of ammunition components and such other articles as are called for by experimental, semi-production and production orders.

To check working drawings for tolerances and design insofar as these factors affect production; to review proposed experimental designs to determine the practicability of manufacture; when components of a new design are being manufactured to report on the practicability of quantity production, and after production has started to report all difficulties and troubles encountered which may affect the design of the article being manufactured.

To prepare estimates, bills of material, route sheets, and to follow up requests for material and services until material is accepted and delivered or service is rendered; and to make production reports and keep such records as are required.

To maintain a tool and stock room with a system for checking all material received and issued.

To assist in designing and to make or cause to be procured all tools, jigs, and fixtures of the type required.

To maintain a system of shop inspection and control which will insure that articles manufactured are in accordance with drawings, specifications, etc.

To do metal plating, cleaning, annealing, heat-treating, buffing, lacquering, and resizing operations on ammunition components.

Section III

Organization and Allocation of Duties.

In order to carry out the functions and responsibilities of the department as laid down in Arsenal Regulations, the shops are organized for production on a job load basis. Wherever possible, those machines required to complete a single article are grouped together so as to minimize handling and so as to balance operations if possible. But by being organized on a job lot basis, it is found that miscellaneous components for fuzes are moved during their processing throughout the whole shop.

During the past year (1939-40) the shop has been fortunate in having had allocated sufficient money to replace some old equipment and to supplement existing lines with new equipment so that at the present time the shop is better balanced from the production view point and has a great deal of modern equipment, both of which have tended to raise the standard of production and to lower the cost thereof.

The shop and its methods have been used as a model for showing one way of doing the job to prospective bidders for fuzes which had to be purchased because of our own lack of capacity, and to bidders for educational orders. It is desired to emphasize the fact that we can show just one way of doing the job. But we also wish to emphasize that this way is considered to be efficient. It is known that if one way of doing a job can be observed, that job from then on is much simpler. It has been established that observation of our methods has been of great help to outside manufacturers in getting started on their production. In many cases this has been the "proving ground" for adaptation of existing standard modern machine tools to fuze manufacture.

Section IV

A comprehensive delineation of duties of the various divisions and sections of the shop follows for those who wish to note in detail how the department operates. Operation is, of course,

quite involved due to the multiplicity of duties. It must be observed that in order to operate successfully, all key jobs must be filled by experienced and capable personnel.

Section V

A chart is appended which shows the organization. Description of duties follows:

1. The duties of the Chief, the Superintendent of Production, and the Assistant General Foreman are those of management. They are responsible for efficient operation of the Department. The Chief of the Department reports directly to the Chief, Manufacturing Group, of the Arsenal.

2. The Chief Inspector (M) is responsible directly to the Chief of the Metal Components Department for checking the quality of all work being produced. He supervises the process inspection of completed articles (components and sub-assemblies) and maintains a process or floor inspection, throughout the shops, through roving inspectors. Roving inspectors make frequent checks, from machine to machine, for quality and compliance with drawings and specifications. If variations are found, roving inspectors are required to notify the foreman who has the work stopped and then instructs a Set-Up-Man to correct the condition. Before production is resumed on the operation, all are assured that the job is satisfactory. Inspection conducted by the Chief Inspector (M) is in addition to that conducted by the Machine (or Process) Operator, to be described later; it is in no way related to the Arsenal Inspection which operates directly under the Commanding Officer, except insofar as it assures quality of workmanship.

3. Production control is secured through the Planning Section and certain administrative functions are performed by it. The responsibilities are as follows:

- a. To prepare estimates, bills of material, tool-requirements, route sheets; and to provide drawings and specifications to the Machine Division.
- b. To schedule work through the shops in accordance with the requirements of other agencies; and to render all reports pertaining thereto, including requests for "Change in Schedule".
- c. To follow up production continuously and to keep daily records thereof.
- d. To receive, store (when necessary), issue, ship, transport (inter-shop) and account for all raw materials and finished components.

- e. To assist in designing and/or to cause to be drawn from tool-storage, manufactured, or procured, all tools, gages, jigs, and fixtures required for production.
- f. To supervise the tool-crib; and to maintain a small -tool follow-up system of servicing to insure that sharp and proper tools are always available for production as and when needed; to assist in all ways possible to lessen machine-down time.
- g. To maintain such personnel and time records as are necessary, and to render the daily cost report of direct labor.
- h. To keep mail, record, and expenditure order files.
- i. To check periodically with cost section on actual costs and balances remaining, and to request or revoke funds as necessary.
- j. To prepare personnel requirements and machine load charts to assist in anticipating the future.

4. The Machine Division is organized into The Fuze Production Section and The Tool & Experimental Section whose respective responsibilities are as follows:

A. FUZE PRODUCTION SECTION:

(1) To manufacture or modify ammunition components in accordance with the schedules set-up by the Planning Section.

(2) To provide for shop inspection by the operator at the machine or process to insure that all products are acceptable and are in accordance with the drawings and specifications. Percentage and method of inspection in all cases is set by the Foremen, and is governed by the gages, the function of the part, and by the necessity for avoiding spoiled work.

(3) To train Machine and Process Operators.

(4) To operate an assembly line for mechanical components.

(5) To maintain continuous count of work, by operation, in process, in the shop and to provide for its orderly progress from operation to operation. This duty is performed by

Shop Checkers who collect the data for the daily production record. Machine Operators are not permitted to count their own work. Rejects and repairable parts are collected by shop inspectors but are accounted for by Shop Checkers. Rejects are collected under lock and key in a central location, are reviewed for indications of corrective measures to be taken, and are periodically disposed of as scrap. Repairable rejects are repaired.

(6) When a job is to be started through the shop, a job card, together with necessary drawings, is delivered, by the Planning Section, to the Foreman who has the job "set-up". When "set-up" is completed the job is inspected by a shop inspector. When passed, the Foreman assigns and instructs an operator on the job, and production begins.

(7) It is highly important that scheduled delivery dates be met; and although the Planning Section is responsible for "follow-up", all executives are responsible within their respective sections for seeing that maximum machine production rates are maintained; that machine "down-time" is kept to a minimum; that conditions beyond their control are immediately brought to the attention of their next superior. They must, insofar as possible, anticipate the future and be prepared to meet contingencies as they arise. This is particularly necessary with materials, tools, and personnel.

(8) "Set-up" men and "Gang Bosses" act as assistants to the Shop Foremen.

B. TOOL & EXPERIMENTAL SECTION:

(1) To manufacture and maintain tools, gages, jigs, fixtures, machines, and to manufacture experimental lots of ammunition components as ordered and as scheduled by the Planning Section. This work is done for all Groups and Departments of the Arsenal when within the capabilities of the Section.

(2) To review proposed experimental designs to determine practicability of manufacture; to check working drawings for tolerances; during manufacture, to note all difficulties encountered, which might prove deterrent to adaptation to quantity production methods; and based upon these experienced difficulties, to make recommendations, as they become apparent, for changes in design, tolerances, materials, and methods.

(3) To maintain the heat-treating unit.

(4) To exercise supervision over the Punch

Press Unit.

(5) To conduct a four-year's course of training for Machinist Apprentices.

5. The Plating Division has the following responsibilities:

a. To conduct all cleaning, plating, and buffing operations; and tests thereof.

b. To resize and renovate cartridge cases.

c. To see that all acid and acid-rinse waters are thoroughly neutralized before dumping same into the brook; and that all cyanide and cyanide rinse waters are thoroughly neutralized, and that they are not dumped until after laboratory test. (Cyanide content must be less than twenty parts per million).

Section VI

There are many other duties which have to be performed by various persons and sections, such as police; rendering First Aid; observance of Safety Regulations; readiness to combat fires within the department and to assist the Arsenal crew in fires within the Arsenal; maintenance of machines, utilities, and equipment; periodic inspection of machinery, motors, etc.; administration of personnel, insofar as qualifying regulations are directly applied within the department, such as efficiency rating, For and Against reports, assignment to work within Civil Service designations, disciplinary measures, etc.; determination of job loads which can be borne; determination of new equipment requirements and specifications therefor; etc.

All in all, the department has all the functions and activities of a major industry, except that its size does not warrant the retention of specialized personnel in all technical capacities. These technical functions are largely performed by personnel who have gained their knowledge by experience and specific cases of application.

The constant effort of the personnel of the shop is to maintain an efficient manufacturing unit which will serve as a model for fuze production.

SECTION VII. MANUFACTURE OF METAL COMPONENTS FOR ARTILLERY AMMUNITION.

2. Projectile Development

The purpose of this paper is to give the progress that has been made in the design of projectile since the World War and to illustrate some of the problems involved in the adoption of new designs. Prior to the World War, our major caliber projectiles were principally base fuze Armor Piercing Projectiles. The Field Artillery Projectiles were, with few exceptions, shrapnel and base fuze thick walled common steel shell.

At the time of the entry of this country into the World War, some of the foreign nations were using thin wall high capacity point fuze shell which because of the greater detonation from the large bursting charge, had quite a demoralizing effect upon the morale of the enemy. It was also demonstrated during the World War that the base fuze shell had a tendency to bury themselves in the ground before detonation, which rendered a considerable part of the fragments ineffective. This condition was the principal cause for the change in this country to the point fuze high capacity shell similar to that used by the French which, due to the use of the direct impact fuze, detonated above the ground.

Before going into the progress made in the designs of projectiles, it is believed well to state here the present day requirements for projectiles. These are as follows:

1. Maximum range with minimum dispersion.
2. Stability in flight throughout their trajectory.
3. Maximum destructive effect on the target.
4. Proper relation between fragments and detonating effect.
5. Practical for production manufacture.
6. Safety against upsetting in gun bore due to the forces obtained upon firing.
7. Capable of being practically loaded with the explosive charge.
8. Minimum amount of wear on the gun bore.

Several of the above requirements are involved in the design of projectiles and will be dealt with in detail later in that part of the course at Aberdeen Proving Ground.

At the present time the types of projectiles which are standardized for service use are as follows:

1. High Explosive Point Fuzed Projectile.
2. High Explosive Base Fuzed Projectile.
3. Chemical Shell including smoke shell.
4. Shrapnel.
5. Armor Piercing Projectile.
6. Semi-Armor Piercing Projectile (A.P. Shell)
7. Proof Projectiles.
8. Target Projectiles.
9. Canister.

There have also been considered, although as yet no standard designs have been prepared, the following types of projectiles:

1. Star Shell.
2. Tracer Shell.
3. Incendiary Shell.
4. Wire Cutting Shell.

As previously stated in the beginning of this lecture, our principal type of shell for Field Artillery Weapons was the base fuzed shell similar to that shown in Figure 1. This type of shell was designed to serve a dual purpose, that of a Fragmentation projectile as well as a demolition projectile. The shell were designed with comparatively thick points in order that they might perforate hard surfaces, such as concrete walls.

At the time this country entered the World War, the French were using a thin wall high capacity shell, similar to that shown in Figure 2. This type of shell, using a direct acting point fuze, gave a shell burst above the ground. The contour of this shell and fuze was not one, however, which had the best flight characteristics. The advantage of this type of shell over the base fuzed type was clearly demonstrated and subsequent adoption by this country followed. A range of approx. 6,950 yds. was obtained with this shell in the 75 m/m gun Mod. 1897.

Following the World War the desire for greater range, with less dispersion caused the development of a shell of the type similar to that shown in Figure 3. It may be seen from this

type that functioning may also be obtained above ground and the contour of the shell has been stream lined to give far greater ballistic accuracy. In the war time type of shell the base of the shell was square while in the newer type a boat-tail was provided which in some instances gave an increase in range of two to three thousand feet with a reduction in dispersion. It was necessary to continue a large series of firings with various lengths and angles of boat-tail to determine that which was most effective and between 6° and 7° angles of boat-tail was finally selected. To provide stream lining at the forward end, a false-ogive or windshield was provided to give a smooth contour.

With the smaller caliber of shell; such as, the 75 mm, no difficulty was experienced in the use of these windshields, however, it was found that the larger calibers in this type of projectile were not very economical to manufacture, the ogive of the windshield being a considerable part of the projectile cost. The difficulty of manufacture discouraged the use of this type of projectile, however, as the demand still existed for greater range, the mono-block type of shell similar to that shown in Figure 4 was developed. It may be seen that the outer contour of the shell in Figure 4 is similar to that in Figure 3. With the mono-block type of shell stream lining has been obtained by providing the fuze with a contour which blends with the shell contour to give the desired stream line effect. This type of design was adopted for the 75 mm to the 8 inch caliber shell and proved very effective in increasing the range. In the 75 m/m gun M1897 a range of approx. 13,000 yds. is obtained with this type of shell.

In more recent years the improvement in methods of manufacture and equipment has suggested a return to the false ogive type of projectile for the larger calibers and designs have recently been made and shell manufactured for 155 mm and 8 inch Shell. This new design is illustrated in Figure 5, which shows the 8 inch H.E. Shell T2. In the original designs of the type of shell for the large calibers, the windshields were generally made of cast iron or cast steel and assembled to the shell and finish machined to form a smooth contour. This prevented a non-selective assembly. The windshield on the projectile shown in Figure 5, however, is drawn from steel sheet and manufactured to very close tolerances at a small part of the cost of the shell. It is expected that this type of shell will give a far greater range than has been previously obtained with any other type of shell.

Dealing with chemical shell, our original types were quite similar to the high explosive shell of the same caliber and were fitted with a short burster in the nose of the shell. Experience indicated that with this type of shell, breakage of the forward half of the shell was generally obtained leaving the remainder of the shell as a cup which carried a part of the chemical filler

into the ground, thereby reducing the efficiency of the shell considerably. This type of shell was also loaded through the nose and the loaded burster inserted into the shell filler. Porosity in the burster casing sometimes resulted in serious accidents in the Loading Plant.

To overcome this defect, experiments are being conducted with a type of chemical shell having a burster tube extending the entire depth of the cavity. Considerable development work is necessary to determine a satisfactory size of burster for each individual caliber of shell, as it is desired merely to open the shell completely with the least amount of breakage, as too great an intensity of burster charge causes considerable disintegration of the shell filler. Experiments are being conducted with this type of shell for Calibers of 75 mm, 81 mm, 105 mm, and 155 mm.

With this type of shell the burster casing is assembled in the filling opening in the adapter in the nose of the shell after the shell is loaded. Sealing is obtained by means of a forced fit of the casing in the adapter which has been welded to the shell. Assembly of the burster charge is not made until after the loaded shell has been examined to detect any leakage of the chemical charge.

The burster charges for these newer type chemical shell were originally in the form of pelleted tetryl wrapped in cylindrical form. Because of difficulty which was encountered in obtaining a rigid assembly to withstand normal handling and shipping, a burster charge of tridite, cast in thin bakelite tubing was later developed for each caliber of chemical shell. Experiments showed that a smaller charge of cast tridite would fragment the shell than would be required if the pelleted tetryl charge were used. Uniformity of results were not obtained, however, with the tridite charges and after a considerable amount of experimental work a new tetryl charge consisting of pellets reconsolidated in a thin aluminum tube was found to be apparently satisfactory. Service tests are at the present time being conducted with several calibers of chemical shell with the new bursters.

Because of limited facilities for the forging of steel shell and the possibility that during the early stages of an emergency these entire facilities will be utilized in the manufacture of high explosive shell an attempt is being made to develop a cast iron shell which can be used for chemical filler. Several advantages are apparent in the use of cast iron as a material for chemical shell in that it has a much higher compressive strength than steel, and as stresses produced in a shell upon firing are principally compressive stresses a much higher capacity can be obtained with the cast iron shell than would normally be obtained in a steel shell, the limiting factor, of course, being the satisfactory stability of the shell. The cast iron shell having lower tensile strength than the steel would also permit the use of a smaller bursting charge to break the shell with a resulting increase in capacity over a similar steel shell.

The principal drawback to the use of cast iron as a material for shell manufacture is the possibility that manufacturers will have difficulty in casting the shell with satisfactory concentricity and lack of porosity. Recent experience in the procurement of 81 mm Cast Iron Shell and a small quantity of 75 mm Cast Iron Shell has indicated that only by very specialized foundry methods and with considerable engineering research can satisfactory shell be produced. For instance, one manufacturer stated that it took his company three months to master the technique of casting the 81 m/m cast iron shell. Several large manufacturers were unable to satisfactorily produce this shell. Approximately 1250 - 75 m/m Cast Iron chemical shell have been manufactured at Rock Island Arsenal and commercially, and are now in the process of service test. Rock Island Arsenal is also producing 500 - 105 m/m Cast Iron chemical shell for test.

Turning briefly to the development of trench mortar ammunition, our original war time ammunition consisted principally of the 3 inch Trench Mortar Shell in the form of a cylinder. This ammunition had a range of approximately 750 yards and the ballistics of the shell were very poor because of the lack of any stabilizing means of the shell. The first attempt to obtain more efficient trench mortar ammunition was with a development of the 75 mm Smooth Bore Mortar in which the old 75 mm French type of shell shown in Figure 2 was modified by tapering the shell from the bourrelet back to the base and fitting an aluminum fin in the base of the shell. The round was propelled by means of an ignition cartridge inserted in a short cartridge case into which the round was assembled and with propelling increments inserted into the cartridge case between the blades of the fins. The stability of the round was not satisfactory and the development was abandoned. A stream lined projectile with fin assembly was then designed for the 3 inch Trench Mortar. Several attempts were made with shell of different contours with unsatisfactory results in that proper stability was not obtained.

About that time a demonstration was held in this country by representatives of the Edgar Brandt Company, who were demonstrating several types of shell for the 81 mm Mortar. One type of shell was a steel shell for high explosives weighing approximately seven pounds. This shell is shown in Figure 7. The type of shell used for practice was manufactured from cast iron and was loaded with an inert filler and a small charge of black powder. The contour and weight of this shell was similar to that of the Shell shown in Figure 7. This shell is shown in Figure 8. The third type of shell called the high capacity shell was manufactured from a steel forging and was used for high explosive use. This shell was fitted with a type of fin assembly with folding blades which open after leaving the gun to provide sufficient stabilizing means for the large shell. The shell weighed loaded approximately fourteen pounds and is shown in Figure 9. These three types of shell have become standardized for use by our services. A range of approx. 3250 yds. is obtained with the small shell and with the large shell 1280 yds. As stated previously, considerable difficulty has been encountered in obtaining the cast iron shell and it has been necessary to utilize the

M43 Shell for practice purposes. With the requirement for a chemical shell for the 81 m/m Mortar, the shell to be of the high capacity type, has also come the demand for greater range of this shell. The folding type fin assembly is not rigid enough to withstand the maximum pressure in the mortar when the heavy shell is fired for greater range and this has led to the development of a new shell and fin assembly as shown on Fig. 10. This shell has been standardized for both high explosive and chemical filler. Ranges up to approximately 2500 yards as compared to 1280 yds. with the old shell, have been obtained.

In recent years, there has been no new development work with shrapnel. At the present the only shrapnel which are standardized are for the 75 mm 3 Inch and the 155 mm Calibers. The problems encountered in the design of shrapnel are much similar to those of common steel shell, except that instead of a large explosive capacity the principal object is to obtain the greatest number of balls consistent with the wall strength, weight requirement, and desired ball velocity which is obtained by a small black powder charge in the cavity at the base of the shrapnel. It is desired to have the weight of the balls approximately 40% of the total weight of the shrapnel. With a development of a satisfactory time fuze high explosive shell, it is believed that the use of shrapnel may be considerably curtailed.

Very little development work has been conducted by the Ord. Dept. with Armor Piercing Projectiles since the World War, except for 37 mm, 47 mm and 57 mm Anti-Tank weapons. The tendency apparently is where new designs of Armor Piercing Projectiles are desired, to adopt them from the Navy.

While not bearing directly on the development of projectiles, some interesting experimental work has recently been conducted in an effort to prescribe a steel for use in the manufacture of shell which will be more readily machined than the steel now used. The standard steel now in use is .45 to .65 carbon steel with a manganese content from .60 to .90. Considerable complaint has been made by the shell machiner on the use of this steel. Within the past few years a free machining steel has become commercially available, which it is believed, might be used in the manufacture of shell. This steel has a lower carbon content of .30 to .40 with a higher manganese content. The test recently conducted indicated that the free machining steel had much better machining properties than the present standard steel and the fragmentation properties were quite similar to those of the present steel. Because of the strategic nature of manganese, further consideration will have to be given to the use of the free machining steel.

PART I

SECTION VIII

1.

LOADING AND ASSEMBLING OF TIME FUZES

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THE LOADING AND ASSEMBLING OF TIME FUZES

1. Scope: For the purposes to be accomplished by this lecture, all of the manufacturing steps involved in the production of time fuzes will not be covered. The preliminary machining of the metal parts, the manufacture of the primers and of the powders used will be covered in other lectures. Furthermore only those fuzes timed by the burning of black powder will be touched upon. These are the 21 second and 45 second types. The manufacturing processes used in producing these various types are so similar that those involved in the 21 second combination, i.e., the Mod. 1907M only, will be covered, and the differences between it and the other types will be commented upon.

2. Types Manufactured: The time fuzes which we are equipped to manufacture at this Arsenal consist of the following:

a. 21 Second Combination, Model 1907M, for use with shrapnel with the following guns:

- (1) 2.95 inch Mountain Guns.
- (2) 75 MM. Field Guns, all models.
- (3) 75 MM. Pack Howitzer, M 1.

b. 21 Second Mk. III A-I, for use with Shrapnel or shell with:

- (1) 3 inch Anti-Aircraft Guns, all models.
- (2) 75 MM. Anti-Aircraft Guns, Model 1916.
- (3) 105 MM. Howitzer, M2.

c. 45 Second Combination M 1907 with shrapnel with:

- (1) 155 MM. G.P.F. Model 1918 M I (Fr.).
- (2) 155 MM. G.P.F. M 1917 and M 1917A1
- (3) 155 MM. Howitzer, Models 1917, 17A1 and 1918.

d. 45 Second Mk. XVI (Navy).

- (1) For Navy Department, used for Anti-Aircraft and illuminating duty committing percussion elements.
(Reference: Complete Rounds Chart O.O. Form 5981)

3. Powder for Rings, General:

a. The first essential for uniformity appears in the powder used. A relatively long train of black powder, Grade A-7, (Spec. 50-14-1A), commonly referred to as meal powder because of its extremely small grain size, comprises the element in the fuze which is expected to burn the required number of seconds. The burning characteristics must be constant from ring to ring to obtain the great accuracy required of the fuzes. The black powder required is purchased, but the manufacturers have difficulty meeting our specifications. Although black powder has been used by military men for centuries, a high degree of uniformity as to burning rate has not been required when used for other types of ammunition. In the manufacture of squibs a variation of approximately 25% in burning time may be permitted, whereas in time fuzes, the accuracy must be within approximately two (2) percent. This means that there must not be a variation between the fastest and the slowest fuzes of over .5 seconds at the full setting of 21.2 seconds in any test group picked at random from a lot. This setting should give a static mean burning time of 23. plus or minus .4 in the 21 second combination 1907M and 22.5 plus or minus .4 in the Mk. III A fuze. Due to the difference in burning conditions, between firing statically and ballistically because of rotation, pressure, atmospheric conditions, etc., the longer times mentioned are necessary in static test to obtain times corresponding to the fuze setting when fired from the gun and burned during flight. Such accuracy requires the powder to be homogeneous as to chemical composition at least. Grain size is also a factor, especially if the various sized grains are differently proportioned as to chemicals. In tests it was found that variation in grain size accounted for a difference of as much as 10 seconds in 31 seconds of burning time due chiefly to the fact that the various grain sizes represented variations in chemical composition. (Ref. Mfg. Group Problem J12). In view of the fact that the powder tested had been subjected, in loading, to a pressure of 68,000 pounds per square inch, which should have crushed the grains, the variation in size alone was not considered responsible for the variation in time. However, it can readily be seen that in production it is extremely difficult to keep the various grain sizes properly distributed due to stratification in handling. If every grain were chemically proportioned like every other grain then stratification would have little effect upon results.

b. In dealing with the present supply of powder, it is therefore essential to blend and to handle carefully all powders to be used for loading rings in order to obtain that homogeneity which is so essential to uniformity throughout.

c. Blending is also necessary to properly mix together such proportions of fast and slow powders as will give the mean burning time desired. The approximate speeds of the fast and slow powders are determined when the powder is inspected upon being purchased. By simple proportion and check by trial, the proper quantities are found which, when mixed together, result in the desired speed. In checking the calculated proportion of fast and slow powders by trial, it is customary to make up three or more trial blends of proportions intended to bracket and include the calculated proportion. These trial blends are 5 pounds in weight and are made by tumbling the proper weights of dry fast and slow powder 3 hours at 12 R.P.M. in five pound, power driven blenders, of the hour glass type which are miniatures of the standard 300 pound production type blender.

4. Preparation of Black Powder for Ring Loading:

a. The proportions of fast and slow powders to be used having been determined, a total of 300 pounds is screened through a 60 mesh screen and dried. This drying is performed in a dryer having a capacity of approximately 500 pounds. The powder is dried at a temperature of 150°F. for six (6) hours. The dryer is charged with copper trays filled with powder to a depth of approximately 1/2 inch. A shorter period of drying under favorable weather conditions would be sufficient, but it has been found that regardless of outside humidity the duration of six (6) hours is sufficient to bring the moisture content of the powder down to approximately .2 percent, which is satisfactory for the blending operations. A powder which is not relatively dry has a tendency to lump in the blending operations and would therefore, not blend as well as free flowing powder. After drying, the proper proportions of fast and slow powders to give a total weight of 300 pounds, are weighed and emptied into the blender. The blender is rotated by power at 6 R.P.M. for six (6) hours. At the end of this time the powder is allowed to run by gravity from the blender into containers. Forty, eight ounce samples are taken from widely separated parts of the blend as the powder is removed. A set of rings is loaded from each sample and assembled with other necessary fuze components to give a group of forty fuzes for firing as a blend test. If the average corrected burning time for forty fuzes is within the allowable range and the mean deviation from the mean burning time is less than .100 second, the blend is considered satisfactory for production use. Samples of powder are also taken after the completion of the blend and sent to the Laboratory for

moisture and sulphur analyses. The reason for using a 300 pound blend is that, if the 300 pounds can be made in one batch and homogeneous, it can be loaded into one lot of fuzes and thereby obviate the selective assembly of rings. This amount of powder is usually sufficient for approximately 12,000 fuzes, and should a lot of 20,000 fuzes be desired, it would be a simple matter to load one 300 pound blend in the upper and one 300 pound blend in the lower. The upper requires about 1/8 less powder than the graduated ring. The 45-second fuzes require approximately 40 lbs. of powder per 1,000 fuzes.

b. Until recently standard practice called for drying of the powder to a moisture content of .2 percent, or less, prior to loading. Due to the varied humidities in which the powders might be handled from the dryer to the loading room, it was desired to have powder at a more practicable moisture content, i.e., one that would not vary in atmospheres similar to that obtained in the loading rooms, namely, 75°F. and 40 percent relative humidity. The present practice termed "conditioning the powder", is to take the powder from the blender, empty the transfer cans into small tin trays each holding approximately 1/2 pound of powder, filled to a depth of 1/2 inch, and expose this powder to an atmosphere of 75°F. and 40 percent relative humidity. These pans are racked in carrying cases of 32 pans capacity. The carrying cases are then placed in such a position in the conditioning room that the conditioned air will pass across the powder. The powder so treated will come to constant weight in from one to four hours, but the time of eight hours exposure has been selected so that all operations in connection with the filling and emptying of the trays may be performed either before or after ordinary working hours, so as not to subject the great number of employees ordinarily in the vicinity to the hazards involved in the handling of the powder. In this atmosphere the powder will hold a moisture content of from .3% to .8% depending on the hygroscopicity of powder used. The present supply of 21-second powder will hold about .45% and the 45-second powder about .3%. These pans are then emptied into 1/2 pound containers well stoppered with rubber corks and held for the use of the loading rooms. A sample from each day's powder is taken in each of the loading rooms and sent to the Laboratory for moisture analysis as a check on the proper conditioning of the powder. The moisture content of 21-second powder (14 percent coal, slow and 86 percent meal fast) averages 0.54 percent while that of 45-second powder (70 percent coal, slow and 30 percent meal, fast) averages 0.20 percent.

5. Loading of Rings:

a. Prior to loading the powder into the ring it is necessary

to coat the powder groove with shellac and aniline dye composition to prevent subsequent chemical reaction between the powder and the brass. The aniline dye simply permits ready inspection of this operation. The solution used consists of $3\frac{1}{2}$ ounces shellac, $\frac{1}{2}$ gallon alcohol, and .17 ounce aniline dye. This solution is applied by cotton swab. To insure dryness of this shellac prior to loading, the rings are stored at room temperature approximately 72 hours. The shellac must be dry before loading or dispersion in burning time will be increased. Cold rings, i.e., much below 75°F. should never be taken into the loading room for loading because condensate would form and raise the moisture content of the powder placed in the groove. The loading and facing rooms are both supplied with conditioned air constantly maintained at 75°F. and 40% relative humidity in an effort to control and maintain uniform, the conditions under which the rings are handled during loading and prior to shellacking. This atmospheric condition is one comparatively easily maintained and practical for the operators.

b. The prepared ring having been taken to the loading room is stamped with a block number to identify it with the date of loading and with the 300 pound blend used. The block number is an arbitrary number and is cross-referenced in the office record for various other reasons also; such as any change, in practice, of shift, of brass used etc., which will permit the segregation of any rings found unsatisfactory or of different characteristics. The chief value of the block number system is to permit the isolation of blocks causing trouble.

c. The empty ring is then placed in what is termed a loading fixture. This fixture supports the ring around its entire surface except for the opening above the groove into which the powder is to be pressed. The ring, having been secured in the fixture, is now ready to receive the powder. The operator removes the stopper from the $\frac{1}{2}$ pound can above mentioned, dips a scoopful of powder, measures the powder used by striking across the top of the scoop with a brass blade inserted in the under side of the stopper, and dumps the charge into a specially constructed funnel which distributes the powder into the groove in the ring and into the space in the fixture immediately above the groove. The column of powder thus produced is approximately three times the height that it will be after pressing, depending upon the initial fluffiness of the powder. It has been noted that more bridging action takes place in this operation when using conditioned powder than when using drier powder. To break up bridging a vertical needle was attached to the under side of the funnel which, when revolved, accomplished this additional mission. In order that all rings will contain a nearly uniform amount and height of compressed powder, the powder which has thus been dumped into the fixture is then leveled off or distributed with a small metal spreader by pushing the powder

around rather than by pressing it into the powder receiving groove (the opening between the punch guide and the powder guide). It is then subjected to gaging, which consists of running a gage into this opening at about midway between the ends thereof and running the gage first to one end of the groove and then back to the other end. The surplus powder is thus plowed out and thrown up on the fixture out of the way of the pressing punch. The compressed height of the powder depends upon the depth of gaging. This gaging is also considered an important operation in that faulty distribution may result in soft ends. If the fixtures used, especially the punch and punch guide, are not good fits they will permit the powder to be blown out by the downward movement of the punch. Such loss of powder is one of the causes of soft ends. The punch is then inserted by hand and is given a preliminary pressing on a hand operated arbor press to insure that the punch is properly aligned before the final pressing. After this operation the fixture is placed in the final press which completes the pressing and consolidation of the powder. All pressing is done in barricaded equipment. The pressure applied in the "final press" is 68,000 pounds per square inch, in the case of the 21 second fuze rings, and 75,000 pounds per square inch, in the case of the 45 second fuze rings. If the brass used in the ring is too soft, i.e., below B-50 Rockwell hardness, the ring will probably be badly distorted in loading and may become a reject. The areas of the grooves and the dead weights necessary to produce these pressures are as follows:

21 second rings (68,000 pounds per square inch)

	Square inches	Dead Weight Pounds
Upper	.552	37,400
Lower (graduated)	.635	43,650

45 second rings (75,000 pounds per square inch)

	Square inches	Dead Weight Pounds
Upper	.735	56,625
Lower (graduated)	.871	65,325

The press which has until recently been used exclusively for the production loading of time train rings in a Richle press of 80,000 pounds capacity, belt driven, cam action, with automatic dial feed table which revolves to place each fixture directly under the ram. This press which makes ten (10) strokes per minute with an 1-1/2 inch stroke of the press requires 32 fixtures and 22 men divided into two crews. Being a fixed stroke press it can readily be seen why extreme care must be used in measuring the powder for each ring. Hydraulic

presses are now installed to replace the cam action presses. These hydraulic presses can be set to give times of approach and application automatically controlled over a considerable range. It has been found that a time of approach of three (3) seconds and a time of application of five (5) seconds give the best results. The principle advantage of the hydraulic type over the mechanically actuated cam action presses is that the longer time of pressure application tends toward a more uniform density of compressed powder train which is reflected in a slightly less dispersion in burning times of the completed fuzes.

6. Facing:

a. In the facing room the rings are brought to dimensional thickness by a lathe operation, using two tungsten carbide cutting tools, mounted on the cross slide in a tool post and rigidly fixed to give the required thickness (.322 plus or minus .004) one cutting on each face of the ring. In the case of the 45 second graduated ring it is necessary to install the safety disc before the facing operation. The lower vent, and the hole for the disc are drilled, to prepare the ring to receive the safety disc. After the safety disc has been crimped into place, the ring is faced to dimensional thickness .322 plus or minus .005. Before removing the lower ring from the lathe, the upper face is scored or serrated with a forming tool, held in the turret-head. The ring is then inspected for size, chipped powder face, and distorted metal. A reject here may be saved by again facing until minimum thickness is reached when, if not satisfactory, it is totally rejected and worth only the brass content. Within reasonable limits the thickness of ring apparently does not affect burning time.

b. Prior to leaving the facing room, the powder train face of the ring is shellacked for protective purposes. This shellac must be carefully prepared according to the following formula as it is not desirable to have any other substances, which may affect it later, come into contact with the powder.

Formula for special powder face shellac: Add eight (8) grams of ground shellac to one hundred (100) C.C. of absolute alcohol. All the shellac "cut in" at least forty eight (48) hours and allowed to settle. The clear portion only is usable. This is decanted off.

c. Throughout all operations it is necessary to prevent oil or water from coming into contact with the powder, as such contacts will most certainly cause large dispersions.

d. After facing and shellacking, the rings are removed on rods to the constant temperature magazine for the purpose of drying out the volatiles introduced by shellacking. The temperature is 100-110°F. and the rings are thus stored for 3 days after which they are "precessed". This constitutes the first part of the so-called 3-3 treatment. After operating the rings are returned for 3 more days storage at this temperature, this being the second half of the 3-3 treatment.

7. Processing:

a. This phase of the manufacture covers all of the operations on the rings between the shellacking of the finished face and the assembly of the rings. From the Dry House the ring is sent to the processing room where the first operation consists of forcing the rotating pin into the hole provided for it in the machine shop. The operation is followed by the cleaning of the locating hole which has been slightly distorted in the loading operation. This is done by simply allowing a .100 drill to enter and seat in the original location. This hole is used on all operating fixtures where mechanical operations are performed, with the exception that on the older fixtures one of the gas chamber vents is used as an alternate location for work hole in drilling and counter-boring the interior vent of the graduated ring.

b. A box fixture was formerly used that permitted all of the drilling, reaming and counterboring to be done from one set-up within the fixture which is moved from tool to tool. Older fixtures permitted only one operation per set-up, the ring being passed along the line of fixtures. A self-contained machine was also formerly used which did all these mechanical operations in a single set-up and in a single piece of machinery. In that device the ring was placed into the machine and properly located by the locating hole; a movement of the operating lever causes the ring to be held firmly while subsequent movements of the lever cause the various tools to move in and out of the ring until all drilling, reaming, and counter-boring are completed. In a later type of self contained machine adopted, all of the drilling operations on the time train rings are performed automatically, the several drill spindles placed at different angles being driven by directly connected motors. With this type of drilling machine it is only necessary for the operator to locate the rings on a revolving table with reference to pins which engage the locating holes of the rings.

c. In this connection, it may be stated that the proper relationship of these holes with respect to each other and with respect to the rotating pin and to the graduations are vital factors

affecting the uniformity of burning time of the fuzes. In the case of pellet holes, largeness will result in bettering of the pellet. These relationships are closely checked with gages constructed especially for the purpose. Likewise the loaded components are inspected.

d. The mechanical operations having been completed by the milling of the rotating pin, the ring is cleaned of powder dust, burrs removed, and the rings fitted with the required pellets. Three (3) pellets are used in the rings and one in the body. These pellets are compressed black powder Grade A-5 and are tubular in shape. The processing unit receives these from the component preparation unit which is charged with the duty of their preparation, which consists of inserting in the aperture and extending throughout the length of the pellet, a wick of nitrocellulose (which is more ignitable than black powder, especially when the black powder is highly compressed) to better insure ignition of the pellet. The pressing of the pellet is done elsewhere in the Loading Department. The pellet in the upper ring is now omitted, recent tests having proved that dependable ignition of the powder train is obtained without the pellet. The interior pellet in the graduated ring is retained in place by the vent closing disc which is crimped into the counterbore of the interior vent. This disc is treated, for the protection of the pellet from premature ignition, by an application of the shellac-aniline dye composition over the disc and around the edges thereof. This pellet is used to insure blowing out of the disc, which, if not blown out, would cause a high gas pressure to be built up which in turn would cause exceedingly rapid burning of the train. It has been found in tests made by varying the relative security of the disc that as much as .2 second variation in burning time could be produced. This being almost half of the tolerance, the importance of uniformity of this operation is apparent. In the case of the 21-second fuzes, it has recently been found impossible to control the staking of the interior vent disc of the graduated ring within the narrow limits required. It is necessary to insure against exceeding the maximum securement allowable for the successful blowing out of the vent disc as the lower powder train is ignited and at the same time to provide for the necessary securement to prevent the disc from falling out in the required jolt and jumble test. As a result the current practice is to stake the metal of the counterbore shoulder directly around the pellet and to eliminate staking the vent disc in place. A heavy coat of shellac-aniline dye over the vent disc provides the only securement between disc and the counterbore which receives it. A guaranteed metal clearance of .002" exists between counterbore and vent disc. Steps are now under way to provide for the same arrangement in the 45-sec.

graduated ring. The remaining pellet is the exterior pellet which transmits the flame from the upper to the lower train. It is placed in the lower ring over an auxiliary priming charge of loose A-7 black powder. It is held in place by the felt washer of the lower ring the attachment of which will be described later.

e. After the interior pellets are inserted and secured in place the powder face of the ring is again shellacked and an onion skin paper washer termed a "groove cover" applied. The rings are held under tension on the table to set the shellac and to await the next operation which is the insertion of the exterior pellet described above. After the insertion of the exterior pellet, the graduated ring is subjected to felting which consists of applying glue to the serrated top of the ring and then applying the felt washer, the holes of which must be in correct register with the holes of the rings and particularly with the nitrocellulose core of the pellet. Care must also be taken to avoid getting any glue on the pellet. The presence of glue on the pellet or covering the pellet with the felt is apt to result in delay of ignition or a dud. The upper rings are placed on rods and separated thereon by rubber washers which are covered with talc to prevent adhesion of the shellacked paper and the rubber washer. The graduated rings are similarly placed on rods after being felted. The nut of the rod in each case is tensioned to 12-1/2 inch-pounds. The loaded rod is then taken to the constant temperature magazine where the glue and felt is permitted to set at a temperature of 100-110°F. for four (4) hours. At the end of this time tension on the rings is fully relieved in order that the air of this magazine may flow between the faces of the rings for 3 days to properly complete the 3-3 treatment above described. (Par. 7 d).

f. At the end of this three-day period the nuts on the rods are again tensioned to 12-1/2 foot pounds. The rods of rings are then transferred to a standby storage room kept at a temperature of 80-85°F. where they remain until ready for assembly. After the rings from the last day of loading on a lot of fuzes has been in this standby storage at the reduced temperature for at least 24 hours, 10 sets of rings from each block combination are assembled to test fuze bodies and fired statically, all on the same day, as an assembly test. After being assembled for this test the fuzes are stabilized for a period of at least 3 hours at a temperature of 75°F. The results of this test indicate the satisfactoriness of the lot as regards variations in average burning times and dispersion for different days of loading, and the overall dispersion and mean deviation that can be expected in the final Inspectors Static Test for the lot. This Assembly

Test is more severe than any other given the lot of fuzes. For example, if in a lot of 20,000 fuzes, the rings were loaded at the rate of 2,000 sets per day, there would be 10 different days of loading represented in the lot. The Assembly Test would consist of firing 100 fuzes of which 10 were assembled with rings from each of the 10 days of loading. If the rings from a particular days loading burned excessively fast or slow or with excessive dispersion, it would be possible to eliminate that days loading or in other words that particular block combination of upper and lower rings from the lot of fuzes. It has been found that, as a result of the 3-3 day treatment, practically no change in burning time in a block of rings take place, whereas before this so called 3-3 treatment was adopted it was necessary to let the rings intended for a lot of fuzes age or season for at least three weeks before subjecting them to an assembly test due to a speeding up in burning time of as much as .5 sec. in 21-second rings and 2.0 sec. in 45-second rings.

8. Assembly:

a. The rings, having been designated for assembly, are sent to the Assembly Unit, where the groove covers are waxed by being rubbed over an electrically heated steel plate which is kept coated with carnauba wax. They are then inspected and placed upon the body of the fuze which has been previously prepared by the Body Preparation sub-unit.

b. The body is prepared by applying the aniline-shellac composition to the surfaces that will come into contact with powder, the bottom closing screw is screwed in and staked, the body pellet inserted, the felt applied and set, and 95 grains of Grade A-4 black powder jolted into the base charge cavity. A base charge of 20 grains of Grade A-4 black powder is used in the 21-second A.A. Fuze, Mk. III A-2 and is poured into the base charge cavity. The combination fuze alone contains the percussion elements. These are tested for safety and then inserted in the fuze body prior to base charging. The primers and percussion elements are furnished to this division by another division of the Arsenal.

c. The body, being complete with rings, is now ready for the next operation which consists of accurately setting the upper ring set line in position and drilling two lock pin holes into the body shank by means of a multiple drill. The two lock pins are then driven into their holes. The concussion primer with resistance ring is then inserted in the top of the body and the cap screwed

on by hand. By means of a tensioning machine, the closing cap is screwed down to a tension of 60 to 65 inch-pounds and the graduated ring is set on "safe". The cap set screw hole is then drilled in the body and the cap set screw inserted and staked.

d. The assembly of the fuze having been completed by the staking of this set screw, the fuze is then polished by buffing, and lacquered to prevent corrosion. Clear lacquer (Spec. 3-36) is used on the entire surface of the assembly except on the base where the closing screw is covered by brushing with orange shellac. The latter operation is done for the purpose of preventing moisture from getting into the black powder base charge. After the lacquer has dried, the graduated ring is rotated through a small angle and reset in the safe position. This is done for the purpose of breaking the lacquer seal which otherwise would in some cases result in excessive torque required in the fuze setter at the gun.

e. The fuze is then inspected and stamped with the lot number, the initials of the manufacturing plant, and in the case of fuzes for the Navy Department, with the initials of the Chief Inspector, who in this instance is the Commanding Officer.

9. Packing:

a. From the assembly unit the fuzes go to the packing room where they are packed in metal lined boxes, the 21-second fuzes, 80 to the box, while the 45-second fuzes are packed, 25 to the box. After the fuzes are placed in the boxes and soldered, the boxes are tested for air leaks by filling, through the test hole, with air under two (2) pounds pressure. An indicator (mercury column) reveals immediately any loss of pressure which obviously represents leakage. The simple expedient of using shaving soap lather locates the points where resoldering is necessary. The box having been pronounced air tight, the test hole is sealed with solder. The cover of the box is painted with black asphaltum paint and dried. The packing boxes are then closed, sealed, marked and sent to storage.

10. Inspection and Tests:

a. The subjects of inspection and tests were not covered heretofore in this paper in order to avoid confusion, but they are involved in the manufacture from the very beginning and these vital operations run parallel to the ones already mentioned. The inspection of the powders, the metal parts, and the sub-assemblies furnished this division having been accomplished prior to receipt of the items, the first tests performed in these manufacturing operations are the blend tests by which the efficiency of the blend and the correct proportions to be used to get the correct burning times are determined or verified.

b. All blends are verified as to burning time and dispersion by what is known as the "Dry Blend Test". This, as has been referred to in paragraph 4 c, is conducted as follows: Forty samples are selected from widely separated parts of the tumbler. The powder is then exposed in trays to conditioned air for a period of about 5 hours. One set of rings is loaded from each of the samples. Immediately after loading, the rings are faced and operated in conditioned air without application of shellac to the powder face. While still in the conditioned air, the rings are assembled into complete fuzes, registering the felts and groove covers in place, dry. They are then removed to the test house and fired for determination of burning time and dispersion. This serves as a quick, accurate means of disclosing the merits of a blend of powder.

c. Loading tests with representative samples of rings from each day's loading to be included in a lot of fuzes are made before starting the assembly of the lot as outlined in paragraph 8 f.

d. From each loading room the first three rings loaded during each eight hour shift are subjected to a hardness test. The rings are faced so as to present a smooth surface to the punch of the hardness testing machine. The latter is a hand operated Riehle testing machine, with beam set at 250 pounds. The cylindrical punch .081 inch in diameter, makes a slight disc-like impression on a perfect ring, but will puncture a soft one when lowered against the train with sufficient force to raise the beam of the press. The powder train is tested in eleven (11) places equally spaced from one end of the groove to the other.

e. As each one of the several blocks loaded from the powder of a 300 pound blend, has completed its 3-3 day dry processing, ten sets of rings are withdrawn for test purposes. These tests are known as "Assembly Tests". With proper care and uniform treatment each block of rings should burn approximately the same. Thus, one complete lot of about 12,000 fuzes may be obtained from each 300 pound blend of powder.

f. When the lot is completed, five (5) fuzes are selected by the Inspector and fired statically as the official test for acceptance. In case of failure, the blocks causing failure are withdrawn and the balance is used for the selection of ballistic samples for the final test which is conducted at the Proving Ground at Aberdeen in accordance with the Proof Officer's Manual. In the event that the fuzes are found acceptable in the original static test, of course no retest is required and the ballistic samples are forwarded to the Proving Ground immediately.

g. Ten (10) fuzes are selected from each lot by the Inspector and subjected to a jolt and jumble test. These tests are designed to simulate the types of shock that the various components will receive in transportation and handling. The fuzes must withstand these tests without having any:

Explosive elements explode.

Fuze come apart.

Fuze partially or fully arm.

Inner parts, including explosive elements, broken, deformed or displaced in such a manner as to make the fuze unsafe to handle or dangerous to fire.

11. Safety:

a. Due to the presence of black powder in the various operations the matter of safety must be given careful and unremitting attention. No changes in operations are made without considering the effects of the change upon safety conditions. Wherever powder or loaded components are handled no more than the smallest quantities consistent with reasonably efficient operation are allowed to be kept in the vicinity of the operation. In addition to limiting quantities in the immediate proximity it is necessary to guard and protect by cover, barricade, or other means the explosive materials being used. The method of handling the powder in the loading rooms has been mentioned. Recently, the mere fact that the rubber stoppers were in place on these two cans prevented a serious accident in a loading room where every other bit of powder and powder dust on the table, walls and ceiling fired, destroying all evidence of the initial cause and yet doing no injury to personnel and equipment. Powder dust must be removed frequently in order to reduce the strength of a possible flash. In drilling holes in powder a breakage of the drill frequently fires the ring. This cannot be avoided but the extent of the fire can be minimized. "Eternal vigilance is the very body and soul of safety".

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SECTION IX. PRIMERS.

1. Primers (Design and Functioning)

From the ammunition viewpoint, the word "primer" covers a large number of items of different uses and characteristics. All of these items have one thing in common; that is, they are used to initiate some action. Since the functioning of a round of ammunition includes a sequence of events, we have a number of primers, one for each event. Thus, when the lanyard of a gun is pulled, we cause the firing pin to impact upon a primer of the small arms type. This primer in turn fires a charge of black powder, which ignites the propelling charge of the round. While the round is in the bore of the gun, if a time fuze is used, a second primer is fired; that is, the concussion primer of the fuze, which ignites the time train of the fuze. If the time fuze fails, or the fuze setting is greater than the time of flight of the projectile, a third primer, the percussion primer of the time fuze, will be fired upon impact.

If the round is fuzeed with an impact fuze, the fuze is armed either in the bore of the gun or in flight, and on impact, a primer is functioned. The impact fuze may contain two primers, one for superquick functioning and one for delay functioning. When set for superquick functioning, both primers may be permitted to function, the superquick primer producing the desired effect and the delay primer being of no use unless the superquick primer should fail.

The combination of primer and black powder charge which occurs in the unit design to ignite the propellant charge is called a cannon primer, and the small arms primer used in the cannon primer is called a percussion element.

Primers are also used in grenades, bomb fuzes, and pyrotechnic devices. All of these primers have the common characteristic of being easily caused to function by impact or friction, except in the case of the electric cannon primer, which can only be caused to function by an electric current properly applied. In the case of the combination percussion and electric primer, used in guns taken over from the Navy, sensitivity to impact as well as to the electric current is present.

Cannon primers are divided into five classes as follows:

- Percussion Primers.
- Friction Primers.
- Electric Primers.
- Combination Percussion and Electric Primers.
- Igniting Primers.

These cannon primers are all loaded with a charge of flame sensitive powder; in general, black powder. In the design of the primers it is intended that the charge shall be sufficient to obtain surface ignition of all of the propelling charge where this is practicable. For large propellant charges, the primer charge is reinforced by igniting charges constituting a part of the propelling charge.

In fixed and semi-fixed ammunition in which a cartridge case forms a part of the round, the primer is inserted in the base of the cartridge case before loading the propelling charge. In Ordnance Department practice, primers are made a force fit in the cartridge case. The Navy practice differs from this in that in many cases the primers are screwed into the cartridge case, using a thread to provide a very close fit. Whether the primer is held in the case by a force fit or by engagement in threads, the intent is that the cartridge case base be sealed by the primer, so that obturation of the base is assured.

Obturation of the base may be destroyed by piercing the percussion element with the firing pin, and one purpose of a recent complete redesign of the Army primers for complete rounds was to eliminate as far as possible this occurrence. These designs employ a firing plug against which the firing pin of the gun will impact. This firing plug, of which the firing pin is a part, is made of brass, and the firing pin has a limited penetration into the primer cup. The possibility of perforation of the primer cup is therefore much less than if the primer cup were impacted directly by the hardened steel firing pin of the gun.

Another purpose of the redesign was to provide for a uniform size of head on the primer so that a standard primer hole could be used in all cartridge cases regardless of the primer which would be employed.

The various types of cannon primers, with the exception of the igniting primers, are illustrated in Training Regulations No. 1370-A, and are also defined therein. For the purpose of completeness the definitions will be repeated here, condensed when possible.

The percussion primer is designed to be fired by means of a blow from the firing pin of the gun breech mechanism.

The friction primer is designed to be fired by pulling a serrated plug through a friction composition.

The electric primer is one designed to be fired by an electric current properly applied.

The combination percussion-electric primer is designed to be fired either by a blow from the firing pin of the gun breech mechanism or by an electric current properly applied.

The igniting primer is designed to be functioned by a flame originating from the service primer of the weapon in which the round containing the igniting primer is inserted.

The various types of cannon primers are used as follows:

The percussion primers are used in complete rounds employing cartridge cases, and separate loading ammunition for guns and howitzers which are not intended to be mounted in permanent emplacements.

The friction primers and electric primers, also the combination percussion and electric primers, are used only in seacoast cannon and in the 7 inch Railway Mount Gun. This latter weapon uses a combination primer and differs from the usual Army practice due to this gun having originally been a Navy weapon.

The friction primer is interchangeable with the electric primer and is used for emergency use in case the electrical equipment fails.

The igniting primers are used in sub-caliber ammunition for the 6 inch to 16 inch Guns, inclusive, where these weapons are provided with sub-caliber tubes.

It is believed that the illustrations of cannon primers are sufficiently clear to make unnecessary a description of the methods of functioning of the various types of primers.

These complete round primers are quite conventional in construction, with the exception of the M22A1 and M31 Percussion Primers. These primers were originally made of sufficient length to accommodate a charge of over 200 grains of black powder, but it was found that better performance could be obtained in the 75 mm. Guns with a primer of this same length, but with reduced charge. The reduced charge is held in the end of the primer tube adjacent to the primer head by means of a cardboard cup. The empty portion of the tube is lined on the inside with a paper liner. The paper liner serves a dual purpose; first, to prevent the grains of propellant powder from entering the upper end of the primer tube; it also serves to support the black powder charge retaining cup.

The present standard complete round primers, together with the weights of charge and their uses are as follows:

<u>Designation of Primer</u>	<u>Charge Weight</u>	<u>Used In</u>
M23A1 Percussion Primer	20 grains	37 mm. Ammunition
M25A1 Igniting Primer	20 grains	1.457 inch Sub Caliber Ammunition.
M22A1 Percussion Primer	75 grains	M1897, 1916, 1917 Field Guns. Used with Mk.I H.E. Shell & Mk.II Chemical Shell only.
100 grain M1B1A1 Percussion Primer. (Alternative M1A1)	100 grains	2.24 inch, 75 mm. Gun, 75 mm. Pack How., 105 mm. How. Ammunition.
M24A2 Igniting Primer	100 grains	2.95 inch Sub Caliber Ammunition.
M28 Percussion Primer	300 grains	3 in. Seacoast Gun, 3 in.A.A.Gun & 105 mm. A.A.Gun Ammunition.
M31 Percussion Primer	150 grains	75 mm. M1897 Gun Ammunition - Super-Charge Rounds.

All of these primers are interchangeable in the primer hole in the cartridge case and the percussion primers use the same head assembly, comprising a head, striker, percussion element and battery cup. To this assembly is threaded, except in the case of the M23 primer, a brass tubing body, closed at the outer end by a plug. This body carries the black powder primer charge, and varies in length, depending upon the charge and method of loading. In the M23 primer, the arrangement is different. Because of its small size (20 grain capacity), the body is formed as an integral part of the head. The percussion element is assembled to one end of this piece and the black powder primer charge is loaded into the other end. As mentioned, the M22 and M31 primers are a special case, being only partially loaded, the forward portion of the tube being a flame carrying tube.

Typical primers of the complete round type are shown on the illustrations (Fig. 1 and 4).

The percussion element in all of these primers is of the small arms type, similar to that used in the .50 caliber ammunition. It consists of a cup of brass, a charge of F.A. 70 mixture (non-fulminate) of one grain, a foiling paper disc, and an anvil. Such a type of primer is illustrated in Training Regulations No. 135C-A.

The primers for use in separate loading ammunition have small charges, since the propelling charges include an igniter pad of black powder at the rear, and in some cases intermediate and front igniter charges to accomplish ignition of the propelling powder. The cannon primer is therefore required only to accomplish ignition of the igniter charge forming part of the propellant charge. The 21 Grain Mk IIA1 is the only primer of this type now standard for issue.

The electric primer, used in seacoast cannon, and standard for use with many guns, has been unsatisfactory in the past. Many instances have occurred in service in which the primer, when inserted in the gun, failed to function. Examination of such primers has shown that in most instances the failure was due to the breaking of the delicate bridge wire. Due to the method of assembly, this bridge wire could easily be broken during the assembly of the primer, and undoubtedly breakage occurred in some cases during subsequent transportation.

A new design of electric primer, known as Primer M30, has recently been standardized to replace the primer discussed in the previous paragraph. This primer employs a unit bridge wire assembly which can be assembled completely prior to insertion in the primer body, and difficulty due to breakage during assembly should be eliminated, at least to a very large extent, by this provision.

In those cases in which the primer functioned satisfactorily, subsequent difficulty was often encountered in removing the primer from the breech block. This difficulty is believed to have been partly attributable to two causes:

(a) The primer body expanded and wedged itself into the spindle plug, this expansion being due to the pressure of the propelling charge gases against the conical contact plug inside the primer.

(b) The deposit of slag between the primer body and spindle plug occurring when obturation was faulty.

It is believed that the new electric primer eliminates the first mentioned cause for the difficulty by changing the conical contact plug to a cylindrical type contact plug. Investigations of the second cause for the difficulty indicate that the spindle plug in the breech blocks may have variations which contribute to faulty obturation.

An electric primer testing set known as the Primer Tester, M1, has been designed and, after thorough test by the using service, has been issued to all establishments using electric primers. This primer tester, by means of a Wheatstone bridge circuit, will detect short circuits, open circuits, or high

resistance in the primer prior to the attempted use of the primer in firing a round of ammunition. This primer tester, replacing make-shift methods previously sometimes used by the using service due to the lack of specially designed equipment, should result in a very great reduction in the number of misfires in experiments.

The use of a black powder charge as part of the primer assembly is not universal. Just as the percussion cap is the igniter for the .30 caliber rifle ammunition, so it may be used in larger fixed ammunition, to ignite an igniter charge in the base of the cartridge case. This was, and may be now, the method used by the French in their 75 mm. round. Neither must the anvil be part of the primer assembly. Frequently, in foreign ammunition, we find the anvil to be formed in the cartridge case and the percussion cap to be merely the cup, priming charge and foiling material.

In shot gun ammunition a primer of a type of which the Winchester New No. 4 is typical, is used. This type of primer, being commercially available, has been used in military ammunition. In fact, the igniting cartridge used in the 3 inch, 60 mm. & 81 mm. Trench Mortar, uses not only this type of primer, but the shot shell as well. The primer has also been used as a grenade fuze primer, and as a primer for the primer detonator assembly for use in bombs. It is at present used in several bomb and artillery fuzes. The Mark V primer, similar to the New No. 4, but using a "softer" mixture, is used in hand grenade fuzes.

Primers can roughly be classed as detonating and igniting. The Mark V, nearly noiseless and "soft" in action, is an instance of the latter type. The New No. 4, containing fulminate of mercury, is an example of the former type. The primer mixtures used in these primers are as follows:

<u>New No. 4</u>	<u>Mk. V</u>
Mercury Fulminate - 35%	Lead Sulphocyanate - 38.13%
Potassium Chlorate - 35%	Potassium Chlorate - 37.05%
Antimony Sulphide - 30%	Ground Glass - 10.45%
	TNT - 5.69%
	Barium Nitrate - 8.68%

The proportions of constituents and the materials used are of such variety as to make an almost unlimited number of known primer mixtures. The combination of mercury fulminate, potassium chlorate, and antimony sulphide, with and without ground glass and a binder, occurs in a large number.

To go into details of the methods of application of the primers in the various items of ammunition would encroach on the lectures to be delivered on these subjects.

References

TR 1370-A
TR 1350-A

List of Illustrations

Fig. 1 - Percussion Primer
2 - Electric Primer
3 - Combination Primer
4 - Igniting Primer
5 - New #4 Primer

SECTION IX - PRIMERS

2. LOADING AND ASSEMBLING ARTILLERY PRIMERS

Numerous types of Artillery Primers have at various times been loaded at this Arsenal. The loading and assembling of some newer type primers will be briefly discussed in the following paragraphs.

Primer, Percussion, 100 Grain, M1 and M1B1

522 111-7 (IX)
431 721

The M1 and M1B1 primers are practically identical from a loading standpoint, the difference in the primers being in the metal parts only. The body of the M1 primer is drawn on punch presses from a brass disc while the body of the M1B1 primer is manufactured from seamless brass tubing.

The percussion elements, bodies, and head assemblies for these primers are manufactured at the Frankford Arsenal. The principal operations accomplished at the Picatinny Arsenal consist of stamping the lot number on the primer head, loading the black powder charge, crimping the body to the head, waterproofing, and packing for the using Services.

Stamping of the lot number is accomplished on a specially modified toggle press with revolving dial feed. The dial of the press is manually charged, all other operations, including ejection of the stamped primer head are automatic. This press as now installed is capable of stamping primer heads at the rate of sixty-two (62) per minute.

The black powder charge for the various percussion primers is loaded by volumetric measurement. A primer loading machine has been designed to measure volumetrically a charge of Grade A1 black powder, and insert this charge into the primer body. It can be adjusted to load artillery primers of from 20 grains to 330 grains capacity. Except for the insertion of the empty primer and the removal of the loaded primer, the operation of this loading machine is automatic. The production of the machine is 10,000 primers per 8-hour day with a calculated accuracy as follows:

68 percent of the primers loaded to within plus or minus $2\frac{3}{4}$ grains avdp.

27 percent of the primers loaded to within plus or minus $5\frac{1}{2}$ grains avdp.

5 percent of the primers loaded to within plus or minus 8 grains avdp.

The two important features of the machine are:

a. The volumetric slide will not operate if a primer is not in place at the charging station, thus preventing the spilling of powder.

b. After the volumetric slide dumps its charge into the primer loading funnel, the primer and funnel are vibrated or jolted vertically, to facilitate the admission of the coarse powder into the primer and prevent "bridging" of the powder in the small cavity of the primer (approximately 7/16 inch diameter).

A suitably barricaded funnel of approximately 5 pounds capacity is provided to feed the volumetric slide. The smaller funnel is serviced from a 30 pound capacity hopper located in a separate barricaded room. The powder is conveyed by gravity, to the machine funnel through a tube provided with a cut-off valve at the bottom of the large hopper for the purpose of keeping the tube free of powder thus preventing the formation of a continuous explosive train.

The drawings of Artillery primers require that the joint between the battery cup and firing plug be sealed with waterproofing wax. This operation is now accomplished by hand. However, attempts are being made to make this a mechanical operation. The most promising machine designed is one that delivers the primer in a vertical position against a small ball of the correct dimensions. The pressure of the primer on the ball raises it, opening an orifice, thus permitting a drop of liquid wax to be deposited, from a heated reservoir, on the center of the firing plug below. The primers are then automatically carried to the next operation by means of a dial feed plate. During the time of travel the wax solidifies and at the next operation a "spreader", which is a revolving steel punch with two "V" extensions at right angles, is brought forward against the firing plug, spreading the wax around the joint and at the same time removing the excess material from the center of the firing plug where the firing pin-strikes.

The specification pertaining to Percussion Primers requires the use of black powder of a moisture content not exceeding 0.7%. The black powder for the loading operation is also procured under the same specification requirement. Under this condition, powder containing the maximum allowable moisture, at the time of delivery, will on subsequent handling and exposure absorb additional moisture, thereby exceeding the specification requirement of 0.7%. It has therefore been found necessary to reduce the moisture content of black powder by drying prior to loading to 0.4% if the finished primer is to comply with the specification. To obviate the possibility of moisture in the waterproofing operation affecting the finished Primer, the primers are waterproofed, prior to loading, and dried in a heated room for 16 hours.

The asphaltum paint used as the waterproofing agent is applied to the flash holes of the empty primer casing by inserting the casing in a small tank of paint. The tank is provided with a floating metal cover through the center of which is a hole of a size large enough to admit the maximum size primer body. Attached to the underside of this cover is a rubber pad. A hole, the diameter of which is considerably less than the diameter of the primer body, is drilled in line with the hole in the metal cover. This Primer Body is gripped by a small fixture secured in the ram of an Arbor press and the Primer Body inserted in the tank of paint. Upon withdrawing the primer from the tank the rubber pad serves to force the paint into each flash hole and owing to the small diameter hole in the pad removes the surplus paint as the primer is withdrawn. The primer after removal from the dipping tank is gripped in a small fixture attached to a drill press and the excess paint not removed by the "stripping" pad is removed with a rag dampened with varsol while the primer is revolved. The Primers are then dried for a period of 16 hours at a temperature of approximately 90° F. The Primer Bodies, after drying are then loaded with black powder, the Primer head assembled to the Body and then crimped in a Geometric die crimping fixture. Care must be exercised in the crimping operation to secure the parts in their correct location, otherwise the primer may be deformed to such an extent that it will not properly gage for diameter or concentricity. All flash holes of each completed primer are then inspected for thorough waterproofing of the flash holes; holes which are not completely closed with paint are corrected by manually applying additional waterproofing compound.

The condition of health of the operators performing the waterproofing operation causes some difficulty owing to the susceptibility of poisoning from the use of varsol saturated cloths used in removing the surplus waterproofing compound. Female operators have been found more susceptible to skin poisoning and for this reason male operators are employed on these operations entirely. Operators employed on this type of work are required to coat their hands with a protective antiseptic grease.

With the presence of gasoline and varsol constantly required in the cleaning operations the need for constant vigil to prevent the use of this material indiscriminately is evident. An excess of the gasoline will destroy the waterproofing qualities of the paper liner in the body as well as introducing surplus moisture to the black powder charge. To overcome this condition several primers are selected at various times during the day, disassembled and inspected to determine if unusual quantities of solvent are being used.

Primer, Percussion, M21

330 grain

The 330 grain or M21 percussion primer is similar to the 100-grain M1B1 type except for the increased length and weight of charge. The loading operations are therefore similar.

Primer, Percussion, M22

75 grain Ser II-7
31

The M22 primer is similar to the M21 and M1B1, the only difference being in the length of the body, weight of charge and the method of loading. The charge, consisting of 75 grains of black powder, is contained in the front end of the body. This part of the tubing is not perforated as is the case with the other primers of this type. The rear end of the primer which is not loaded is perforated in the usual manner. The theory of this design has already been explained in a previous lecture by a member of the Technical Group. This primer is slightly cheaper to load than the other types previously discussed. The charge being contained in the forward portion of the tubing, it is not necessary to dip the primer in asphaltum paint to obtain waterproofing. The cardboard diaphragm retaining the black powder in the solid portion of the primer is first floated in asphaltum paint, removed and allowed to dry slightly, then inserted in the tubing to the proper depth. The paint is used for the purpose of waterproofing this end of the primer and also to hold the diaphragm in position. In order to prevent the paint on the diaphragm from entering the threads of the primer body when being inserted, a thin tube long enough to extend beyond the threads is inserted in the body as a guide, and removed when the diaphragm is seated. The other operations in connection with the loading and assembling of this primer similar to those pertaining to the primers already discussed.

Primer, Percussion, M23

20 grain

This primer is of a recent design. It contains a charge of approximately 20 grains of black powder and has a Percussion Element assembly identical to the other primers described. The end of the primer is closed with an onion skin paper disc, then covered with waterproofing wax. The end of the primer is crimped before loading.

The waterproofing wax is prepared by melting in an electrically heated tank, commonly referred to as a "glue pot". Special installation of these tanks is made from a safety standpoint, having dust proof heating elements with control switches located on the outside of the operating building. Molten wax is poured over the onion skin paper disc by the use of a medical eye dropper. The other operations including stamping the lot number, loading of primers, and other processing operations are similar to the operations previously described.

Primer, Percussion, 20-grain, MK I

The loading of 20-grain percussion primers, Mk. I is typical of all pressure loaded and drilled primers. The loading and assembling of this primer is entirely different from those previously discussed. They are usually loaded and pressed in a semi-automatic loading machine. The empty primer bodies are inserted by hand in a specially prepared fixture which forms part of the loading machine and holds three primers at a time. The operator then places this fixture with the three empty primers in place in the loading machine. This machine is located in a barricaded room and is so installed that it cannot be operated until the operator has withdrawn his hands and the protecting metal doors are closed. The operator then operates a lever which lowers a pin in the center of each primer, these pins forming the center holes of the charge. A second lever connected to the charging block is then operated, causing a charge of black powder to drop into each primer, forming the first increment. The operation of a third lever brings down the hollow loading punches consolidating the powder to the correct density. The pressing of the second increment is accomplished in a similar manner, it being necessary for the operator merely to open the door and drop the loading platform to the next lower position.

The primers are then removed from the loading fixture and placed in a crimping fixture for inserting the closing wads and crimping. The fixture for this machine is an aluminum plate approximately 20 inches long and 2 inches wide, having two rows of holes in which each primer is supported on its flange. This plate has notches on the side which are used for centering each primer under the ram of the press used to crimp the end of the primer. These notches also serve as a means for automatically moving the plate along the machine, bringing the next primer under the crimping ram.

The crimping of the wad is done at this stage of loading in order to support the pressed powder during the operation of drilling the vent holes. The drilling of all vent holes is accomplished simultaneously, the machine for drilling being located behind a barricade. The primers after loading and crimping are inserted in the hole of a slide on the drilling

machine. The slide is then moved forward, placing it behind the barricade and in line with the drills which are operated by control lever. The three drills, one at an angle of 90 deg. from the other two, enter the primer at the same time. The difficulty encountered at this operation is in obtaining drills to properly drill the brass body of the primer as well as the black powder without crumbling the charge. Invariably when a drill breaks during the drilling operation, the black powder is ignited. It has also been found necessary to carefully control the height of powder charge for, if sufficient powder is not available between the upper drilled hole and the top of the charge, this portion is very often displaced during the drilling operation. To prevent the breaking of the charge, it is also necessary to control the loading pressure to insure the necessary density to withstand the vibration of drilling.

The burrs or outside roughness caused by drilling the vent holes are removed by placing the primer in a bench lathe and filing. All burrs must be removed to permit the primer to satisfactorily gage for diameter.

The final loading operation consists of inserting the loaded percussion element. These elements are loaded at the Frankford Arsenal but are assembled in the Artillery Primer at the Picatinny Arsenal. They are inserted in the primer body by the use of a small press. It is necessary to use reasonable care in this operation in order to avoid damaging the percussion element. To accomplish this the element should be carefully centered in the cavity of the body before applying a pressure adequate for firmly seating the element without causing displacement of the primer mixture.

SECTION X.

1. GRENADES, DESIGN AND FUNCTIONING.

Although hand grenades had been employed since the fifteenth century, and in the seventeenth century were favorite weapons, their use declined during the eighteenth and nineteenth centuries until they became practically obsolete. The special conditions at Port Arthur during the Russo-Japanese War, however, revealed their possibilities for fighting at close range. They were adopted by both armies and used with great effect.

That they were not taken up subsequently by other armies, and seriously considered as weapons of major importance, was probably due to the belief that such conditions as prevailed in the Far East were unlikely to arise again. At all events, when the combatants of the European war settled down to trench fighting after the first battle of the Marne they were unprovided with grenades, but soon discovered the use of them. They improvised at first, as the Russians and Japanese had done. Before long, however, they developed well-designed grenades of various types, to suit various ends, and these were improved and standardized.

The United States Army had the experience of the allies to guide it when, in 1917, it took up the design of hand grenades for the use of our troops. The problem was to choose and to adapt the manufacturing conditions in this country to the types that had proved most useful in trench warfare. After a year's effort, grenades were developed to meet the needs of the Army in any contingency, and production on an extensive scale was established.

Grenades, as we use them, may be divided into two types according to their usage:

1. Fragmentation.
2. Chemical.

These types are self explanatory, fragmentation grenades being those of thick case with sufficient explosive charge to break the case into a maximum number of damaging fragments - the chemical grenades being those grenades loaded with any of the usual chemical agents such as are used for lachrymators, irritants and smokes.

The Mk. II Fragmentation Grenade is the present standard hand grenade and is illustrated in Fig. 1, Section III, of Training Regulations 1350-B. The body section of the grenade is made of soft gray cast iron filled with a low explosive. The fuze is of the time igniting type, consisting of a die cast body which holds a primer, a Bickford fuse, and a small charge of black powder. The fuze is equipped with a lever arrangement that fits over the top and holds the firing pin in the cocked position. A safety cotter pin holds the lever in place. In throwing, the grenade is held in the hand with the lever pressed tightly against the grenade body. The cotter pin is withdrawn and the grenade thrown. As the grenade leaves the hand, the firing pin spring forces the lever out of the way and the firing pin against the primer with sufficient energy to fire it. The primer ignites the Bickford fuse which burns for 5 to 6 seconds and ignites the relay charge of black powder in the base of the fuze which in turn ignites the bursting charge of the grenade. This grenade was adopted during the war and at the present time the design is practically the same as it was originally. Two notable changes, however, have been made in the filler charge. Originally TNT was used, which, being a high explosive, was much too strong for the cast iron of the grenade body, and, therefore, tended to pulverize the grenade on functioning. Later, Trojan powder, which is a powder of a nitro-starch type, was substituted for the TNT. This was a considerable improvement; however, the nitro-starch powder was not sufficiently stable, and for this reason in 1926 recourse was taken to EC Blank Fire, which is a low explosive, with satisfactory stability. At the present time this fragmentation hand grenade functions satisfactorily.

In the central European countries, development of grenades has taken a course which has led to the use of grenades which are markedly different from ours. A case in point is the Lebensart (Austrian) Grenade. This Grenade is illustrated in Figure 1, attached. The distinguishing feature of this grenade is that if it is armed and about

to be thrown, it can be dropped to the ground without causing its functioning, either on impact or at any later time. If it is thrown and strikes a near-by object, it will not function. If it is thrown, but without force enough to project it a safe distance, it will not function. When it is thrown a sufficient distance it goes off immediately on impact. In contrast to this, the Mk. II Grenade once the lever is released functions on expiration of the 6 second delay. If a soldier is about to throw a grenade and is caused to drop it, a highly serious condition prevails which is not the case with the Lebensart Grenade.

Referring now to the illustration, note that the body is made of thin sheet metal, in contrast to the thick case of the Mk. II Grenade. This means that the Lebensart is an offensive type of grenade, the Mk. II type of grenade being termed a defensive type. The offensive type can be used by troops in the open, such as in an advance against an enemy trench, machine gun nest, etc. The defensive type of hand grenade must be thrown, however, while the thrower is under cover, as the danger radius from fragments is greater than the throwing range. The offensive type of grenade is effective by reason of the blast effect, whereas the defensive grenade is effective mainly by the projection of fragments from the grenade body. Getting back to the illustration, it will be seen that the grenade consists of a body part which contains the explosive and a large portion, comparatively speaking, which houses a firing mechanism, or fuze. This fuze is of the allways type and similar in principle to the Mk. VI Trench Mortar Fuze, except for the safety feature. The firing mechanism consists of an upper or striker assembly and a lower section corresponding to the primer holder in the trench mortar fuze. For safety, it depends on an arming stem, similar to that used in the trench mortar fuze, except it is not assembled at an angle of 90° to the axis, but on a slant and projected through the striker and primer housing, so as to hold the firing pin away from the primer. In addition to the arming pin arrangement, a toroidal spring is assembled between the head of the striker and the upper part of the primer housing so that in the safe position the striker and primer can not move towards each other. Upon withdrawal of the arming pin the striker is forced upward slightly, by a straight coil spring, so that the toroidal spring can assume a position indicated at A on the sketch, at which time the fuze is in the firing position and because of its allways feature the striker will be moved toward the primer or the primer toward the

striker on impact. Under certain conditions the spring can move into the position indicated at B, in which case the fuze is locked in the unarmed position and can not be fired no matter what reasonable external forces act on the grenade assembly.

The arming pin is held in position by a lever similar to our Mk. II Fragmentation Hand Grenade lever in that it lays over the side of the grenade and releases by spring action. A lip on the upper part of the lever engages under the false head of the grenade and a large coil spring whose ends are attached together to form a toroid assembles over the outside of the grenade and holds the lever in the safe position. In throwing, the operator places his hand around the grenade with his forefinger over the top; with his other hand he lifts the coil spring away from that part of the grenade opposite the lever and raises it above the grenade and over the top of his forefinger. He throws the grenade so as to give it a tumbling motion to impart centrifugal force to the fuze.

Centrifugal force is necessary in order to assure the fuze spring assuming the armed position A, and retaining it until impact. When the grenade is thrown the heavy outside spring is retained by the thrower's finger, and the arming pin spring being freed pushes off the lever and ejects the arming pin; at the same time the toroidal spring under the striker head raises it slightly, and since this spring is in tension it contracts and slides down the conical section to position A. Under end-over-end rotation, since the center of gravity of the grenade is below the geometric center of the fuze, there will be a pressure, due to centrifugal force in excess of the restraint of the straight coil spring, exerted on the toroidal coil spring to hold it in position A, but if there is no centrifugal force to hold it in the armed position, such as would occur on a weak toss of the grenade or if the grenade were to be dropped without being thrown, the coil spring below the firing pin will exert enough pressure to force the upper and lower parts of the fuze far enough apart to permit the spring to slide upward on the conical surface and assume position B, where it will prevent the striker and primer moving near enough together to fire.

The objection to a grenade of this type is that it is rather complicated and, therefore, costly, Production in case of an emergency would be delayed because of the

number of tools and fixtures required for manufacturing. It appears to have a further disadvantage in that it cannot be used at close range, such as tossing it into a dugout, since it must be thrown with considerable force and given a tumbling motion in order to fire.

If a grenade of the Lebensart type were to be adopted by the Ordnance Department, it would be used in a thick cast iron case, so that it would be of the defensive type.

An offensive type of grenade (Fig. 2) was once used by the United States Army, but has been abandoned. This grenade was loaded with a TNT charge, using a fuze similar to that of the fragmentation grenade. The body, however, was made of paper in the form of a cylinder and capped with a thin die casting to accommodate the fuze.

At the present time there is no standard fragmentation rifle grenade, the rifle grenade situation being in a state of flux. During the war, the French grenade was used which has been standard up until quite recently. This is known as the V.B. Rifle Grenade (Fig. 3). The grenade is projected from a discharger, which assembles to the end of the standard service rifle. The standard service cartridge propellant gases are utilized to throw the grenade. At the same time functioning of the grenade delay fuze is initiated by the bullet from the cartridge passing through the center of the grenade and forcing a striker against a primer. The normal range when the rifle is aimed at 45 degrees is about 200 yards.

There are three standard chemical hand grenades at the present time; one lachrymatory, one combined lachrymatory and irritant, and one smoke. The lachrymatory grenade is illustrated in Figure 4. It consists of a tin can body housing the solid chemical charge. The charge (designated as CN) consists of a small amount of chloracetophenone in a nitrocellulose powder. Three grooves are moulded the entire length of the moulded charge adjacent to the container wall. The entire exposed surface of the charge is coated with a black powder igniter or starter composition. A fuze is attached to the top of the can.

The fuze is similar to that used in the fragmentation hand grenade but is shorter and instead of using a Bickford fuse the delay element consists of compressed black powder. All fuzes made for chemical grenades by the Ordnance Department to-date have been constructed of wartime-manufactured fragmentation grenade fuze bodies trimmed to the proper length, and with the base counterbored to receive

an igniting charge of loose black powder. The upper part of the fuze contains the regulation Mk. V Grenade Fuze Primer. Functioning is the same as the Fragmentation Grenade Fuze, i.e. upon withdrawal of the cotter pin and throwing of the grenade, the firing pin is released to strike the primer which ignites a delay column that burns for 1-3/4 seconds, sets off the igniter charge in the base of the fuze, and ignites the starter composition of the body. As the charge burns, a heavy white cloud of tear producing gas is forced out of the body through holes in the top of the container and along the sides of the container opposite the three longitudinal grooves. The present standard lachrymatory grenade is designated as Grenade, Hand, Tear (CN) M7.

The irritant hand grenade is almost an exact duplicate of the tear grenade, except for the composition which consists of the nitrocellulose powder base, a small amount of lachrymatory agent, chloracetophenone, plus an irritant, diphenylamine chlorarsine, designated DM. This grenade produces a smoke cloud which in addition to the tear producing CN charge produces a sneezing and nauseating effect by reason of the DM. The grenade is designated Grenade, Hand, Irritant (CN-DM) M6.

The smoke grenade (see Fig. 5) is similar to the other chemical grenades. It uses the same fuze and same body except instead of having holes in the sides the smoke cloud issues from four holes only on the top. It does not have longitudinal grooves as do the other two. The smoke producing agent in this grenade is hexachlorethane. The grenade is designated Grenade, Hand, Smoke (HC) M8.

The CN and CN-DM Grenades burn approximately 20 seconds. The smoke grenade burns approximately 3 minutes. The fuze used in these grenades is designated the M200A1 Igniting Hand Grenade Fuze.

Combination Grenade. From time to time enthusiasm has been aroused over the development of a combination grenade which could be either thrown from the hand or, if necessary, from a rifle. Many designs have been proposed without a successful solution. At the present time it appears to be the consensus of opinion of those interested in grenades that a combination grenade is impracticable, because the design must be complicated to permit performance of the dual requirements, and therefore no attempt at the development of a type of this sort is being made.

REFERENCES.

- T.R. 1120 - 5 - Candles (Chem. Hand Grenades).
T.R. 1350 - C - Rifle Grenades.
T.R. 1350 - B - Hand Grenades.

LIST OF ILLUSTRATIONS.

- Fig. 1. Lebensart Grenade.
Fig. 2. Offensive Type Hand Grenade.
Fig. 3. VB Rifle Grenade.
Fig. 4. Grenade, Hand, Tear (CN) M7.
Fig. 5. Grenade, Hand, Smoke (HC) M8.

SECTION XI. BOMBS

1. An Introduction to Bombs and Bomb Fuzes.

GENERAL

The Ordnance Department defines a bomb as an explosive projectile that is made to be dropped from aircraft. The use of the term "bomb" is limited to this purpose only.

The development of bombs was dependent on the prior development of the airplane; therefore, the earliest recorded use of bombs dates back only to 1911 and 1912, when the Italians used them in Tripoli.

It is interesting to note that when the use of bombs was first conceived, the designs were patterned after artillery projectiles. It was the story of the early automobile and the horse-drawn carriage repeating itself. The first bombs used were actually nothing more than artillery projectiles equipped with some crude stabilizing fins.

The World War provided the necessary impetus to firmly establish the bomb as a weapon of warfare. During this period from 1914 to 1918, bombs were brought to the stage where they were quite effective against both personnel and materiel targets.

During the War, although bombs had been manufactured in large quantities in this country, the forces in France were limited to bombs of British and French designs, since no bombs of American manufacture reached the front before the Armistice was signed. At that time we had been using demolition bombs of three sizes; viz., 45, 112, and 230 pounds overall, with smaller bombs of approximately 25 pounds for fragmentation effect. At home the bombs that had been designed and adapted for manufacture were, for the Demolition Bomb of 25, 50, and 100-pound size, and for the Fragmentation Bomb, 17 pounds, in addition, an incendiary bomb was contemplated weighing approximately 40 pounds.

Such discussion of the various types of bombs leads to a classification dependent on the purpose to which the bomb is to be put, with a statement of the required characteristics of the several classifications of bombs. At the present time we require three types:

- a. Demolition Bombs.
- b. Fragmentation Bombs.
- c. Chemical Bombs.

Demolition bombs, as the name implies, are used for destroying structures and materiel, where the resultant damage is done mainly by explosive or blast effect. It has been found most practicable, in the experience since the War, to have these bombs in sizes varying from 100 to 2000 pounds in convenient increments

in order that the explosive in the proper amount might be pitted against the target in proportion to its resistance. The fragmentation bomb has been found to be most effective if the overall weight is kept under 30 pounds. This type of bomb is used mainly against personnel. However, the fact that it has also been found effective against materiel targets, such as airplanes and trucks, has dictated to no small extent its weight and construction. Chemical bombs, as the name implies, are those bombs which are loaded with a filler other than explosive, which may or may not be toxic but which have a definite tactical use, such as HS, WP, CN, CG, etc.. In this category also is included the incendiary bomb, since incendiary agents are considered to be chemical materials.

Bombs might also be classified in the manner in which they are used; i.e., whether they can be assigned a place in bombardment, attack, or pursuit aviation. However, this is not a clean-cut classification, since bombardment aviation may use both demolition and chemical bombs, including not only toxic agents but incendiary and smoke agents as well. Attack aviation may use fragmentation, demolition, and chemical bombs, and pursuit aviation, as is the present plan, may use fragmentation bombs.

We look upon bombardment aviation as using all of the demolition bombs for the assortment of targets that may be required to be destroyed in case of warfare, such as bridges, ammunition dumps, highways, railway centers, fortifications, factory buildings, water mains, power lines, etc.. As mentioned before, the size of bomb used will depend upon an estimate of the resistance of the target when the bombing mission is planned. All of the targets mentioned will require demolition charges for destruction. However, it is planned, if necessity requires, to use chemical agents to follow up bombardment attacks with explosive charges, by covering the damaged area with chemical agents such as HS in order to retard the enemy to the utmost in his repair of the damages.

In attack aviation, as mentioned previously, all three types of bombs may be used with the exception that in all probability the use of demolition bombs will be confined to the smallest size. The targets will be mainly personnel, for which fragmentation bombs will be used. However, for targets such as trucks, airplanes on the ground, tanks, and rolling stock, it will be necessary to use something more powerful than present fragmentation bombs. It is for this purpose that the 100-pound Demolition Bomb will be found suitable. Attack aviation will use chemical bombs of a smaller size than used by the bombardment aviation and, instead of using them in conjunction with other types of bombing, will probably drop them only on territory which is later to be occupied or utilized by enemy troops; as an example, bridges or highways over which enemy troops must pass to gain their objective.

When pursuit planes carry bombs they will be of the fragmentation type and used primarily against enemy bombardment planes in the air.

Both bombardment and attack aviation may be conducted at either high or low altitudes, although high altitude in the case of bombardment aviation is to be construed as meaning a much greater altitude than for attack aviation. It appears that the present plan is for the large bombers to fly as high as possible, in order to avoid enemy anti-aircraft, and to fly at low altitude only when they have reached an objective far removed from their base and weather conditions prevent their flying at high altitude. The plan for attack aviation, however, is to fly as low as can be safely done; i.e., in the neighborhood of 75 to 100 feet for surprise attack and in order that they may be in range of the enemy a minimum of time before releasing their bombs and retiring. A high altitude, which for attack aviation may be considered 500 to 1000 feet, will be flown only when visibility is poor, such as in fog or at night when altitudes must be maintained to prevent crashing into tall buildings, smoke stacks, irregularities of terrain, etc. The usual term "high altitude bombing," as applied to bombardment aviation, would mean altitudes around 15,000 feet or more.

It will be remembered that at the end of the World War there were three sizes of demolition bombs available, 25, 50, and 100 pound, then called high capacity drop bombs; the term "high capacity" meaning that the explosive charge made up a fair percentage of the total weight of the bomb. These had been designed in the summer of 1917 from samples of French bombs known as the "Gros Andreau" type, which were brought to this country for that purpose. The cases were streamlined and made entirely of pressed steel sections joined with circumferential and longitudinal welds; the nose sections being thicker than the rear, in order to provide adequate strength without excessive weight. The bases of these bombs carried stabilizing fins to assure accuracy in flight and nose impact. Soon after the first three sizes of bombs were completed, development of larger bombs was undertaken. These resulted in the adoption of 300, 600, and 1100-pound sizes, the entire series from 25-pound to 1100-pound was known as the Mk. I Series of Bombs. The three larger sizes had cast-steel noses with rear portions of pressed steel. The bombs were fabricated by both circumferential and longitudinal welds. The percentage of explosive varied from 50 to 58 percent in the various sizes. As originally designed the bombs carried tail fuzes only, the original fuze being a non-delay type, and later both nose and tail fuzes were adapted, with the tail fuzes made a .1 and a 2.5 second delay.

Since the efficiency of a bomb depends greatly on the type of fuze used, it may be well to mention at this time the types of fuze action required for various targets.

The greatest effect of any explosive is obtained when the charge is tamped; therefore, it follows that the greatest effect of a demolition bomb is when the bomb explodes after having penetrated. For this reason, a great majority of targets against which demolition bombs will be used will have maximum damage done if the bombs are fuzeed for delay action; the delay considered the optimum is usually long enough for the bomb to come to rest within the target. At the present time .1 to .15 second is considered satisfactory. However, the extent of penetration into objects of various resistances from various altitudes of release is not fully known, and it is possible that the delay might well be decreased or increased to suit special conditions. In the case of bombing ships, for example, it has been considered that the optimum delay would permit the bomb to get under water a sufficient depth before exploding to exert its maximum force against the plates near the bottom of the hull. It is believed that the .1 second delay is sufficiently close to meet average conditions in this respect, although it is realized that penetration in water will probably vary greatly with the velocity of impact. In this respect, the fuze delay necessary for bombing submarines has been given considerable thought from time to time and at one time this delay was set at 2.5 seconds, later reduced to 1.2 seconds, and finally the 1.2 second delay was abandoned and the .1 second retained as a suitable delay.

For those bombardment targets which require the bomb to explode without penetration such as very light structures, ammunition dumps, trucks, airplanes on the ground, etc., instantaneous fuze action is provided. Probably the demolition bomb to be selected for any of these would be the 100-pound and the larger sizes restricted to use against targets requiring penetration.

Recently a further requirement regarding fuze action has been introduced by the long flying range of the modern airplane. It is now possible that a bombardment mission may extend to some point sufficiently distant to prevent the forecasting of weather conditions at the target. Ordinarily, with bombs fuzeed either for instantaneous or very short delay action, it would be hazardous to the plane to drop its cargo of bombs at an altitude of less than a few thousand feet. Should weather conditions at the target be such that the visibility is so low that the target can not be seen from a safe altitude, a fuze is now provided that will delay explosion of the bomb sufficiently to permit all planes in a mission to retire safely after all bombs have been released from an altitude as low as it is possible to fly.

To summarize: the present requirements are that demolition bombs be fuzeed to function: instantaneously, with short delay (.1 second), or with long delay (45 seconds).

The problem of low-altitude bombardment may raise the question as to the value of a demolition bomb which is dropped but which does not penetrate, as may sometimes be the case in low altitude demolition bombardment. It is realized that the explosive effect of an unconfined bomb is greatly reduced. On the other hand, against structural targets at least, the effect of a bomb plunged through the wall from low altitude would be just as effective as one dropped through the roof from high altitude. Also, since a ricochet shot may also penetrate the walls, of a structural target is easier to hit at low altitude than at high. But whatever the effect may be, low altitude release in bombardment aviation is primarily an emergency measure to prevent the necessity of a return from a very long mission without having dropped a bomb, and to remove the handicap of a return to base with fully loaded planes.

Since it has been established that maximum efficiency of a demolition bomb required its penetration into the target, and since it was believed that fragments from a bomb case might materially aid in destruction, an attempt was made early in the development of demolition bombs to determine the optimum thickness of the bomb case. In doing this an arbitrarily resistant target had to be established and some definite means of measuring the explosive force of the bomb had to be available. For the former, a standard resistant target (hard surface) was built at Aberdeen Proving Ground. This consisted of one foot of concrete over two feet of crushed stone, and the requirement was arbitrarily set up that a demolition bomb must withstand impact on this target with sufficient velocity to penetrate to its maximum diameter. A method of obtaining comparisons of the explosive effect of bombs was determined by:

a. The size of the crater the bomb made on land impact properly fuzed.

b. By blast meters developed for the purpose, which were standard panels with ten holes of various diameters closed with a membrane of definite type. The holes are so graduated that the area of each is one-half that of the next larger. The number of the smallest hole in which the membrane is ruptured by the blast is taken as a measure of the efficiency.

In conducting tests with new series of thick-case (Mk. II) and thin-case bombs (Mk. III) for comparison, it was concluded

that the most effective bomb was that in which the case was only of sufficient strength to retain the charge while penetrating the target. On the basis of this test, further consideration of the thick case bomb was abandoned. Some time prior to consideration of the thick and thin case bombs, it was considered that the 1100-lb. Bomb might not meet all tactical requirements and a 2000-pound Bomb was designed, and accepted. Further, the Board which recommended the 2000-pound Bomb also suggested the design of one of 3000 pounds. However, it was later recommended that, since the 3000-pound Bomb was not materially more effective than the 2000-pound Bomb and since planes were available to carry a larger bomb, the greater size should be 4000 pounds. Such a bomb was designed, tested, and later abandoned because it was considered too large for any known target. It also appeared that two 2000-lb. Bombs gave better opportunity to strike the target than with only one bomb of a larger size.

The work on the thin and thick case bombs was completed in 1919, and by 1921 the final decision had been made in regard to disposition of the 4000-pound bomb. By this time the sizes of Demolition Bombs, i.e., 100, 300, 600, 1100, and 2000-pound had become firmly established, and the development continued in two directions; first, to increase the ratio of explosive to the metal parts of the body; and second, to provide designs which would have adequate strength and that could be readily manufactured. The designs of bombs up to this time all called for welding; the larger ones having cast noses plus stamped metal bases. It was discovered that the welding that had been used in fabricating bombs was not reliable and, therefore, a new series of bombs was designed to utilize forgings for the main body section. This eventually resulted in one-piece bodies forged from steel in the form of a cylinder with a heavy nose section and a swaged-in tail section closed by a rear cap screwed in place. However, before these bombs were finally standardized some attempt had been made to machine one of the forgings (2000-pound size), so that the body wall would be of uniform strength, it being tapered from the nose to the tail section. For this bomb, an explosive content as high as 67% of the total weight was gained. However, since the cost was estimated as being twice that of a normal bomb containing approximately 50 percent explosive, the machined-wall bomb was abandoned and the bombs having straight cylindrical sides were standardized in the various sizes from 100 to 2000 pounds.

In addition to increasing the explosive capacity by thinning the walls to the minimum, attempt was made to utilize high strength aluminum alloys as bomb cases in order to increase the ratio of explosive to metal. During this period of experimentation, it was found that steel having a tensile strength of

around 70,000 pounds per square inch would withstand the hard-surface impact, and that aluminum alloys (Duraluminum) could be obtained in a tensile strength almost equal to this. Therefore, bombs were procured (300 lb. T3), and tested on the hard surface at Aberdeen. It was found, however, that even though the tensile strength of aluminum was high the impact values were not correspondingly high and the bomb shattered on impact. The idea of using any aluminum alloy was then abandoned.

Because of the unsatisfactory results of welding in the earlier types of demolition bombs, it was a long time before any consideration was again given to the use of welding and fabricating bomb bodies. However, around 1930, manufacturers claimed that the welding technique had advanced to such a stage that properties equivalent to those of the parent metal could be obtained. On this basis, bombs of various sizes were procured with circumferential and longitudinal welds in which nose and tail forgings were welded to tubular body sections. These bombs were manufactured by:

- a. Flash welding.
- b. Automatic metallic arc welding.
- c. Automatic carbon arc welding.
- d. Atomic hydrogen welding.

All of these bombs failed except the flash-welded bombs, which were considered as satisfactory as forged bombs.

No further thought was given to bomb welding until within the last two years when a manufacturer again approached the Ordnance Dept. claiming improvements in welding technique which would warrant further consideration. As a result, this manufacturer and several others were permitted to manufacture bombs by welding and submit them for test. These bombs were found to be as satisfactory as any manufactured by the forging process. Welding is, therefore, now permitted by qualified welders.

In determining the suitability of these bombs from a strength standpoint, a test was developed utilizing a hard surface at Fort Sill, Oklahoma, consisting of a bared rock surface on one of the mountainous ridges on the Field Artillery range. A satisfactory bomb was arbitrarily established as one which, dropped from a set height, would compare favorably with a standard bomb of the same size with regard to deformation and penetration.

Within the last year (1939), a series of tests has been developed at Watertown Arsenal, which will probably eliminate the necessity for conducting hard surface tests such as this to determine the impact values of bombs. The new tests include careful observation of expansion and failure under hydrostatic

loads, and high speed impact tests together with other standard laboratory tests. Therefore, after satisfactory hard surface tests of the fin and nose section, drawings were revised and in June, 1939, bids were obtained on the new type bomb. However, when received it was found that the manufacturer who proposed to manufacture by drawing from a billet was low, and at the present time an entire series of demolition bombs from 100 to 2000 pounds is being manufactured by the old method.

Because of the interest that was aroused among various manufacturers who found that, in addition to forging, bombs could be made by welding which would unquestionably reduce the cost of manufacture and, more important, greatly increase the sources of supply in emergency certain engineers believed that the bomb could be suitably formed by swaging or spinning from tubing. These processes were also investigated and it was found that, although the resultant nose section was thinner, steel of much higher physical properties would be available and would more than compensate for the thin nose section.

In order that Army and Navy bombs may be interchangeable the 600 and 1100 pound sizes have recently been reduced to 500 and 1000 pounds, making the series 100, 300, 500, 1000 and 2000 pounds.

It is considered that this discussion of demolition bombs would be incomplete without at least a reference to the several bomb tests on naval vessels that have been conducted in the past. During the War many bombs were dropped on submarines, but no important bomb attacks on battleships appear to have been undertaken. The largest bomb used at the Dardenelles is thought to have been the British 112-lb. In 1920 a foreign demolition bomb weighing 1,600 lbs. was detonated statically on the deck of an obsolete battleship, resting against an 8-inch gun turret. The damage was such as to arouse great interest in the possibilities of using large demolition bombs against naval vessels and served to open up a new method of attack against such targets. These tests paved the way for later tests against other naval vessels and resulted in all possible priority being given to the development and manufacture of the 2,000 and 4,000 lb. Bombs. In 1921 an obsolete destroyer was sunk by direct hits with 300-lb. Bombs. A cruiser was damaged by direct hits with 300-lb. Bombs and was sunk by a 600-lb. Bomb. A battleship was damaged by 600- and 1100-lb. Bombs striking close and was sunk by an 1100-lb. Bomb which penetrated the afterdeck, blew off that deck and a portion of the side. Another battleship was sunk by an 1100-lb. Bomb which as a result of good bombing, together with luck, struck a ventilating shaft and passed through the bottom of the ship.

These tests, together with the results of more recent battleship tests, have demonstrated that our demolition bombs

can put naval vessels of the first class out of commission and sink them, even though the bombs are insufficiently strong to penetrate the main protective deck of thick armor. It has also been demonstrated that a large demolition bomb with the proper delay fuze action in striking water within a limiting distance from a modern battleship, can produce sufficient damage to the unprotected bottom to put the ship definitely out of commission.

In June of last year 1000-pound Bombs with steel having tensile strength as high as 150,000 pounds per square inch were procured and have been delivered to the Navy Department for test against deck plate. Bombs of the 600-pound size, having tensile strengths in the neighborhood of 90,000 lbs. per square inch, have successfully penetrated two-inch armor and it is for this reason that the outlook for the heavier and stronger bomb is optimistic. The armor-piercing bomb was not looked upon so favorably in the past because of the difficulty in getting a direct hit on a ship, however, the great improvements recently made in bomb sights have changed this picture.

The standard explosive specified for demolition bomb loading at the present time is 50/50 Amatol. Alternative charges are 80/20 Amatol, TNT, and Trimonite.

Demolition bombs, with the exception of the 100-lb., are furnished the service in two main packages. One package consists of the bomb body assembly unpacked except for two shipping bands which encircle the straight cylindrical section over the lugs in order to protect the lugs and permit rolling the bomb. The other package is a wire-bound wooden box containing the fin assembly and an accessory box in which the fuzes and arming wire will be packed in wartime. In peace-time shipment, however, the fuzes and arming wire assemblies are shipped separately. The 100-pound Bomb is an exception and is shipped in a steel crate, the fin being attached to the bomb. The crate also provides space for an accessory container in which the fuzes and arming wire may be held for emergency shipment.

The complete demolition bomb consists of the loaded body section with a steel fin assembly on the tail, and with both nose and tail fuzes. The nose fuze is of the selective-setting type, which can be made to function either instantaneously or short delay, and the tail fuze is a single-purpose type, functioning 45 seconds after impact. The bomb is suspended in the airplane from the two lugs which are welded to the body and engage in what is known as a bomb shackle. An arming wire is threaded through both the nose and the tail fuzes to engage safety devices which prevent the fuzes from arming until the bomb is dropped and the arming wire withdrawn in the arming

process. A swivel loop, attached to the center of the arming wire between the two fuzes, is engaged in a hook in the bomb rack which retains it, thereby withdrawing the arming wire from the fuzes when the bomb is dropped to function, or which may release the arming wire should the bomber desire to drop the bomb "safe". "Safe dropping" is provided to permit dropping of the bomb over friendly territory should it be necessary in case of accident or attack for the bomber to lighten his load prior to making a forced landing or escape.

FRAGMENTATION BOMBS:

Contrary to the demolition bomb whose case is only sufficiently strong to keep the charge intact during penetration, and whose military effect is obtained entirely from the blast of the explosive, the fragmentation bomb is constructed with a very heavy metal case which is utilized to effect practically the entire damage that is done. In this type bomb the explosive charge is only sufficient to break the case into optimum size fragments and impart a satisfactory velocity to them. These bombs are always fuzed for instantaneous action in order that the burst may occur above ground and maximum range and velocity of fragments be assured.

At the close of the War we had two fragmentation bombs which had been manufactured in rather large quantities, one a 17-pound bomb with a fuze mounted on an extension approximately 6 inches long, and a British 25-pound pearshaped bomb, the body of which was manufactured of malleable iron or semi-steel. Both bombs were stabilized by fin assemblies and were intended for high altitude bombing; i.e., and altitude sufficiently high to be reasonably safe from enemy firing. In the subsequent development of fragmentation bombs after the War, the Ordnance Department was committed to a 30-pound bomb, which of course was not a very great step above the 25-lb. bomb. This size was established probably more on the influence of the size of the British bomb than for any other reason. The 17-pound bomb that was manufactured during the War was a makeshift, since it was an adaption of rejected 3 inch and 75 mm Shell, patterned after similar use of 90 mm shell by the French. The 30-pound bomb, therefore, was considered satisfactory, standardized, and issued to the service up to within the last few years.

The development of low altitude tactics by attack aviation made it necessary to reconsider the entire scheme of fragmentation bombs. In about 1927 or 1928, with the advent of the hedge-hopping type of attack, there was a tendency to go to the very small all-ways fuzed delay action type of bomb. Several sizes and shapes of bombs were manufactured using various

explosives from black powder to granular TNT with five-second delay primer detonators and all-ways fuzes. These were tested at Aberdeen Proving Ground by dropping from a plane, and by other comparative static tests, and it was determined that in order to be at all satisfactory the bombs should weigh at least 17 pounds overall. These decisions were based on tests which have become more or less standardized for fragmentation bombs.

In determining the fragmentation efficiency of bombs at the proving ground, three types of tests are conducted. The pit test, the low panel test, and the silhouette test. In the pit test the bomb is placed in a wooden box and buried in a sand pit of suitable size, and detonated statically. The sand is then screened and the fragments recovered on four sizes of mesh, the openings varying from .165 to .838. These fragments are carefully weighed, screened, and classified, and a decision as to the effectiveness of the bomb based on the data obtained. Any of these sizes is considered an effective fragment. However, the more fragments the better the bomb is considered.

The low panels consist of four quadrants of panels, 12 inches wide, 5-3/4 feet high and 7/8 inch thick, of spruce lumber. Each panel represents the height and width of a man. Quadrants of panels are placed 10, 20, 30 and 40 meters from the center at which the bomb is fragmented statically. By substituting either the total number of perforations counted or the number of panels perforated at the several distances in a formula, a figure is obtained which represents relative fragmentation effectiveness in terms of casualties over a definite area and with a definite and uniform distribution of personnel over this area.

The silhouette test consists in dropping a bomb on a field of silhouettes spaced 15 by 45 feet apart. The silhouettes are of the same dimensions as the low panels and represent the height and width of a man. The bombs are dropped from altitudes between 2,000 and 4,000 feet. The perforations of silhouettes within radii of 10, 20, 30, and 40 meters from the point of hit are counted and used in a formula to obtain a figure of effectiveness. This test is identical with the low panel test except that the bombs are actually dropped and fragment on impact rather than being set off statically. This brings in the effect of the forward motion of the bomb, angle from vertical at which impact occurs, and any delay in functioning, and thus gives a measure of the actual performance of the bomb.

In subsequent tests of the Proving Ground and continuing with the development of a bomb for low altitude work, a 17-pound unstabilized bomb was developed and was furnished the service for test. Upon completion of the test, a recommendation was made that, although the size of the bomb was satisfactory,

it was not efficient because it usually bounced along the ground until it came to a hollow place and there came to rest. Naturally it would be lying on its side and in exploding a good percentage of the fragments would go into the ground and the remainder straight up in the air.

The problem now became one of having the bomb strike nose-on and go off in this position. At the same time flight of the bomb had to be retarded in order that the dropping airplane could attain a safe distance from the point of impact before the bomb exploded. The answer seemed to be the retarding of a bomb by a parachute, and about 1930 this development became active, and has continued to the present time keeping pace with development in airplanes until it appears that the parachute can now be made sufficiently strong to withstand speeds of dropping of 350 miles per hour and possibly more. The bomb, however, has grown from 17 pounds to 23 pounds.

Although it had been indicated in service tests that the 17 lb. bomb was satisfactory, additional tests were made at the Proving Ground to determine the actual effect of the fragmentation bombs against materiel targets, such as trucks, and airplanes parked on the ground, since it was a basic requirement that any fragmentation bomb furnished the Air Corps should satisfactorily combat targets of this type. With the 17-pound bomb, as designed, it was found that very little damage could be done to a truck or plane. Attempt was made to increase the effectiveness of the bomb by making the size of fragment the same as produced by the 30-pound bomb, which was found to be quite satisfactory against materiel targets. However, no improvements resulted, since the resultant velocity was still not sufficient to pierce a vital part of a truck. The next step, which satisfactorily solved the problem, was to increase the charge slightly so that the resultant energy of the fragment would meet an arbitrary standard. This final attempt was successful, and as a result a new series of fragmentation bombs was standardized in 1939 and manufacture started for war reserve. These bombs may be equipped either with fin assemblies or parachutes for high or low altitude bombardment, and, since pursuit ships will carry time fuze fragmentation bombs for use against enemy bombardment formations, this same bomb may also be used for that purpose.

CHEMICAL BOMBS:

At the close of the War, no chemical bomb was standard, although during the War several incendiary bombs, which are included in this category, were considered.

Since the War only one chemical bomb has been standardized, and that bomb although still standard will probably not be

manufactured because of certain inherent faults of design. This bomb, weighing only 30 pounds overall is made up of a relatively thick steel case, streamlined, and formed by spinning from tubing. It is fuzeed instantaneously and designed to contain WP, HS, or CG. Because of its relatively heavy case, the amount of gas contained is limited.

Subsequent to the standardization of this bomb, there was a policy established that all demolition bombs would be designed so that they could be converted to chemical loading. Later on this policy was reversed and it was established that all chemical bombs should be designed so that they could be converted to H. E. loading. However, quite recently the opinions of the Army at large have been precipitated into definite ideas regarding the characteristics of chemical bombs. As it now stands, the policy is that there shall be only two chemical bombs, one for bombardment aviation and one for attack aviation, both of these bombs to be of the thin-case type; i.e., that the chemical charge shall be housed in a container only sufficiently strong to withstand handling and transporting stresses. The bomb for bombardment aviation is to be of the 100-pound overall size. The attack aviation bomb is to be of the 30-pound size.

The small bomb will have a simple impact fuze with a burster running the entire length of the bomb, which can be depended upon to scatter the filler whether the bomb is dropped from a very low altitude or a reasonably high one. The larger bomb will be similarly fuzeed and burstered, but will probably always be dropped from a high altitude. At one time, it had been planned to provide the small bomb for attack aviation with a weak mid-section and to use the bomb without fuze or burster depending upon impact and subsequent tumbling from low altitudes for distribution of the filler.

The 30 lb. Bomb is being standardized. At the same time, however, experiments are being conducted to increase the stability of the bomb. This improvement is necessary, as in the original design it was not contemplated dropping from a higher altitude. This fact, together with the necessity for obtaining nose impact, has necessitated the increased stabilization. The 100-lb. Bomb is ready for standardization with the exception that certain confirmation tests are required to assure proper high order detonation of the burster. Some difficulty had been experienced in communicating the detonating wave from the detonator in the fuze to the tetryl column in the burster.

The military requirements have been established for an incendiary bomb for both bombardment and attack aviation. However, very little progress has been made towards the actual design of the bomb because of the basic research necessary

to determine the most satisfactory type of filler and to establish satisfactory test conditions. Most of the work done to date has been by the Chemical Warfare Service, and it appears that the best agent is a combination of a case of magnesium alloy (Dowmetal) filled with a compressed charge of airplane flare mixture (flake aluminum, barium nitrate, sulphur, and linseed oil). The flare composition produces the heat necessary to ignite the Dowmetal which burns with an intense heat.

A chemical bomb loaded with smoke composition (WP) might possibly serve as an incendiary bomb for burning easily ignitable targets. With this in mind, 100 lb. Demolition Bombs are being loaded with WP by the Chemical Warfare Service for service tests.

However, as mentioned before, the necessity for an incendiary bomb is by no means firmly established. The development work being undertaken results more or less in an investigation of the possibility of such a unit.

SECTION XI - BOMBS

2. Demolition Bombs and Fuzes

World War Types.

Demolition Bombs, as manufactured in this country during the World War, were of the type which has since been designated as "Mark I". Typical of this series, which ran from 25 pounds to 1100 pounds in size, is the 100-lb. Mark I Demolition Bomb shown in Figure I. The smaller sizes were formed entirely of pressed steel sections welded together. The larger sizes had cast-steel nose sections welded to pressed-steel rear sections. All were joined by both circumferential and longitudinal welds. The forward sections were thicker and heavier than the center and rear sections. Both nose and tail were completed by forgings. The nose forging was threaded to receive a closing plug and the tail forging to take a firing mechanism or fuze.

This tail firing mechanism consisted of a die-casting supporting a long axial tube at the closed inner end of which was a wedge-shaped firing pin. Around this tube, somewhat above the inner end, a booster charge was provided. A primer-detonator assembly was suspended in the open end of the tube by a transverse arming pin in the cone of the fin assembly. The arming pin was held in place against the action of its spring by an arming wire entered through a hole in the opposite end of the pin. The other end of the wire terminates in a loop which was engaged by an arming pawl in the bomb rack.

When the bomb was dropped, the arming wire, being retained by the arming pawl, was withdrawn from the arming pin. The arming pin spring then ejected the pin and freed the primer-detonator assembly. As the bomb descended the primer detonator assembly was free to slide slowly forward in the tube until its rim-fire primer rested against the end of a small lead pin extending slightly above the ridge of the firing pin in the end plug of the tube, and the collar-shaped detonator was centrally located within the booster. Upon impact with the target, the forward motion of the entire bomb was arrested sufficiently to cause the inertia of the primer detonator to deform the lead pin and plunge the rim-fire primer against the firing pin. The flash from the primer, augmented by the explosive effect of the axial charge of black powder in the primer detonator body, exploded the detonator, whose effect was relayed to the booster and thence to the entire explosive charge of the bomb.

The action of this tail fuzing arrangement was slow enough to permit some penetration of the bomb into the target, but when deeper penetration was found desirable the axial charge of the primer detonator was changed to highly-compressed black powder whose slow-burning properties gave a delay between the firing of the primer and the eventual detonation of the bomb.

Post-War Modifications.

The Mk. I series of demolition bombs proved generally unsatisfactory. Their bodies, or cases, were not of sufficient strength, due largely to the numerous welded joints. The stabilizing fins were not stiff enough to prevent wobbling in flight. The fins had to be removed in the field in order to insert the tail fuze. After the Armistice a modification of the Mk. I series was undertaken with a view to eliminating, insofar as possible, the unsatisfactory functioning that had been experienced. The 25- and 50-lb. sizes were declared obsolete due to their small capacity and these were not considered in the modifications. All of the other sizes were provided with newly designed fuzes for both nose and tail, together with new boosters and detonating arrangements. The modified series of bombs was called the Mark III Bombs and is illustrated in Figure 2.

These Mark III bombs were equipped in the nose with the Mark VII fuze (Fig. 3). This is a simple firing mechanism and requires for its completion either an instantaneous or a short delay Mark IIB primer-detonator (Fig. 4) and an adapter booster (Fig. 5), which is really a part of the bomb. The tails were fitted with a similar adapter booster and used the Mark V Tail Fuze (Fig. 6) with a second primer detonator.

The Mark VII Nose Fuze consists of a threaded body into whose axial bore a flanged striker is secured by a transverse copper shear wire. Between the flanges of the striker and body is a circle of steel cylinders or discs which maintain the relative position of these two parts. Securing these discs in place against the action of a bent leaf spring is an arming cup, mounted in an axial thread and equipped with a double wind vane. Affixed to the cup and the body are two sets of eyelets through either of which the arming wire may be passed to restrain the cup from being unscrewed by the action of the air against the vanes. When the bomb is released, the arming wire is withdrawn and the vane cup assembly unscrews from the fuze and liberates the discs. This leaves the striker held in place only by the copper shear wire which is readily sheared when the striker contacts the target. The striker is then driven inward and its point fires the primer of the primer detonator, the booster, and the bomb.

The Mark IIB Primer Detonator, which is held in its place within the adapter booster by the fuze, consists primarily of a Head, a Body, and a Detonator. The Head was originally the brass end of a commercial 16-gage shotgun shell, but later a turned metal part of approximately the same general shape and size. It serves mainly to hold a percussion primer in axial alignment with the firing pin of the fuze, and to seal the primer detonator assembly against escape of the gases produced by the combustion of the explosive elements. The Body serves as the connecting link between the Head and the Detonator, and holds a relay charge of black powder pellets whose purpose is to supplement the flash from the primer and insure proper functioning of the detonator. The Detonator is a drawn cup of the same dimensions as a commercial No. 8 blasting cap, and contains an upper charge of mercury fulminate or lead azide and a lower charge of tetryl. In the delay primer detonator

the small tubular section just below the primer is filled with highly compressed black powder to produce the desired interval between impact and explosion.

The Adapter Boosters each consist of an adapter; a booster case, which contains the tetryl pellets of the booster charge; and a socket which provides the seat for the primer detonator. These units are always assembled to, and shipped with, the bomb, while the fuzes and the primer detonators are shipped separately.

The Mark V Tail Fuze is also of the arming-vane type of firing mechanism without any integral explosive parts. Its lower end is arranged so that a Mk. IIB Primer Detonator may be assembled to it before it is screwed into the tail adapter booster. When the arming wire is withdrawn, the vane unscrews the long arming stem that secures the plunger and leaves the plunger restrained only by a light spring between it and the primer detonator. When the bomb is retarded upon impact with the target, the plunger drives forward and its striker point fires the primer.

Since there is an inherent delay in the mechanical action of this type of tail fuze, and therefore strictly instantaneous action cannot be obtained, a delay primer detonator is always used in the tail of the bomb. In the nose, either an instantaneous or a delay primer detonator is used, depending on the probable nature of the target.

The Mark III Series.

While the foregoing modifications to the war-built bombs improved them considerably, their bodies, principally on account of the longitudinal welds, were incapable of passing the strength tests that had been decided upon, and their fin assemblies were not sufficiently rugged to insure the desired degree of stability. Therefore, a new series of demolition bombs was developed (See Fig. 7). These Mark III bombs were also made in the 100-lb., 300-lb., 600-lb., and 1100-lb. sizes. They employed the same fuzes, primer detonators, and adapter boosters as the Mark III bombs. The 100-lb. size is built with deep-drawn nose and rear body sections joined together with circumferential welds. No longitudinal welds are used. The 300-, 600- and 1100-lb. sizes are designed with cast-steel noses and deep-drawn rear body sections joined together with circumferential welds. The fin assemblies are designed as units, capable of easy assembly in the field, and do not require removal from the bomb body in the fuzeing procedure. The fin surfaces are held in a rigid assembly by braces. The Mk. III type bombs carry an explosive content of approximately 55 percent of the total weight.

Cylindrical Demo. Bombs.

In 1921 the design of a 2000-lb. demolition bomb was started and was based in general on the British 1600-lb. bomb, but was made considerably stronger through the use of seamless steel tubing in place

of a riveted drum used by the British for the cylindrical body. This initial design of our 2000-lb. Mk.I bomb had a cast steel nose riveted and welded, and a cast rear cap welded, to the cylindrical body. It carried nose and tail fuzes and detonating trains similar in principle to those used in the standard type of streamline bodied bombs. The explosive content was 49 percent of the total weight. Proving ground tests were conducted on July 18, 1921, and the battleship Ostriesland was sunk with one of these on July 21 of the same year, or 115 working days after the first experimental order was placed. This bomb proved to be generally satisfactory but several changes were found to be desirable. The first change was to attach the rear cap to the cylindrical body by means of a large screw thread rather than by welding. This facilitated and reduced the cost of loading. The second change was the elimination of the heavy nose casting and the substitution of a forged nose integral with the cylindrical body and formed by a swaging operation. This arrangement resulted in a stronger bomb, reduced the total weight 100 pounds and increased the explosive content from 49 percent to 52 percent.

Experience showed, however, that a threaded rear cap of large diameter was often difficult and sometimes impossible to remove for loading after the empty bodies had been in storage for some time. In order to avoid this difficulty the design was again changed. The new design, illustrated in Figure 8, is made by forging the heavy nose and the cylindrical portion in one piece as before and then the open end is reheated and swaged into a conical form until the opening is reduced to about one-third of its original area. A rear cap of practical size is then threaded over the end to close the body. This design and contour is the standard for all sizes of demolition bombs today.

Concurrent with the foregoing change in body design was a redesign of the fin assembly and the development of new fuzes for both nose and tail. The new fin assembly, also shown in Figure 8, is attached to the bomb by a shallow drawn cup which fits over the rear cap, instead of by a long tapered cone extending well forward over the rear part of the body. The four radial fins are attached to the sidewalls of the cup, and a large portion of each fin is bent at a 45-degree angle from the radial section so that it joins and is riveted or spot-welded to the adjacent fin. Thus the greater part of the assembly is formed into a very rigid square box with four diagonal extensions. This design has reduced the manufacturing cost, has greatly improved the stability characteristics of the bombs, and has produced a fin assembly that is far more convenient to handle in the field. The tail fuze developed for the cylindrical bombs is the M100 type (Fig. 9) and is supplied in three lengths, the two longer fuzes being designated M101 and M102 respectively. The shortest fuze M100 is being used in the 100 and 300 pound bombs, the next size in the 600 and the largest in the 1100 and 2000 pound bombs. This fuze is not complete in itself, consisting only of a firing mechanism and

a primer-detonator unit, the booster (M102) being supplied with, and as part of, the bomb. The M100 tail fuze (Fig. 9) consists of a body housing the primer-detonator assembly, or the delay element assembly as it is called, and a plunger restrained in the unarmed position by a threaded stem engaging in a threaded hole in the plunger and the base of the fuze body. The rear portion of this stem is attached to a wind vane through a delayed arming mechanism, the delayed arming mechanism being simply a set of gears which reduce the number of turns of the arming stem with respect to the number of turns of the arming vane to 1 in 30. Therefore, as the arming vane spins, the arming stem slowly unscrews from the plunger until it is entirely free, then on impact, as the bomb is retarded by the target, the inertia of the plunger will carry it forward to strike a primer of the delay element assembly. The delay element burns and then sets off the detonator which transmits the detonating wave to the booster and thence to the bomb filler.

The new nose fuze (Fig. 10) is designated as the M103 and is a complete fuze, housing firing mechanism, delay element and booster, and which may be set either for superquick action or short delay. No booster need be supplied in the bomb. The M103 fuze consists of a body housing, a delay element of the type used in the M100 type of fuze. The lower portion of the body is slotted perpendicular to the axis to accommodate a slider which carries a detonator. A booster is assembled to the body in a thin metal cup below the slider cavity. A brass plate with two booster leads is placed below the slider and between it and the tetryl pellets of the booster. This plate is provided to secure "bore" safety in case the detonator should be exploded anywhere except in the two armed (instantaneous or short delay) positions. A firing mechanism is assembled in the upper part of the body. This firing mechanism consists of a striker head equipped with two firing pins, one on the axis and extending for a considerable distance into the body, the other rather short and situated directly above the primer of the delay element. A setting device is provided in the body. This consists of a stem mounted perpendicular to the axis and extending through the entire length of the body, projecting into the slider cavity on the one end, and against the arming gear on the other. This arming stem is provided with a shoulder. A setting pin is mounted perpendicular to the arming stem hole and, from the outside of the fuze, may be so adjusted to project into or clear the arming stem hole. If it is desired to set the fuze for delay action, the setting pin is allowed to project into the arming pin hole where, upon spinning off of the arming vane assembly (which is similar to the action of the Mark XIV fuze) the arming stem, since it bears against the arming assembly, will follow it as it rises, being forced upward by a coil spring. The distance that it can go upward, however, will be governed by a flange on the arming stem coming in contact with the setting pin. As the arming pin moves upward it clears the end of the slider and allows it to be pushed over far enough for the detonator to align with the relay of the delay element assembly and the first

booster lead. The slider is stopped in this position by the arming pin engaging against a stop on it. Further, it is located by a latch mechanism mounted in the body, which engages in a groove in the slider. For instantaneous setting, the setting pin is so positioned that it clears the arming pin hole, in which case the arming pin entirely clears the slider cavity and the slider springs force the slider over until the detonator aligns with the instantaneous firing pin and the second booster lead. Delayed arming of this fuze is accomplished by a gear mechanism, mounted within the arming vane cup, which reduces rotation of an arming screw, to 1 turn in every 70 turns of the arming vane. As the arming screw moves upward it carries with it the arming vane cup and at the proper time releases a series of steel cylinders from between the pressure head and the body assembly, as in the case of the Mark VII MII fuze. In addition, it allows the arming stem, governing slider motion, to move.

Modernized Bombs.

The box-type fin assemblies developed for the cylindrical demolition bomb (illustrated on the 100-lb. M30 Bomb in Figure 8) proved to be such an improvement over all earlier types that experiments were undertaken to determine whether this type of fin assembly would improve the stability of the old streamlined bombs of the Mk. I Series. These tests were so successful that all remaining bombs of the Mk. I Series are now being equipped with fin assemblies of the new type. The 100-lb. Mk. IMIV Bomb shown in Figure 11 illustrates the result of this modernization program.

On account of a lack of concentricity between the fuze threads of the nose and tail adapter booster and the detonator sockets in the bombs of the older types, difficulties have arisen from time to time in attempting to fuze these bombs with a Mk. IIB Primer Detonator assembled to the Mk. VIIMII Nose Fuze and the Mk. VMI Tail Fuze. Consequently, the present modernization program will include an improvement in the nose and tail fuzeing arrangements in addition to provision of the box-type fin assemblies. All nose adapter boosters which now require the Mk. IIB Primer Detonator will be modernized by filling the primer detonator sockets with a socket charge assembly consisting of small tetryl pellets encased in a light aluminum container. These charge assemblies will be secured in the sockets by a force-fit sheet metal cup, which will be pressed into the interior of the adapter until it seats firmly on the top of the detonator socket flange. The tail adapter boosters of these bombs will be removed and will be replaced by new adapter boosters designed for either the M100 Tail Fuze, previously described, or a new type tail fuze (T18) which is being considered to supplant the M100.

Since the fin assemblies of the streamlined bombs of the Mk. III series and the 2000-lb. cylindrical bombs of the Mk. I series, which remain in War Reserve, are considered sufficiently rugged for continued

use, they will be retained and the modernization of the bombs of these two types will be confined to the foregoing improvement in the nose and tail fuzeing arrangements only. These bombs, as they will appear after modernization, are illustrated in Figures 12 and 13, respectively.

The nose fuze intended for all modernized demolition bombs is the T18 (M105) shown in Figure 14. This fuze is of the arming-vane type and, like the M103, is provided with a gear reduction between the arming vane and the arming thread, so that approximately 500 revolutions of the vane are required before the arming discs are released from between the flange of the striker and the fuze body. This fuze is also of the selective type, which may be set for either instantaneous or delay action; the setting being made by manipulation of a convenient setting pin projecting from the side of the fuze body. When set for instantaneous action, one firing pin fires a primer which flashes directly to a relay charge and thence to the detonator. When set for delay action, the instantaneous primer is removed from the firing position and a second firing pin fires another primer, which must operate through a delay element before reaching its relay charge and the detonator. It will be noted that the delay feature of this fuze is always in the firing position and, even when the fuze is set for instantaneous action, it is available to explode the bomb if the instantaneous element should fail.

The tail fuze, which is being provided for the modernized demolition bombs is the T17 (M106) shown in Figure 15. This fuze is of the arming-pin type and carries the conventional tail fuze plunger which, after ejection of the firing pin upon release of the bomb, is restrained only by a light spring situated between it and the primer. Since this fuze is intended primarily for low-altitude demolition bombardment, the plunger is considerably heavier than usual and the plunger spring is correspondingly lighter. Likewise, the primer is of a much more sensitive type than is usually found in bomb fuzes. When the primer of this fuze is fired upon impact of the bomb with the target, its flash, reinforced by the effect of the black-powder pellet directly beneath the primer, ignites the end of a coiled length of miner's fuse. This slow-burning fuse provides a length of delay sufficient to enable all planes of a low altitude bombardment formation to reach a point of safety before ignition is communicated to a second hollow black-powder pellet and thence to the detonator and the bomb.

Practice Bombs.

In order to make use of the large number of empty bomb bodies remaining from wartime manufacture and to provide the various air units with target practice ammunition, several methods have been employed from time to time to equip these bodies with a satisfactory practice loading. A recent example of a target practice bomb produced in this way is the 100-lb. M39 Practice Bomb shown in Figure 16. This is a 100-lb. Mk. I Bomb Body equipped with one of the new box-type fin assemblies and filled with approximately 62 pounds of dry sand and

2 pounds of black powder. In order to provide the maximum of field training to both ground and air personnel, two fuzes and the usual arming wire assembly are supplied. Both fuzes are fitted with blank-loaded 24-gage shotgun shells instead of Mk. IIB Primer Detonators. The nose fuze and shotgun shell assemble into a metal adapter and closing cup and are furnished for training in the fuzeing operation only, since the two-pound practice charge of black powder is located in the tail of the bomb. This bomb gives adequate training in all of the phases of high altitude bombardment, but has the disadvantage that, if dropped from high altitudes onto soft soil, it penetrates too deeply into the ground before the tail fuze functions and the powder charge bursts the body. The result is that the smoke from the powder charge, instead of being liberated as a rather large puff above the surface of the target, is obscured by the loose earth which falls into the hole after the bomb.

A more satisfactory and a cheaper practice bomb for high-altitude bombardment is the M38A2 Practice Bomb shown in Figure 17. This bomb has a very light sheet-metal body which is filled with sand up to the bottom of the cylindrical opening within the conical rear end. A large size commercial tin can containing about three pounds of black powder and equipped with a simple arming-pin-and-plunger type of fuze fits into the loading tube to provide a spotting charge. The empty bomb bodies and the spotting charge assemblies are shipped separately. The bomb bodies are filled with sand and the spotting charges are assembled to them in the field. A blank-loaded shotgun shell attached to the inner end of the fuze acts as a primer detonator. The usual arming wire is employed to retain the arming pin until the bomb is released from the airplane.

For low altitude bomb bombardment practice a miniature practice bomb, M36 (Fig. 18), is provided. This bomb consists of a one-piece die-cast body, about 8-1/2 inches in length and weighing approximately 2 pounds, with a cylindrical opening extending along its axis. In this cylindrical opening a blank-loaded 10-gage shotgun shell and a very simple percussion firing pin are placed. When the bomb is dropped, impact with the target deforms the light metal cup of the firing pin assembly and fires the charge of the shotgun shell. The smoke from the charge is projected upward through the opening in the tail and is readily visible from low altitudes, particularly in dive bombing.

SECTION XI - BOMBS

3. Chemical Bombs and Fuzes

The term "chemical bomb" at the present time is considered to embrace aircraft bombs loaded with any type of chemical agent whose development is the responsibility of the Chemical Warfare Service. These chemical agents are classified as:

- Gas
- Gas, Persistent
- Gas, Irritant
- Smoke
- Incendiary.

The first class includes all non-persistent agents which are considered as toxic in their effect. The second class includes all persistent toxic agents. The third class includes all agents, both persistent and non-persistent, which have a powerful physiological effect but are not ordinarily toxic. The other two classes are self-explanatory.

World War Types

Wartime use of chemical bombs by the air units of the American Expeditionary Forces, so far as is known, was limited to incendiary bombs. These bombs were of both "intensive" and "scatter" types. The so-called "intensive" bomb burned as a single unit, concentrating all its effect on one spot. The "scatter" bomb consisted of a large number of smaller units which were distributed over a relatively large area.

Probably the most widely used of the intensive type was the French "Chanard" Incendiary Bomb. This bomb weighed about 30 lbs. and consisted of a thin metal case, streamlined in shape and filled with a mixture of nitrate, cellulose and resin. It carried a tail fuze of the wind vane type in which a spring-impelled firing pin was released about five seconds after the bomb was launched from the airplane. The primer in the fuze ignited a powder delay charge which burned for an additional five seconds before reaching a small powder igniting charge. This charge ignited not only the incendiary composition, but also charges of thermite mixture contained in three tubes, one of which extended through the center of the bomb, and two of which extended along opposite sides of the body. These thermite charges served to carry the ignition to all parts of the incendiary mixture, and also to cut the body into two parts, along the greater part of its length so that upon impact the incendiary mixture, which was already well ignited, would be liberated, even though the bomb struck targets of relatively low resistance.

Of the scatter type incendiary bomb, the one most frequently used was the 8 oz. Incendiary Bomb, Mk. I (See Fig. 1). This bomb consists of a tubular body, roughly 1" in diameter and 8" in length, made of tin plate and fitted at one end with a steel plug whose inner end is provided with a firing pin point, and at the other end with a tin plate cap carrying stabilizing vanes. A small incendiary charge of thermite was contained within a 12-gage shotgun shell placed within the tubular body and resting on two small ears punched inward from the sides of the tube a short distance away from the firing pin point on the steel plug. The combined effect of the steel plug and the stabilizing vane gave assurance that the bomb would always strike in such a position that the inertia of the shotgun shell caused it to bend the supporting ears and plunge forward, driving its primer against the firing pin. A small propelling charge within the shotgun shell ignited the thermite composition and expelled it from the tubular body so that it could come in contact with and ignite the target.

In the American squadrons which were equipped with French airplanes, about 250 of these individual bombs were carried in a vertical tubular rack, and were released at the target by opening the bottom of the tubes. In the American model, as illustrated in Fig. 1, 200 individual bombs were carried within the two halves of a large case and were released by dropping the entire assembly. Upon being freed from the bomb rack, the two steel cable belly bands fell free and permitted the two halves of the bomb case to separate and release the individual incendiary bombs. In either of the two methods the individual bombs were subject to considerable dispersion and therefore covered a rather large target area.

Further wartime developments of incendiary bombs included the 40 lb. incendiary bomb Mk. I (Fig. 2) which was of the scatter type and the 40 lb. incendiary bomb Mk. II (Fig. 3) which was of the intensive type. The Mk. I bomb carried a charge of about 19 lbs. of cotton waste balls soaked in turpentine, or solid oil balls wrapped in burlap, separated by a light metal diaphragm from a small black powder charge in either end of the body. It was adapted for both nose and tail firing mechanisms.

The tail mechanism consisted of a firing pin which, after release of the bomb, was held away from the primer of a caliber .30 service cartridge only by a light spring. Upon impact, the firing pin was driven against the primer and the bullet from the cartridge ruptured both diaphragms and permitted ignition of both powder charges which burst the bomb case and scattered the ignited balls of the incendiary charge. The nose fuze, which was

for use whenever extremely rapid functioning was desired, consisted of a simple percussion firing pin which was driven against the primer by impact with the target. The flash from the primer ignited the nose powder charge, which effected superquick burst of the body and ignition of the main charge.

The Mk. II bomb was equipped with a tail firing mechanism similar to the Mk. I and was loaded with 10 lbs. of thermite composition and 16 lbs. of oil emulsion. Upon impact, the bullet from the cartridge in the tail firing mechanism punctured the container holding the small black powder igniting charge in the center of the bomb and ignition was communicated to both the thermite composition and the oil emulsion.

Post-War Development

For several years after the Armistice, no attention was directed toward development of chemical bombs except for demonstration purposes. For this use, the 50-lb. Mk. I Demonstration Bomb (Fig. 4) with a smoke filler was used. This bomb was made from the 40-lb. Mk. I Incendiary Bomb by removing the tail firing mechanism, providing an inside container with a charge of titanium tetrachloride (TM), and equipping with a long central bursting charge of black powder functioned by the Mk. XIV Nose Fuze (for description of fuze see Section XI-4).

Thick Case Bombs:-

Subsequently, development of chemical bombs with gas fillers was initiated, with a general requirement that the bomb case must be strong enough to withstand "safe-dropping" from a height of 7,000 feet on normal soil. Attempts to adapt the 40-lb. Mk. I Bomb cases for filling with toxic or irritant gases were made but were abandoned owing to the difficulty of producing a permanently gas-tight assembly.

The 30-lb. M1 Chemical Bomb (Fig. 5) was developed and standardized for use by attack aviation. The body of this bomb is made by swaging a length of seamless steel tubing to a streamline shape, fully closed at the tail end. A full-length burster well is assembled to the nose end of the body by means of pipe threads, which seal the bomb against leakage of the filler. The two authorized chemical loadings for this bomb are HS (mustard gas) and WP (white phosphorus). A full-length tetryl burster is used with both fillers, but the burster for use with WP loading is of reduced diameter since the full-sized burster charge was found to scatter the WP too widely for best smoke screen effect. In either case, the burster is functioned by an instantaneous primer-detonator and the Mk. XIV Nose Fuze.

The 100-lb. Bomb was selected as the optimum size for use by bombardment aviation after early tests of 300-lb. Demolition Bomb bodies, loaded with phosgene, indicated that anything larger than the 100-lb. size would be very inefficient for distributing chemical agents. Development tests were carried out with a 100-lb. TLE1 Chemical Bomb which was made from a demolition bomb body adapted for chemical filling. Development of this bomb was abandoned with the advent of the thin case chemical bombs described below.

The distribution of filler with the 30-lb. M1 Chemical Bomb is not considered fully satisfactory since the forward velocity of the bomb at the moment of impact and burst tends to drive the filler downward into the ground. In an attempt to improve the filler distribution, a 30-lb. expulsion-type bomb was designed which consisted essentially of a 30-lb. M1 Body with a heavy metal cap fitted over the nose of the bomb. The nose cap carried a Mk. XIV Fuze and a .1-second delay primer-detonator, and contained a fairly large charge of black powder. A plunger-type firing mechanism with a 1.2-second delay primer-detonator communicated from the black powder charge to the bomb burster. When the bomb struck normal soil, it penetrated to a moderate depth and probably came to rest before the expiration of the .1-second delay of the first primer-detonator. When the powder charge was exploded by this primer-detonator, it propelled the bomb back upward and projected it to a height of about 25 feet, at which point the 1.2-second delay primer-detonator operated to cause the bomb to burst and distribute its contents. The limited tests to which this bomb was subjected indicated that it might give better filler distribution than the 30-lb. M1 Bomb, but the improvement was not judged sufficient to warrant the added complication involved in manufacturing such a bomb.

Thin-Case Bombs:-

In 1934, the requirement that chemical bombs must withstand "safe-dropping" was eliminated and a new program for chemical bomb development was set up in 1935. The safe-dropping requirement had made it necessary to use bomb bodies with relatively heavy walls and this resulted in a relatively low efficiency (that is, ratio of weight of chemical filler to total weight of bomb). Thus, the "efficiencies" of the 30-lb. M1 Chemical Bomb and the 100-lb. TLE1 Chemical Bomb, with HS filling, were 31% and 52%, respectively. With this restriction removed, it was possible to give consideration to the suggestion of the Chemical Warfare Service and Air Corps that chemical bombs be made of sheet metal and that the shock of ground impact be depended on to rupture the container and disperse the chemical agent, thus greatly simplifying the design.

The Air Corps desired the retention of the two sizes of chemical bombs, one of approximately 25 pounds for attack aviation and one of approximately 100 pounds for bombardment aviation. The 25-lb. size would be dropped from a minimum altitude of 25 feet and a maximum of 1,000 feet, with an average of about 150 feet. The 100-lb. size would be dropped from altitudes between 1,000 feet and 20,000 feet. It was further contemplated that 100-lb. bombs would be dropped to a limited extent by attack planes at the same altitudes as those indicated for the 25-lb. bombs.

Preliminary tests to determine the practicability and limitations of thin-case bombs without fuzes and bursters were conducted with small commercial tin cans and with 100-lb. M35 Practice Bombs filled with simulated chemical agents. The conclusions reached were that proper distribution of the chemical filler without the use of a burster charge is impracticable, except possibly when dropped from the lowest altitudes.

A 30-lb. chemical bomb, consisting essentially of a cylindrical steel can .02-inch thick equipped with a hemispherical nose and suspension lugs, was designed for further tests. This bomb satisfactorily withstood handling and transportation tests and gave satisfactory distribution of the filler, in most cases, when dropped from altitudes of 300 feet or lower. However, filler distribution was not satisfactory when bombs were dropped from altitudes higher than 300 feet, since the bomb generally embedded itself in the ground at the point of impact; whereas, those bombs dropped from lower altitudes broke in half upon initial impact and ricocheted, scattering their contents over a fairly large area. It was, therefore, decided advisable to equip the bomb with a fuze and burster for use when dropped from altitudes higher than 300 feet, especially since a change in Air Corps tactics extended the probable conditions of use of this bomb to altitudes as high as 5,000 feet. A small fin assembly was also added to insure nose impact. It was originally intended that the bomb should be used without a fuze and burster when dropped from altitudes lower than 300 feet; however, the stabilization, resulting from the addition of the fin assembly, caused the bomb to strike nose first and bury itself in the ground even when dropped from low altitudes, thus preventing ricochet. It was accordingly decided to use the fuze and burster regardless of the altitude from which the bomb is dropped. Since breakage on impact was no longer required, the thickness of the bomb body was increased to .031 inch to decrease the likelihood of the development of leaks during storage and handling. The bomb, thus modified, gave satisfactory distribution of the filler and was standardized in 1940 as the 30-lb. M46 Chemical Bomb (Fig. 6). The fuze used with this bomb was

standardized as the M108 Nose Bomb Fuze (Fig. 7). Although the M46 Bomb is apparently stable enough to insure nose impact, its flight is extremely variable and considerable dispersion results when the bomb is dropped from 2,000 feet or higher. Although extreme accuracy is not required on the type of missions for which this bomb would be used (namely, "area" targets, such as airplane landing fields), modification of the fin design was being investigated at the time of writing this lecture with a view to improving the flight characteristics of the bomb.

A 100-lb. thin-case chemical bomb (Fig. 8) is also under development and at the time of writing this lecture the design, designated as 100-lb. T6E1 Chemical Bomb, had reached the stage where it was apparently ready for standardization. Like the 30-lb. M46 Chemical Bomb, the 100-lb. T6E1 Bomb utilizes the M108 Nose Fuze and a full-length tetryl burster.

The 30-lb. and 100-lb. thin-case chemical bombs when loaded with HS have "efficiencies" (ratio of filler weight to total weight) slightly over 75%. The bursters for both bombs are large enough to cause scattering of the HS filler over a large area. The combination of the superquick M108 Fuze and the large burster acts to counteract the downward momentum of the filler. This results in better filler distribution when the bombs are dropped from high altitudes than is the case with the 30-lb. M1 Chemical Bomb with its comparatively small burster and "instantaneous" primer detonator, which usually has an inherent delay of approximately .001 second.

Incendiary Bombs:-

For some time after the World War, the incendiary bomb as a specific type was not considered necessary. Among the reasons for this attitude was the uncertainty as to the need for such a bomb, since high-explosive bombs have a considerable incendiary effect in themselves. In 1936, however, tentative requirements were set up for two sizes of incendiary bombs, a 30-lb. bomb for attack aviation and a 100-lb. bomb for bombardment aviation. As the first step in the development of these bombs, the Chemical Warfare Service conducted an investigation of various types of incendiary agents. This investigation, recently completed, led to the conclusion that a 94%-magnesium alloy (similar to the so-called "electron" metal used by several European countries) loaded with a pyrotechnic flare composition was the most effective incendiary agent of those tested. In the meantime, changes in Air Corps tactics have made a 30-lb. incendiary bomb much less necessary. It was, therefore, decided to adopt the 30-lb. M1 Chemical Bomb,

with WP (white phosphorus) loading, as a substitute standard to meet the 30-lb. incendiary bomb requirements and to cancel the development of a 30-lb. incendiary bomb. Pending further consideration of the necessity for a 100-lb. incendiary bomb, plans are being made to conduct preliminary tests with 100-lb. M30 Demolition Bomb bodies loaded with WP and with thermite. The purpose of these tests is to obtain information as to the relative performance of high-explosive and incendiary bombs.

SECTION XI - BOMBS.

4. Fragmentation Bombs and Fuzes.

30-lb. M5 Fragmentation Bomb.

Since the effectiveness of fragmentation bombs is dependent entirely upon the fragments produced when their heavy-walled bodies are ruptured by the explosive, it is of the utmost importance that those fragments be large in number, of suitable size and weight, and of a fairly high degree of uniformity. Extensive tests made with World War bombs, and with several experimental types, have shown that haphazard fragmentation of a cast or forged body may produce results varying between an insufficient number of relatively large fragments and a very large number of small fragments which are too light to be effective.

As a result of those tests, a fragmentation bomb was designed so that two dimensions of each of nearly all of its fragments are predetermined. This bomb, the 30-lb. M5, (Fig. 1), has been the standard for issue for several years, and is only now being replaced by another. The body is constructed of a series of rings, cut from seamless steel tubing, assembled over a tubular sleeve and secured by two end forgings screwed to the ends of the tube. The width and thickness of the fragments are determined by the width and thickness of the individual rings; only their length is governed by the effect of the explosive. When this bomb is detonated in a vertical position, a remarkably even distribution of fragments of very uniform size is obtained.

The objection to the design of this bomb as shown in Fig. 1 was the somewhat excessive manufacturing cost because of the wastage of material and the time involved in cutting the rings from seamless tubing. Experiments leading toward a reduction of the cost showed that expense could be reduced without loss in fragmentation effectiveness by substituting a closely wound coil of square wire for the separate rings. Most of the bombs of this type which have been issued to the service have been so manufactured. The wire used is of low-carbon steel, and is not actually square at the start, but is of such a shape that it becomes square during the winding operation.

The detonating train of the 30-lb. M5 Fragmentation Bomb is of the three-unit type, consisting of the Mk. XIV Fuze (Fig. 2), the Mk. IIB Primer Detonator (Fig. 3), and the M26 Adapter Booster (Fig. 4). The Mark XIV Fuze is of the simple firing-mechanism type, which, in itself, contains no explosive parts. It consists of a brass body drilled axially to receive a firing pin. The

lower part of the body is threaded to fit the nose of the bomb. The firing pin is held in the body by a steel pin which fits into a slot in the lower part of the body and definitely locates it so far as forward movement is concerned. Above the body the firing pin carries a sloping shoulder and, when assembled, a circle of steel balls is placed between this shoulder and the top of the body, limiting the movement of the firing pin to the rear, so that, with the steel pin holding it against forward motion, the firing pin is fixed with respect to the body. The forward end of the firing pin is threaded and an arming vane cup assembly screwed over it. This cup retains the steel balls in position. When on the plane, an arming wire, which is hard drawn brass wire of .036 diameter assembled to the bomb and threaded through an eyelet on the fuze body and a hole in the arming vane prevents the vane cup assembly from being turned by action of the air stream on the arming vane. The end of the wire projecting through the vane hole is secured by an arming wire safety clip which is nothing more than a Fahnestock electrical connector. The other end of the wire is assembled to a swivel loop and attached to a pawl in the bomb rack. The Primer Detonator is always of the instantaneous type previously described in Section XI, Part 2, "Demolition Bombs and Fuzes". The M26 Adapter Booster is similar except in size to the one for demolition bombs described in that section also.

In action, the bomber releases the finger of the bomb rack that engages the suspension lug of the bomb, whether it be suspended in the horizontal or vertical position, and the bomb falls away. The arming wire, however, is retained by the pawl which engages the swivel loop and the free end is withdrawn from the arming vane of the fuze. The action of the air on the arming vane causes it to turn and release the balls from between the body of the fuze and the flange of the firing pin. The firing pin is now held away from the primer only by a light copper wire assembled through both the firing pin and the fuze body. Upon impact, the copper wire is sheared, the firing pin is driven inward against the primer, and the bomb is fired.

Like demolition bombs, this bomb, and all other fragmentation bombs, may be dropped safe by releasing the arming wire with the bomb so that the arming vane of the fuze is kept from rotating and the fuze is never armed.

20-lb. M41 Fragmentation Bomb. (Fig. 5)

As a result of belief by certain authorities that the 30-lb. bomb was too large for maximum fragmentation efficiency, a bomb of the same general design, and using the same fuze, but

approximately half the size of the 30-lb. (actually about 17-lb. in weight) was designed, and approximately 500 were manufactured for tests. The Air Corps found this bomb quite satisfactory and enthusiastically recommended its standardization. Proving Ground tests, however, showed that, though the pound-for-pound efficiency of the smaller size was higher when considered for use against personnel, the fragments produced by the new bomb, being correspondingly smaller than those of the 30-lb., were much less effective against targets such as motor transport vehicles and airplanes on the ground.

Later improvements in the design have produced a bomb of about 20 pounds weight, complete with stabilizing fins and fuze, which yields fragments equal to those of the 30-lb. bomb in both size and destructive effect. It is expected that this 20-lb. M41 Bomb will be standardized in the very near future, and that it will supplant the 30-lb. M5 in future issues. The exact fuze to be used with this bomb has not been definitely decided, but, following the recent trend, it will be of the complete-detonating-train type; that is, the primer, detonator, and booster will be contained within the fuze. The bomb contains only the bursting charge. The fin assembly is of simpler construction than that of the 30-lb. M5 Bomb, and is attached to the body in such a way that it may be adjusted with one fin blade in line with the suspension lug on the body or with the blades at 45° to the lug, to suit the type of bomb rack on which it is to be carried. The rearward end of the fin assembly is provided with a suspension eye for use when the bomb is to be carried on a vertical bomb rack.

20-lb. M42 Fragmentation Bomb (Fig. 6)

In addition to the use of the 20-lb. Stabilized Fragmentation Bomb against ground troops, consideration is being given to its use against invading bombardment formations. For this purpose, the same bomb body and fin assembly will be equipped with a combination mechanical time and percussion nose fuze, and will be designated as the 20-lb. M42 Fragmentation Bomb. This bomb is intended to be dropped at the enemy formation from pursuit aircraft flying at a suitably higher altitude. In addition to the mechanical movement, which may be set so as to detonate the bomb at any desired time between five seconds and thirty seconds after release, the fuze is equipped with a percussion firing pin to explode the bomb in case a direct hit on one of the airplanes is obtained. An arming vane mechanism prevents the fuze from functioning either by time or percussion until after the vane has rotated a definite number of revolutions, corresponding to a fall of approximately 500 feet below the airplane from which it was released. Withdrawal of an arming wire upon release of the bomb starts the timing movement and releases the arming vane.

20-lb. M45 Practice Bomb (Fig. 7)

In order that the Air Corps units, which may be called upon to do anti-aircraft bombing, may have material with which to develop the tactical use of such a bomb, the 20-lb. Practice Bomb has been designed. This bomb consists of a relatively heavy cast iron body equipped with a fin assembly of the same type as the fragmentation bomb, and is fitted with the M107 Mechanical Time Fuze (see Figure 8). A small spotting charge of black powder, contained in a suitable bag, blows the sheetmetal cover from the hole in the side of the bomb body and simulates the burst of a high explosive bomb, but is not sufficient in explosive effect to fragment the cast iron body of the practice bomb. The T10 Fuze is an adaptation of an obsolete artillery mechanical time fuze. The base of the fuze is similar to that of the artillery 21-second powder-train time fuze, containing a base charge of black powder and a primer of the percussion type. The base also holds the movement, which is spring driven and governed by a high-speed vibrator-type escapement. Timing is controlled by the rotation of a disc on the top of the movement containing a firing notch. A trigger mechanism bears against this disc and to fire falls into the notch, releasing a firing pin. Setting is governed by moving the upper part of the fuze to position the setting notch at the proper angle with respect to the trigger. Arming of the fuze is accomplished by a simple spring-ejected arming pin, which disengages from the movement as the arming wire is withdrawn, and allows the movement to turn. There is no delayed arming mechanism for this fuze, since it will be used only in practice bombs, and there is no percussion firing element. The fuze may be set anywhere from 5 to 30 seconds. The 5-second minimum delay is provided to prevent functioning of a bomb within a reasonable distance below the plane dropping the bomb.

23-lb. M40 Bomb (Fig. 9)

During the course of the foregoing experiments the Air Corps introduced a new tactical use for fragmentation bombs in which the bombing was to be done from altitudes as low as 25 feet in order that the screening effect of trees and low hills might be used to hide the approach of the attacking plane. Extensive tests were conducted with the unstabilized body of the 17-lb. bomb equipped with an all-ways fuze and a 5-second delay primer detonator. This arrangement proved unsatisfactory, however, because the bomb usually bounced along the ground under the plane so that at the expiration of the burning time of the primer-detonator the plane was not far enough away to be out of the danger zone. Further, it was found that if the bomb came to rest within the burning time of the primer-detonator it usually lodged in a hollow place

resulting in great loss of fragmentation efficiency. Even though the bomb were on level ground when explosion occurred, it can be seen that the bomb would be lying in a horizontal position and, for this reason, a loss of efficiency would occur.

It was evident, therefore, that two things must be done - the bomb must be retarded so that the plane may have time to get beyond the danger zone of the fragments before the detonation occurs, and the bomb must be exploded while its axis is as nearly vertical as it is possible to maintain it. The most practical way to accomplish these results was to equip the bomb with a small parachute housed within a case that occupies little more space than the stabilizing fins of the high-altitude bomb, and to return to the use of a superquick nose fuze instead of the 5-second delay all-ways fuze. The parachute serves to retard the descent of the bomb for the required time and to cause it to impact with its axis nearly vertical. The super-quick fuze detonates the bomb immediately upon impact, before the vertical position is lost.

This bomb, which was recently standardized as the 23-lb. M40 Fragmentation Bomb, uses the same body as the 20-lb. M41 and M42 Bombs and is equipped with an 8-foot diameter parachute. The parachute is constructed of mercerized cotton airplane fabric and is attached to the bomb by twelve silk shrouds affixed to an eye that screws into the base of the bomb. Horizontal suspension of the bomb is provided for by the usual suspension lug on the side of the bomb body. For vertical suspension a flexible steel cable, attached at two points on the side of the parachute case, terminates in a suspension link above the end of the case.

Inside the parachute case cover, which is removed before the bomb is attached to the airplane, is an inner cover to which is attached a length of flexible steel cable terminating in a swivel loop. When the bomb is attached to the bomb rack, the swivel loop is engaged in the pawl which normally holds the arming wire of bombs of other types. When the bomb is released, the flexible cable withdraws the inner cover from the end of the parachute case and liberates the parachute. Actual withdrawal of the parachute from the case is affected by means of two cardboard discs assembled to a six foot length of silk cord, which is attached to the top of the parachute. These two discs act as pilot parachutes and withdraw the main parachute from the case. From a point somewhat above the lower end of the parachute shrouds, another length of silk cord extends through an opening in the bottom of the parachute case and terminates in a short length of brass arming wire, which is inserted through a hole in the arming pin of the fuze. As the parachute fills with air and retards the

forward motion of the bomb, the arming cord is drawn back into the parachute case and the arming wire is withdrawn from the arming pin of the fuze.

Since the bomb and parachute may be oscillating as a pendulum, and may be at any point of such an oscillation when impact occurs, a specially designed fuze with a semi-allways percussion head is used with this bomb. This fuze, the M104 (Fig. 10), is also provided with a delayed-arming device to prevent functioning of the bomb in case the parachute should fail or for any other reason impact should occur in less than 2-1/4 seconds after release.

The body of the M104 fuze is constructed of aluminum and contains a slider mounted perpendicular to the axis. The slider houses a detonator. A time ring similar to those of the 21-second artillery time fuze is mounted on the upper part of the body and above this is the semi-allways striker head. An initial firing device, consisting of a cocked firing pin and percussion primer, is mounted in the body below the time-train ring. An arming pin assembles through the fuze, and when in position restrains the slider from moving into the armed position, and at the same time retains the initial firing pin in the cocked position. The delayed-arming mechanism consists of a steel pin mounted on the same axis as the slider and between the slider and a disc crimped in the side of the fuze. So long as this pin is in position the slider can not assume the armed position. A flash hole beneath the time-train ring leads to a small black powder charge assembled behind the head of the delayed-arming pin. When the powder explodes, sufficient pressure is generated to shear the restraining disc and allow the slider to arm.

The fuze functions as follows: As the bomb is dropped, the parachute of the bomb is pulled out of its case and in opening pulls the arming wire from the arming pin of the fuze. A spring on the arming pin forces it out of the fuze, allowing the initial firing pin to be forced forward by its spring to fire the primer and ignite the delay charge in the time ring. After burning for 2-1/4 to 2-3/4 seconds, the ring charge flashes down through the hole to the black powder charge surrounding the delayed-arming pin, and the pin is forced out of the fuze. The slider is then pushed over by the spring assembled behind it. The detonator then aligns with the booster lead and firing pin. On impact, the firing pin is forced against the detonator to fire it and the bomb.

17-1b. M37 Practice Bomb (Fig. 11)

This bomb is for target practice use by the air force units

requiring training in the use of the low-altitude fragmentation bomb. It is composed of a parachute unit practically identical to that of the high-explosive bomb and a cast-iron body of suitable weight and strength. It employs the "M104 Practice" fuze, which is identical with the M104 except that all explosive parts but the detonator have been omitted. A pyrotechnic smoke-charge is supplied as a separate unit which may be placed within the after end of the body if desired. When used, the smoke charge is ignited by the flash from the detonator upon impact.

The bomb bodies, parachute units, fuzes, and smoke charges are shipped separately and are assembled in the field as they are required. Though actual target practice may be obtained by use of the inert bomb, without fuze or smoke charge, the complete assembly furnishes training to the ground crews in assembling and fuzing the bombs, and to the bombers in the manipulation of the arming and safety controls of the racks, as well as the sighting and releasing.

No parts of the bomb and parachute are lost in use, and all parts are made sufficiently rugged to stand repeated use under normal conditions. Only the fuze and smoke charge need be renewed. In the near future it is planned to omit the separate smoke unit and supply a similar charge assembled to the base of the fuze as is the booster of the fuze for the high-explosive bomb.

SECTION XIII. PACKING, STORAGE AND SHIPMENT OF AMMUNITION

1. Packing of Ammunition

I. INTRODUCTION.

a. Definition and Explanation of the Subject. The packing of ammunition implies the placing and securing of ammunition and ammunition components in boxes, crates, metal drums or other types of containers for storage or transportation. The subject covers the various kinds of containers, as wooden boxes, wooden crates, metal crates, metal cartridge storage cases, fiber containers and metal containers used in handling and transportation of the ammunition; the methods of packing the ammunition and components in the various containers; the design, manufacture and use of these containers; and proper identification of the contents. In this discussion wooden boxes and crates will probably be referred to, and used as an example, oftener than other types, as they form by far the largest proportion of ammunition containers.

Practically all materials or articles of any sort, particularly small articles, are boxed or crated for shipment from the manufacturer to the storage point or to the person who ultimately uses the article. This is particularly necessary with ammunition, and especially with small parts or components, due to its nature, i.e. a hazardous material which must be protected for the safety of those handling it and to prevent damage.

b. Objects and Purposes of Packing.

1. To Insure Proper and Safe Transportation.- The primary object of packing of ammunition, then, is to provide a means whereby the complete rounds and components of ammunition are prepared to insure safe transportation to point where used, packed in a manner acceptable to the carrier and in form for convenience in handling, storage, transportation and issue to depots or the using Service. Ammunition must be packed safely and securely, due to its hazardous, and some times its somewhat delicate nature to insure as far as possible that it will not be injured in handling or transportation to such an extent that it will cause an explosion. Also it is imperative that the ammunition reach the depots or using Service in an undamaged condition in order that when used as received or when assembled with other components it will function properly, and there will be no question in the mind of the receiver but that

it will function properly. Any visible damage to the components which affect their functioning will cause doubt in the mind of the consignee as to the condition of the remainder of a shipment. The packing must also provide such protection that invisible damage will not occur.

The ammunition should be packed in such quantities and in such amounts that the containers, as far as possible, may be easily and conveniently handled and yet carry the maximum number to allow economy in construction and in the number of containers. In other words, for components that are to be stored or assembled before issue to the using Service, as large a quantity of the various types as can be properly handled, without exceeding maximum quantities that may with safety be packed in one container, should be packed together, rather than small amounts. With ammunition which is to be issued directly to the using Service, the nature of the container, material of which constructed, size, etc., will depend upon tactical requirements and other particular requirements as, convenience in handling, facilities for removing contents, the degrees of hazard involved, the particular type of protection desired, storage or transportation facilities, etc.

2. To Comply with I.C.C. and Other Regulations.- The secondary purpose of packing, or rather a factor influencing the design and method of packing, is to meet the different requirements and regulations for packing and shipping explosives contained in Ordnance Department Regulations, Technical Regulations, Army Regulations and, particularly, the I.C.C. Regulations for transportation of explosives and other dangerous articles. These last named regulations apply, to a large extent, to the Army and Navy, but primarily to commercial shippers of explosives. They will be covered more in detail later.

II. DESIGN.

a. General Policy and Trend in Design.

L. Past.- It has, apparently, been comparatively recently that a great deal of attention has been given to the proper design of packing by commercial concerns, and a large amount of research in the search for suitable and proper containers has been carried on.

The I.C.C. Regulations for shipping explosives, however, have existed for some time and it was required that they be followed. Then, too, it was necessary to pay some attention, more so than with other commodities, to the proper packing of ammunition. During this period the Ordnance Department designed packing which was generally

considered satisfactory and was apparently designed with the idea of meeting the I.C.C. Regulations. Some of these old type containers are still in use for shipment of components of the earlier design and many containers in accordance with recent drawings, follow the general type of construction of the earlier designs.

2. Present.— The general trend followed in the design of boxes and crates apparently seemed to be towards the use of boxes made of standard 1 inch, or heavier, lumber. This trend still exists, although in a good many cases the I.C.C. Regulations would permit the use of thinner material and lighter construction, or containers of a different type. However, the tendency has been apparently, not only to meet the I.C.C. Regulations, but to "go them one better" and not to use material thinner than 1 inch standard lumber (25/32 inch thick when finished on both sides), although there are a few exceptions. This results in a good many cases in boxes and crates much stronger than required. However, consideration has been given to the Ordnance Department's desire to very definitely assure the safe transportation of the ammunition, and to the particular problems in each case to meet the requirements of packing. 1" lumber

Recently a study and investigation of more up to date methods of packing, used commercially, which will provide greater economy with lighter construction and reduction in storage space, have been carried out. In particular, boxes of wire-bound construction using a thin veneer lumber with reinforcing cleats, with strands of wire encircling the box, have been made up and tested in a number of cases with a view to substitution for the standard type of box or crate of heavier lumber. This type of construction will not only be more economical as regards cost, weight and storage space, but it is believed it would be more logical for use in an emergency. The results of the tests indicate that this type of box furnishes suitable protection for the items packed, and it has been adopted as standard in several instances.

Wirebound boxes will probably not stand as much reuse as the heavier wooden box, but their original cheaper cost will probably make them more economical and particularly at times when reuse of the box would not be warranted.

While corrugated or fiber board boxes are commercially replacing, to a great extent, wooden packing boxes, or crates, their use has not been undertaken or investigated to any great extent as a substitute for the wooden boxes in packing ammunition, and probably will not be, evidently because it has been felt that in the packing of explosives it is better to use the safer, stronger,

wood box. There are, however, a few cases in which corrugated board or fiber board boxes are used in the packing of ammunition components. For example, certain pyrotechnics are packed in corrugated board containers, but these are in turn, however, in an outer container of wood. There are also two or three other exceptions. The wooden box, which includes the box of wirebound construction, is the better from the standpoint of long time storage, insurance against tampering, the number of handlings received, marking, and particularly where continued reuse is desired. With respect to this last point they may possibly be more economical in the end. Some investigation has been made on fiber drums for the packing of certain loose explosives as a substitute for metal containers and wooden boxes.

Some types of packing, as, for example, the packing of complete rounds in individual metal or fiber containers, are not required by the I.C.C. Regulations, but have been adopted for reasons peculiar to the particular ammunition or due to the desire to pack the ammunition in a certain way to meet certain conditions, as moistureproofness, or convenience in handling single units, or several units together, after being unpacked from the outer container in which several are shipped together. Such containers are designed without reference to the I.C.C. Regulations, but with reference to the Ordnance Department Regulations and the desires of the using Services to meet the particular purpose for which they are to be used.

b. Drawings and Drawing Policy.

For each container for packing ammunition there is prepared an assembly drawing, and where necessary additional detail drawings, and a packing and marking drawing. The present policy with regard to container drawings, principally with regard to the packing boxes, is that the assembly and detail drawings of a container will pertain only to the manufacture of that container, and that the packing and marking drawing will show the marking of the container and the necessary instructions for properly packing the ammunition and sealing the container. For example, a drawing of the packing box with metal liner for fuzes shows on the assembly drawing three views (plan and side and end elevations) of the assembled box, necessary notes regarding nailing etc.; the List of Parts required for the manufacture of the box and metal liner, List of Specifications, and other pertinent information. If this box has separators the construction of the separators will ordinarily be shown on a separate detail drawing, as will also the construction of the metal liner. All material used in the final packing, as for example, fillers, and instructions relative to packing, shall be omitted from the assembly drawing. The packing and marking drawing will have two representations of the box showing the marking required

for proper identification of the contents, the shipping addresses, marking to comply with the I.C.C. Regulations and other required or informative marking. This drawing also carries packing instructions to cover the method of packing the contents, the final closure of the box and sealing to prevent tampering. A List of Parts and a List of Specifications covering materials used in the marking and sealing of the box are included. Where the packing of the contents is complicated and can not be clearly explained in the notes on packing instructions, a delineation of the box with part in section to indicate the contents in place may be added, to supplement and make clearer the packing instructions.

c. Regulations Governing Design of Container: Packing: Shipping.

1. I.C.C. Regulations.— The Interstate Commerce Commission under act of Congress has formulated a set of regulations, published in book form, covering the transportation by rail in freight, express and baggage services of explosives and other dangerous articles. The Ordnance Department is primarily interested in the portion of these regulations dealing with the transportation of the explosives by freight, as practically all shipments are made in this manner. To aid in carrying out these regulations there has been set up by the American Railway Association, the Bureau of Explosives, which is maintained by the Association and is officially recognized by the Interstate Commerce Commission. This Bureau republishes the I.C.C. Regulations and publishes other regulations, furnishes inspectors, "who are stationed throughout the country to observe, investigate, and report upon shipping methods", and furnishes and publishes information relating to proper packing and shipping of explosives to aid the railroads and shippers. "The carriers utilize the services of the inspectors to enforce regulations and approved practices". Since Colonel B. W. Dunn was head of the Bureau, its republication of the I.C.C. Regulations - which leaves out certain summaries and adds only a list of railroads agreeing to the regulations, with exceptions - has been generally referred to as "Agent B. W. Dunn's Freight Tariff No. 2". It is now referred to as "Agent W. S. Topping's Freight Tariff No. 2".

The I.C.C. Regulations state that "Shipment of explosives offered by, or consigned to, the War and Navy Departments of the United States Government must be packed, including limitations of weight, in accordance with these regulations, or as required by their regulations". In general, in the design of the packing containers for ammunition the requirements for these containers are made at least as severe as the I.C.C. Specifications and in most cases more severe. It is required, however, that the marking on the container for proper classification of its contents for shipping purposes, be in exact agreement with the nomenclatures listed in the subject regulations.

These regulations classify explosives as "Dangerous Explosives, Class A", "Less Dangerous Explosives, Class B", and "Relatively Safe Explosives, Class C, and Non-Explosives Materials", depending upon the degree of hazard involved in the construction of the ammunition and attached to its handling and transportation. The explosives falling under each class are clearly defined and given a definite nomenclature to enable the proper classification by the shipper and by the carrier. Shipping clerks and agents connected with handling shipments for the carriers are trained in the specific nomenclature given under the different classifications and any material deviation from the wording of these designations would result in confusion, and in most cases, probably, in placing the ammunition in at least the classifications next above that under which it belongs, due to the desire of the person classifying to make sure that it would not be placed in a lower classification, or to actual misinterpretation of the erroneous nomenclature. This is the reason why it is required that shipments made by the Army show the proper nomenclature marking for proper classification. These regulations, in requiring packing in certain types of boxes or other containers, in accordance with a particular specification, do not generally require more substantial packing for explosives of the higher ratings.

2. Army Regulations and Technical Regulations.-

General regulations governing the packing, marking and shipping of military supplies are set forth in Army Regulations 30-955. These regulations have a short section relating to the shipment of explosives, which requires compliance with the I.C.C. Regulations for packing and shipping of explosives and covers claims for damage. Regulations for the transportation by water of explosives are contained in Army Regulations 30-1270, which covers overseas shipments of materials by the Quartermaster Corps. Packing and methods of shipping of individual items of ammunition are usually covered in the particular Army Specification which covers this item, although such requirements for packing are usually stated in a general manner.

Methods of packing ammunition and components, and the marking of the containers, are given in Technical Regulations covering the different types of complete rounds of artillery ammunition, grenades, bombs, etc., though this matter is usually descriptive and instructive. However, Technical Regulations TR-1370A, "Miscellaneous Ammunition - Ammunition General", contains, as well, certain paragraphs on packing and marking which are mandatory.

3. Ordnance Department Regulations.-

The Ordnance Safety Manual, Pamphlet No. 7224, under the Section headed "Packing, Marking and Shipping" refers to the various regulations (I.C.C., Army and other special regulations) for the packing of ammunition,

shipping and the marking of the containers for all types of shipment and prescribes compliance with the proper Federal Specifications and regulations, and where necessary, compliance with state and municipal laws and ordinances. This Section also details Safety Regulations for shipments. The Manual, under Sections for each particular item or component of ammunition, prescribes somewhat in detail the method used for packing the component, type of container used, the safety precautions necessary in packing, storage and shipment and marking of the containers. This little booklet contains much valuable information on all phases relating to safety. The Ordnance Office also issues Field Service bulletins which may cover details of packing or shipping instructions of a special nature or which supplement other regulations. Pamphlet No. 2036 - "Service Markings of Ammunition and Ammunition Containers" - has several plates showing the marking of ammunition boxes, but this pamphlet is principally of an informative nature. "The Standard Nomenclature Lists on the various items of ammunition give some information on the containers for the components, with, in some cases, plates showing the marking".

Of all the regulations, which govern packing and have a bearing on the design of containers, the I.C.C. Regulations are the most important, and in the design of new containers, they are followed, due consideration being given to the other factors involved.

d. Testing.

1. Connection with Design.- Whenever a new box or crate or some other type of ammunition container is designed, it may not be known whether the container will be strong enough to carry the contents satisfactorily to meet the Ordnance Department requirements, or the I.C.C. test requirements, although it may meet the construction requirements of the I.C.C. Specifications. Also, it may be desired to determine from time to time whether containers in accordance with old designs, which have not changed and which have not been previously tested, meet the requirements, or, in cases where such containers have actually failed in service, to determine as far as possible the nature of such failure with a view to correction. It may be desirable to determine the strength and satisfactoriness of an existing design before preparing a new design of similar type of construction. Further, it may be necessary or desirable to determine the satisfactoriness of other characteristics of the container.

2. Kinds of Tests.- Where and How Conducted.- In order to determine whether the container is satisfactory or not in every respect, to determine causes of failure, and to get a comparison of

its strength with other types of containers, it is necessary to conduct tests of it. Strength tests should be of such a nature that they give conditions simulating, as far as possible, actual transportation, handling, and storage conditions, and at the same time be of a sufficiently definite nature to afford comparisons of tests between containers of identical or similar types, or of different types. Tests to determine the satisfactoriness of other characteristics, as for example, moisture proofness, may be conducted so that conditions similar to actual service conditions - usually the worst - are met, or an accelerated test, giving conditions of greater severity than would be met in service, may be conducted.

Tests on ammunition containers, principally on boxes and crates, are conducted from time to time by the Packing Section and though the tests are usually mechanical tests of the strength of a container they sometimes include other tests, such as for moisture-proofness, as in the case of fiber containers. Some of the tests are conducted at this Arsenal but usually those on the containers intended to simulate the hazards of handling and transportation are conducted by the Package Research Laboratory of Rockaway, New Jersey, which is a part of the 4-One Box Machine Corporation, Manufacturers of machinery for making a wirebound type of packing box. The tests conducted at the Arsenal are usually drop tests, static tests or packing tests for strength determination, and the other special tests on the various containers. Other tests, of an investigative nature to solve problems connected with packing are also conducted - for example, tests to determine effect on a box of variation of moisture content of the lumber, tests of possible substitutes for shellac varnish. Occasionally, containers loaded to weight, or filled with the proper material are shipped away by freight or truck, to be returned, to determine their ability to withstand actual transportation and handling incident thereto.

The Package Research Laboratory has two revolving drums which are now accepted as standard in the packing industry for tests on packing containers. A small hexagonal drum, 8 feet in diameter, is used for testing small boxes, and principally boxes of corrugated board or fiber board. The large drum, a 14 foot hexagonal revolving drum, is used exclusively for tests on containers for this Arsenal. This drum is similar to a drum of the same diameter developed by the Forest Products Laboratory for testing containers. The drum revolves at the rate of one revolution per minute, the box receiving approximately 6 falls within that time. Four baffles of two different types between sections of the drum, carry the box up some distance permitting it to fall on the side of an adjacent section, the height of fall depending upon the shape, size and weight of the container. The drops range from a drop of a few inches, and a slide along the

floor of the adjacent section, to a drop of approximately six feet, clear across one section onto the second, depending upon the shape of the container and location of the center of gravity. The drops also range from a flat or broadside landing to a landing on one edge or a corner.

The general rule for shipments as stated by the director of the Package Research Laboratory in one of his test reports, is as follows: "A satisfactory container is one which, in a series of five or more tests in the 14 foot drum, fails at an average of not less than 15 drops with no container failing before the 10th drop". He stated that he believed that it was of no use to continue the test on boxes beyond 15 drops in accordance with this definition. However, in tests of containers by this Arsenal, the tests have been run to 30 drops before completion, due to the desirability of obtaining a container stronger than the ordinary. Boxes which stand this number of drops successfully, or can stand well beyond the 15 drops should, according to the definition, be able to withstand any hazards of transportation.

The design and construction of packing depends to a large extent on the nature of shipment and the intended use of the ammunition packed, and falls into the following classes:- Packing of complete rounds of all types or components in containers in which this ammunition will be finally issued to the Using Services; packing of components for inter-arsenal shipment or shipment to Field Depots for use in renovation work or assembly of new complete rounds; and packing of components for intra-arsenal movement or temporary storage pending the assembly into complete rounds.

1. Complete Rounds or Components for the Using Services.- Packed for issue:- Complete rounds are practically always packed in containers in which they will be finally issued to the using Services, even though they may be stored in War Reserve for a number of years. Such storage in the containers used for issue obviates the necessity of transfer from other types of containers at the time it is desired to issue War Reserve ammunition. The design of the containers depends upon the special requirements for issue, convenience in handling, transportation, etc., of the different services using the ammunition. For example, complete rounds of artillery ammunition of the medium caliber are packed individually in fiber containers to afford complete packing and moistureproofness to each round and to permit the handling of these complete rounds in single units. For pack howitzer complete rounds, the size of the box, and weight per box, must be such that they can be conveniently packed on, and easily carried by, the pack animals. Bombs are packed in a manner which permits of convenient handling in transportation, i.e.,

in metal crates or with shipping bands, depending upon the size of the bomb. Certain components of ammunition are shipped as such directly to the using Service for issue separate from the complete round. Examples of those are fuzes for complete rounds shipped without fuzes and components used in making up complete rounds of separate loading ammunition for the large caliber guns, in which projectiles, fuzes, propelling charges and primers are each packed separately. The packing for some of these may be of the same nature as that for components which are shipped from one Arsenal to another, as, for example, the packing for primers or fuzes.

2. Components for Other Arsenals or Depots.- Components packed for shipment to other Arsenals or Field Depots for assembly into complete rounds are usually packed in as economical a manner as possible, the containers being designed to carry the maximum number that may be handled conveniently and taking into consideration the hazard involved in the packing, i.e., limiting the quantity in each container to a certain amount dependent upon the nature and amount of the explosive in the component and its characteristics.

3. Intra-Arsenal Storage.- Complete rounds of ammunition or components assembled at an arsenal, which are to be stored there in War Reserve for shipment at some future time, are packed in the same manner as under the headings prescribed above, standard packing being used for this purpose. Where components are assembled or loaded at an arsenal for later use in assembling into complete rounds at the same arsenal, it is not necessary that these components be packed in the same containers which would be used for interplant shipment, unless the storage of the components is likely to be for some length of time and it is desired to pack them in a moisture-proof container, or there may be a possibility of shipping them out. The standard packing for shipment may then be used, or other improvised packing which will give the same results. Where moisture-proofness is not necessary any type of secure, improvised packing designed by that Arsenal for its own use, may be used.

At this Arsenal such improvised packing is often obtained by using old boxes which may have been intended for another component, or special packing may be designed for use in temporary storage of the ammunition. An example of such type of packing is that for temporary storage of the M20 Booster before assembly into the complete round. The standard packing for shipping this booster was formerly a metal lined box, with wooden separators inside, used for packing 50 boosters. (The present packing consists of individual cardboard cartons in an unlined box). For temporary storage here, fiber containers were purchased which held two boosters each. These containers have a screw cap and are waterproof by dipping in paraffin after the boosters are inserted in each. These containers are then

packed in a hinged box for easy access, and the fiber containers as well as the boxes, may be reused a number of times. In this particular case this method of packing would undoubtedly serve as well for shipping purposes as the previous and present standard packing, though the metal lined box would probably be more convenient on the assembly line.

a. Types of Packing.

1. Boxes - Types.- Boxes for complete rounds of ammunition and components fall under three main types: end opening, chest type or hinged top, and screw top. End opening boxes are square or rectangular in cross section with the width of the sides varying, usually not being greater than 17 inches. The length is approximately 2-1/2 to 4 times that of the greater side. One of the ends is nailed in place, the other being removable, so that the contents may be drawn out longitudinally. This allows stacking in piles on the sides, and with the loose ends of less area than the cross sectional area of the box permits the boxes to be opened without being removed from the pile. With complete round boxes, the loose end is held in place by means of a carriage bolt extending from one end to the other and a wing nut outside the loose end. Another type usually used for pyrotechnics has metal straps holding the loose end in place without the long carriage bolt, but with a wing nut holding the straps against the loose end. Metal strapping is almost always used to strengthen this type of box.

The chest type boxes are of all sizes and are used generally when easy access to the contents is desired and repeated use of the box is contemplated. The top is cleated for strengthening and provided with two hinges, and two hasps and swivels for securing the top. Boxes of the screw top type also are of all sizes and shapes, and differ somewhat in construction. Nails are practically never used for closing the tops of boxes, screws being used to permit reuse of the box and cover. The design of these boxes varies from boxes without cleats and with an under-cut groove on each end for hand holds, to boxes with four cleats on each end. One design of box which may be considered under this class is a box in which the top is secured by means of wing nuts screwed onto hooks fastened into the boards of the sides and ends, the wing nuts fitting into depressions in the top, in order not to project above the surface of the top. This type of box is more easily opened than with the ordinary screw top box and is used in some cases in place of hinged top boxes, in which quicker access to the contents is desired. Rope handles are used on end opening boxes for rounds of the larger caliber, in which the total weight of the box would be too great for handling without handles. They are also used on a few boxes of the

other types, where the weight is excessive and they are desirable due to the handling the box will receive.

2. Crates, Metal and Wooden.- Crates are used for the packing and shipment of bombs and certain components which are of such a size and character that packing in a closed box, with its consequent protection from the atmosphere, is not necessary; and are used to add additional strength and give protection to metal containers in which are packed powder.

Crates are of two kinds, metal and wooden. The metal crates, of steel, are used entirely in the shipment of some of the smaller bombs, where rigidity and great strength are needed for proper protection of the contents, particularly the attached fins, against the hazards of transportation. They also make for convenience in handling the bombs. All other crates are wooden. Their construction varies from the lighter crates of 1 inch lumber, to the very strong crates for certain large caliber cartridge storage cases, made from 2" x 4" and 2" x 6" pieces. The designs also vary, depending upon the article or container protected. More detailed uses of crates will be given later.

3. Cartridge Storage Cases.- Cartridge storage cases are fiber or metal cylindrical containers used for packing propelling charges for separate loading ammunition. The fiber cartridge storage cases used in the past were for war time production, and were used with propelling charges for certain mobile artillery weapons, where a container of great strength was not needed. These wartime containers consisted principally of a spiral or straight wound tube with crimped-on metal ends. A slip cover type of fiber container, similar to that used with complete rounds, has been developed, to replace the metal cases, for both peace time and wartime use in packing propelling charges for the 155 mm Gun and Howitzer and 240 mm Howitzer. The main advantages of the fiber cartridge storage case are: reduction in weight, reduction in cost, increased production, obviates necessity for salvage and reuse.

Of the metal cartridge storage cases the designs are many and varied, due to the difference in size and weight of the contents, different conditions involved and attempts made to improve various designs. The cartridge storage case must be airtight, as well as protect the contents against moisture, and must be able to retain this airtightness over a long period of time in order to properly protect the powder against deterioration. The case also protects the powder against possibility of ignition from heat or sparks. A rubber gasket is provided between the cover and body to procure a proper air seal, and the cover is provided with an air test hole,

by means of which the case, when filled, and closed, may be tested to determine its airtightness. The method of closure usually consists of a spider arrangement on the cover which engages under a turned over flange on the open end of the body - or under lugs on slots cut in a rim band extending above the cover with a screw for exerting pressure through the spider on the cover, holding it tightly in place.

The case, in addition, must be of sufficient strength to carry a heavy load, to provide the necessary rigidity in order to prevent damage to the charge, and to provide, as far as is possible with the weight involved, a means of conveniently handling the charge. Some of the charges for the heavier guns, particularly the single section charges, are very large, weighing over 200 pounds, and require a very strong container to satisfactorily pack them. The steel case then is absolutely necessary. Some of the steel containers are crated to add strength and protect them against rough handling, because of the thin metal of the body. This is particularly true with certain types which have a wooden cover to protect projecting portions of the metal cover. This is an undesirable feature when the cases are not crated, as the wooden cover is larger in diameter than the body of the case and in addition to the possibility of being knocked off, causes trouble in stacking and shipping. In some recent designs a metal rim of larger diameter than the body is welded to it, and projects above all portions of the cover. This protects the closure and when an angle or rim at the bottom is provided, stacking and shipping are made easier. It has been recently decided to eliminate, as far as possible, the use of the wooden shipping cover in future shipment of charges. To effect this change, existing cartridge storage cases to be used for future shipment will be modified by having a rim band welded on to protect the cover, and any future manufacture of cases of this type will include this modification.

4. Fiber, Metal and other Miscellaneous Containers.- One type of container in common use for different purposes, principally for the packing of complete rounds, is known as a fiber container. The complete container usually consists of two tubes (the cover and body) each with one end closed with metal end, and each tube built up of layers of the same or several different paper board materials, secured with proper cementing materials. The thickness of the tubes vary considerably depending on the size, strength and amount of protection desired. The cover slides over a projection of one of the tubes of the body, hence this container is referred to as the "slip cover" type. The name "fiber container" has been taken from a trade name often applied to containers made of certain types of paper board products, though it is believed that the usual application is to boxes made from these materials.

The uses for this type of container are for the packing of complete rounds; propelling charges for separate loading mobile artillery weapons; hand grenades; assemblies of M20 boosters and fuzes; fuzes; etc.

Metal cans, of terne plate or tin plate, are used to a large extent packing individually, or in small quantities, small components of ammunition which it is desired to preserve against moisture. Metal liners for boxes, of terne plate or tin plate, are used in many cases in the packing of ammunition components, or in certain cases for small caliber complete rounds, where moistureproofness is desired. Packing of components in individual moistureproof containers is considered preferable to packing in metal lined boxes.

For packing primers or small fuzes, cartons made up from paper board products, which may be classed as fiber cartons, are used, a small number of the components being packed in each carton. These cartons are not only to provide protection for the component, but using the small quantity as a unit furnishes a means for convenient handling on the assembly line. Where moistureproofing of this type of container is desired, it is practically always done by immersing in hot paraffin, though some other moisture resistant material may at times have been used.

The containers discussed here under "Types of Packing", cover practically all the types of containers used for packing ammunition and ammunition components, but other means for use in packing, or for protection in shipping, ammunition and components, which would not be classed as containers, will be covered under the detailed packing for the ammunition and components in each case.

b. Detailed Packing.

1. Complete Rounds of Artillery Ammunition.- During the World War complete rounds of fixed or semi-fixed ammunition for the medium caliber guns were packed in fiber containers, rather thin walled, with metal ends, and tear strip soldered to the cover and crimped to the wall of the container; or in tin containers. A great deal of the 75 mm ammunition used during the War was packed in 9-round boxes of hinged cover type, and it is believed there are still many rounds left in War Reserve in this type of box. Upon renovation of rounds, in most cases, they are being repacked in the present type of slip cover fiber container and in the 4-round box or 3-round bundle. Packing for certain medium caliber rounds in the past, i.e., prior to, and during the World War, consisted principally of 4 and 6-round boxes, metal lined with screw tops (2.95" Mtn. Gun) and hinged tops (3" Seacoast and A.A. Guns, 4.7" Gun), in which the rounds, not in individual containers, were held in place by spacers; and unlined boxes (2.95") in which the rounds were packed in individual tin containers. Partitions were used even with these individual containers. The end opening box for four rounds made its appearance during the War. This type box was developed by a commer-

cial manufacturer of ammunition and used for the shipment of millions of rounds of ammunition to the British before our entry into the War.

The present policy of packing complete rounds of fixed and semi-fixed ammunition, except small arms ammunition, is as follows: Ammunition for the 37 mm guns is packed with 40 or 60 rounds in a single box of hinged top construction, with metal liner. Ammunition for the 2.24 inch Tank Gun is packed 12 rounds per box, in a screw top, metal lined box. This type of packing, for the 2.24 inch ammunition, has been in use since 1903.

For rounds above 2.24" packing is as follows: The 3-round packing bundle has been standardized for ammunition for the 75 mm Gun, M1897, the 75 mm Pack Howitzer, M1, and the 81 mm Mortar, M1; has been developed for 3" A.A. Gun, M1918 (Mobile) ammunition; and is being investigated for 105 mm Howitzer, M2, ammunition. The end opening packing box is used for ammunition for which the packing bundle has not been standardized. With each type of packing, each round is first packed in an individual fiber container.

The number of rounds packed in the end opening type of box depends upon the size of the round and weight of a full box. Rounds for the obsolete 75 mm Infantry Mortar were packed six in a box, those for the 105 mm Howitzer and 105 mm Anti-aircraft Gun are packed two in a box, rounds of 81 mm Mortar M43 and M44 (short) shell are packed eight per box. Rounds for other weapons are packed four per box. Rope handles are used on the heavier boxes to permit convenient handling by two men.

The adoption of the bundle method of packing complete rounds was the result of considerable investigation and test at certain posts. Tests were conducted by the 1st Cavalry Division Board with ammunition carts, in which some of the rounds in fiber containers were put up in bundles of six rounds, wrapped with hardware cloth with wooden or metal ends for the bundles, and with and without flat metal strapping around the containers. Tests at Aberdeen Proving Ground covering investigations of the limber for the 75 mm Pack Howitzer and of the ammunition trailer T8 included bundles consisting of three rounds in containers held together only by steel strapping.

As a result of these tests and investigation of other means of making up a bundle, there has been developed a special, cupped metal end for use in bundle packing. The bundle, then, consists of two of these ends connected by means of a carriage bolt and wing nut

which hold in place three fiber containers with the complete rounds packed therein. The ends are of clover leaf design to permit nesting of bundles and as much utilization of space as possible. A flange around the edge protects the wing nut, and furnishes a hand hold. The drum tests conducted on this type of packing indicate it is satisfactory for packing complete rounds. Several rail shipments of 75 mm Field Gun ammunition, packed in bundles of this type, arrived in good condition. The designs of end plate and other accessories for 105 mm Howitzer ammunition have been developed, and these accessories satisfactorily withstood the revolving drum tests. Because of the weight of the complete rounds, the bundle for this weapon has been designed as a two-men load.

The use of packing bundles results in the exposure of the fiber containers to the elements and eliminates the protection afforded by the boxes, but test conducted at Fort Bragg on bundles in the open indicated that exposure of the fiber containers to the weather did no result in detriment to the containers themselves or the rounds which were packed therein.

The packing of complete rounds in bundles will, in most cases, result in a saving in shipping and storage space, a reduction in weight with consequent saving on freight charges, and a reduction in cost of packing material. In some cases, the three round bundle will be more convenient to handle than the four round box, the more handling will be necessary. Adoption of the bundle, in place of the present heavy box, where possible, indicates a desire to facilitate transportation in vehicles used by the artillery and handling by personnel, and to eliminate what is considered excess packing material.

The fiber container now used is of the slip cover type, in two parts, the cover and body, each with a metal end ofterne or tin plate. The cover is made of one tube while the body is composed of three separate tubes glued one within another - an inner tube, intermediate tube and outer tube. The outer tube of the body is identical in construction with that of the cover tube and is built up of layers of different types of waterproof paper board materials, as asphalt impregnated Kraft paper and waterproof container board, several of which contain asphalt in their makeup, and it is the main moisture resistant and waterproofing part of the container. These tubes are made of a thickness sufficient to provide proper moistureproofing and to give, with the intermediate tube, proper strength to the container. The thickness is approximately the same on all sizes of containers.

The intermediate tube is usually of about the same thickness as the outer tube and provides additional strength to this tube as well as forming an extension over which the cover tube slides. The end of this tube also carries a ring which supports the complete round, in the case of fixed rounds, by means of the overhang of the cartridge case. With semi-fixed rounds the base of the cartridge case is usually raised slightly above the ring. The inside diameter of the intermediate tube is such that it allows only a slight clearance over the diameter of the cartridge case just in front of the base. With a tapered cartridge case the inside diameter of the container near the front end of the case is a great deal more than the outside diameter of the case. The container must furnish its own support along the length of the cartridge case. This intermediate tube is made up principally of layers of chipboard glued together.

An inner tube made up of several layers of chipboard and waterproof container board (which is two plies of chipboard with asphalt between) is glued inside the intermediate tube and extends from the metal end of the body tube to a point just in front of the rotating band of the projectile. This tube is of a little larger diameter inside than the bourrelet of the projectile and furnishes the support for the projectile to prevent its working loose from the cartridge case due to shaking around in the box, during transportation. This tube also strengthens the container and at the projectile end prevents mashing in of the tube, the projectile here furnishing some support. The thickness of this inner tube depends upon the amount of taper of the cartridge case, and in the case of the 105 m/m antiaircraft ammunition, particularly, it is about 9/10 inch.

In working up the design of the new type of slip cover container it was found that some means for supporting the projectile in the case of semi-fixed rounds to prevent longitudinal movement in the cartridge case would be necessary. For this purpose wood supports, of cylindrical shape with conical opening fitted to take the nose of the projectile or the fuze, were designed to be placed at the closed end of the body tube. In order to strengthen containers for fixed rounds, the wood support was used also in the containers for these rounds. These supports were at first designed to be removable so that the same container could be used for different rounds by insertion of a different support. This caused difficulties, so the supports were glued and nailed within the inner tube, the nails passing through this and the intermediate tube. After the containers had been in use for some time it was decided to determine whether or not the wood supports were necessary to strengthen the containers. Tests were conducted and it was found that containers for fixed rounds, manufactured without the wood supports, gave

sufficient strength. Accordingly, new drawings have been prepared covering fiber containers for fixed rounds in which the wood supports have been omitted. This has enabled, in some cases, a considerable shortening of the container.

With semi-fixed rounds, the projectile is supported, by its nose or fuze, on the wood block. The mouth of the cartridge case rests on the rear of the rotating band, and the container is so designed that when the cover is put on tightly and secured by the adhesive tape, the base of the case is still a short distance above the ring on the intermediate tube. This, then, prevents longitudinal movement of the projectile in the case.

When the M39A2 Fuze, or fuze of similar profile is used with 75 m/m Pack Howitzer and 105 m/m Howitzer ammunition, if packed in a container with a wood support with an opening turned to fit the fuze, there would undoubtedly be a wedging action and the fuze with projectile attached would wedge into the support and not come out with the cartridge case upon its removal from the container, but remain inside until force is exerted to remove it. To prevent this, a metal "gadget", called "packing stop", has been designed. This consists of two pieces of brass joined together by means of spring steel. The brass parts have projections which fit into the wrench slots on the fuze. A portion of the upper surfaces makes contact with the shoulder of the wood support. This prevents the projectile from wedging in the support, the brass pieces being of such shape that the inner tube of the container holds them in place. Since the two stops are joined on one side only, when they are brought past the inner tube they are actuated by the spring steel and forced out of the notches falling off of the projectile as it comes out of the container.

To place the round in the container is a rather difficult operation, requiring the use of twine and a certain amount of expertness in its performance. An objection to this method is that in the field when it is desired to replace unfired rounds in containers for further transportation and future use, the operation must be performed by troops who may not be skilled in the method, and the time may be limited. As the result of investigation and tests, a type of packing stop was developed which, it was believed, overcame the objections to the present type. This stop is automatically released from the projectile upon removal of the round from the container, and can be placed easily in position on the projectile when it is desired to return the round to the container.

The design of the automatic packing stop was considered unnecessarily complicated, and it was indicated by Field Service that a stop requiring manual removal would be satisfactory. A U-shaped stop of flat steel, heat treated, gave satisfactory results in drop tests, and following service test of caliber board orders of complete rounds, packed with stops of this design, it has been adopted as the standard for use with 75 m/m Pack Howitzer complete rounds.

Complete rounds of blank ammunition are packed individually in fiber containers which are of the same general design as the fiber containers for complete rounds, except that the body of the container is composed of only two tubes. These rounds are then packed in hinged top boxes carrying from ten to one hundred rounds, depending upon the caliber. This type of box permits reuse and easy access to the contents.

2. Other Complete Rounds.- Bombs, Grenades, Pyrotechnics.- Packing provided for the standard bombs is of two types. The 30-lb. fragmentation, and 100-lb. demolition bombs are packed with fins attached, in metal crates, two of the former and one of the latter to each crate. The components for the bombs - fuzes, swivel loops, safety clips, arming wire, primer detonators - are packed in an accessory tray in each crate, or otherwise secured in the crate.

The 300-lb., 600-lb., 1100-lb., and 2000-lb. cylindrical demolition bombs, now standard, are shipped without fins, and with shipping bands around the body for ease in handling, and to protect the suspension lugs. The fins for these bombs are packed one each in a wire-bound box, in which there is also packed an accessory box of the same type of construction, containing the other components for the bomb. Packing for the formerly standard bombs of the stream-lined type is similar, except that the 2000-lb. bomb is shipped without suspension lugs, since these are assembled in the field; and the fins and accessories are shipped in crates of 1 inch lumber. A wire-bound box was adopted for the 300-lb. Mk. IMI bomb fin and accessories before investigation for use with the new types.

The packing just described for the standard bombs is for war time shipment. For peace time shipment, the fuzes are packed in bulk and are issued directly to the organizations in this manner. The fuzes of the type which use the Mk. IIB primer-detonator are shipped inert. Primer-detonators used in these fuzes are also shipped in bulk for assembly into the fuzes at the time the latter are placed in the bombs. Adapter-boosters are shipped assembled in the loaded bombs.

The M36 Practice Bombs (Miniature) are packed, empty, in wire-bound boxes, with the cartridges shipped in bulk. The M37 Practice Bomb bodies and parachute units are packed separately in wooden boxes.

The non-standard bombs, 17-lb., 25-lb., 40-lb., 50-lb. and certain 100-lb. and 300-lb., are packed in boxes or crates, ranging from five to one per package. The components are shipped in different ways, in a few cases certain ones are assembled to the bomb for shipment, but most are shipped in bulk.

Grenades were formerly packed in three ways: (1) With the grenades and fuzes or other components each in a separate compartment of the same box. (2) With the grenades and grenade fuzes each in separate boxes. (3) With the grenades shipped fuzed. The Mk. II fragmentation hand grenades, assembled with fuzes, - H.E. and practice - were packed 10 in a box, with metal liner. The present standard packing for the Mk. II practice and fragmentation hand grenades, and chemical hand grenades, consists of individual fiber containers for the fuzed grenades and unlined wooden boxes holding 25 grenades.

The fiber containers were developed to permit retaining the grenade as long as possible in such a manner that the firing mechanism is not exposed and is thereby kept protected against accidental operation, and at the same time to provide moistureproof protection to the grenade during this period. This will permit carrying the grenade in the belt, and consideration has been given to this feature. The grenade need only be taken from the container at the time it is to be used. This container is similar in construction to complete round fiber containers and is water-proofed by sealing the joint with adhesive tape after packing.

Pyrotechnics are packed in various ways depending on the nature of the material, size, shape, etc. Small smoke charges are wrapped in a cylindrical waterproof bundle and several of those packed in an unlined box. Certain air and ground signals are packed in corrugated board cartons, waterproofed, several cartons are packed in corrugated board carton containers, then one of these in turn packed in a box, usually of the end opening type. Aircraft parachute flares, which are considerably larger than the signals, and vary in size, are packed one or two to the box. For the M8 and similar flares, the formerly standard box for the two flares was rather an elaborate affair, with padded spacers, for holding the flares in place, padded ends and a wedge on one side for tight packing.

The M8A1 Flare is now packed, without suspension bands, in an individual fiber container, similar to that for complete rounds. This type of packing for the flare is considered moisture proof and equivalent to hermetical sealing, and for this reason when flares are packed in this manner, the life is indicated as six years, whereas with the previous type of packing it was only three years. When the fiber container was first adopted, two flares were packed in the old two-flare box, with the elaborate spacers removed. The present practice is to pack the flares in single-flare wirebound boxes, without suspension bands. Where required, the suspension bands are shipped in wirebound boxes, twenty per box.

3. Components.

(a) Policy on Packing of Empty Components.

Although at one time drawings were prepared to cover the packing for certain empty components, as cartridge cases, projectiles, etc., the present policy is that packing for empty components of ammunition will not ordinarily be provided. For commercial procurement, any type of packing may be used which will be acceptable to the carrier and will insure safe transportation of the articles. This is in line with requirements for packing given in specifications relating to other types of material for the Government.

There are certain exceptions to this policy with regard to packing of empty metal components which apply to certain articles in general or in specific cases, for example, packing is prescribed for the peacetime shipment, in bulk, of certain inert bomb fuzes, (previously discussed) from the manufacturer to the organizations. In this case the type of packing is prescribed to insure the proper protection to the components, due to their nature and possibility of damaging the fins, and also because the fuzes are issued as shipped originally, and the packing must meet the requirements of the using Service.

In the particular case of adapters and boosters, or bomb adapter-boosters, the metal parts are usually made at Frankford Arsenal or taken from renovated rounds, and loaded at Picatinny Arsenal, (peacetime manufacture). In the case of those in which the metal parts are shipped here from Frankford, the same packing is used as is used after the parts are loaded for shipment elsewhere, as this avoids the necessity of having two kinds of packing for shipping the same item. Frankford Arsenal then makes the boxes or uses boxes sent in by Field Depots where ammunition has been renovated and ships the empty components in these boxes.

Practically the same procedure is followed in the case of primers. At the present time Frankford Arsenal makes practically all primer bodies and primer percussssion elements. The empty bodies are shipped to Picatinny Arsenal for loading in the same cartons, or cans, and packing boxes which are later used for shipping the loaded components, the metal lined boxes being not sealed except that when the primers are to be used for assembly into complete rounds at this Arsenal, the bodies, in the cartons, are usually shipped in corrugated board boxes. The percussion elements were formerly assembled to the bodies for shipment, but are now shipped separately in paper tubes and corrugated board boxes.

Although the shipment described above for empty adapter boosters and primer bodies are special cases for peacetime requirements, the same procedure may be followed in time of war in certain cases for shipment of empty components from a metal components plant to a loading plant.

Empty 3 inch A.A. projectiles have been shipped in corrugated fiber board containers, 6 projectiles to a container. Such packing, of course, furnishes very little support to the projectiles, which need none, but supplies the proper protection to the rotating bands and furnishes a means of handling a number as a convenient unit. In the future, following a recent decision, all empty projectiles up to and including 105 mm will be shipped in solid fiber containers. This requirement will be provided for in the specification. Cartridge cases are often shipped in corrugated fiber boxes, to facilitate handling and protect the cases.

(b) Projectiles.- The methods of shipping projectiles are in boxes, in crates and unpacked with rope grommets. In the case of small or medium caliber projectiles, if the shell loading plant is not at the same location as the complete round assembly plant the loaded projectile will probably be shipped to the latter from the former in boxes with adapter closing plug inserted in the projectile to keep out dirt. However, this is not a condition desired as it is preferable to have the shell loading and complete round assembly plants at the same location. Considering only field shipment, the only case where loaded projectiles are boxed is with the 155 m/m Shrapnel, which are shipped fuzeed and must be boxed for protection to the fuze, and due to lack of convenient means of handling these projectiles individually.

All other separate loading projectiles are shipped crated or with rope grommets, eye bolt lifting plugs being provided with

point fuze dummy projectiles, in addition to the grommets, to facilitate handling. The shipment of projectiles, depending upon the type, will be made, in general, in accordance with the following basic rules; point fuze shell with fuzes or false ogives will be crated; point fuze shell without ogives - rope grommets and eyebolt lifting plugs; base fuze shell with fragile parts, as false ogives, steel caps, and windshields - crated; base fuze shell without fragile parts - rope grommets; dummy projectiles - crated; cast iron projectiles - rope grommets.

The rope grommets used with projectiles are for the purpose of protecting the rotating band during shipment and storage to prevent scarring or serious deformation of the band which might affect the ballistics of the projectile. These grommets are of two types, one in which an eye or loop is spliced into each end of a short piece of rope, and the ends tied together by means of twine after placing the grommet around the rotating band; and another type in which the ends of a short piece of rope are spliced together to form a ring of the proper size. The former type is more easily applied or taken off as it can be easily tied and untied, but is apt to have one point, where the two ends do not come together, where the band is not properly protected. The latter type gives more uniform protection to the rotating band all around, but is harder to remove and replace on the projectile (an operation which is often necessary during the painting of the projectiles). Eye bolt lifting plugs are used with point fuze projectiles which are shipped unfuzed to aid in handling and are of sufficient strength to take the weight of the projectile.

(c) Fuzes.- Fuzes are packed in individual metal or fiber containers or in metal lined boxes which are hermetically sealed for protection against moisture. Exceptions to this are: (a) Inert bomb fuzes, which are shipped in unlined boxes, no protection against moisture being needed due to the absence of explosives; (b) Grenade Fuzes, which in the past have been packed in unlined boxes, but for which packing consisting of fiber cartons similar to those used in the packing of primers has been designed for future use; (c) M38 minor caliber base detonating fuzes, which are packed in a fiber carton.

For 21-second fuzes, a metal-lined box has been adopted as standard in place of the former type of individual packing can. An investigation and contact with a commercial manufacturer have resulted in the development of an individual packing can of a commercial type for use in packing these fuzes, in cases where individual packing is desired. A number of cans were purchased

for use on a production order and actual packing of fuzes in the cans indicates that cans of the design furnished should be satisfactory.

(d) Adapters and Boosters and Adapter-Boosters.-

Ordinarily adapters and boosters, and adapter-boosters for bombs, of a type which consists of a metal adapter and a booster casing with tetryl loading, are packed in unlined boxes with separators for supporting the adapters and boosters. Liners are not considered necessary for this type of adapter and booster as the component itself is sufficiently waterproofed. For packing boosters of a different type in which there is a detonating element, in addition to an explosive charge - as for example, the M20 Booster, - metal lined boxes are used, as in the case with detonating fuzes. Since these components are shipped only from the loading plant to complete round assembly plant, they are packed in as large a quantity as can be conveniently handled, although some of the boxes of bomb adapter-boosters weigh over 300 pounds.

(e) Primers.- Primers for domestic shipment, i.e., in the continental limits of the United States, are packed in cartons made of paper board materials, as chipboard, strawboard, news board, etc. in quantities of ten or fifty, depending upon the size of the primer. These cartons are hermetically sealed by dipping in paraffin or by use of some other material; for example, cartons in the past have been waterproofed by painting over with shellac. These cartons are then packed in metal lined packing boxes for additional protection against moisture. The packing of primers in small quantities in the cartons provides an easy and convenient means of grouping them for packing and for use in the loading plant and on the assembly line. For certain primers, packing in tin containers in place of, or in addition to the carton is provided, for additional protection, or in some cases as indicated, for overseas shipment. The same quantities are packed in the tin containers as in the cartons. These are in turn inclosed in a box without metal liner.

The waterproofing of the individual cartons, although packed in a terne plate lined box, serves as an additional precaution in case a box may be left open for some time. The packing in the tin containers instead of cartons insures the moistureproofing of the primers in the small containers after the box is opened, as the metal containers furnish more positive protection from moisture than the paraffined carton. This permits moistureproofing of the primers in a damp climate until each small container is opened for actual use on the assembly line. The boxes are of the size for convenience in handling and economy of material without containing an undue

amount of explosive. Primer-detonators for bombs are usually packed in tin containers, the Mk. IIB in the same container for bulk shipment which is used for complete round shipment in the bomb crate or tin crate.

4. (a) Smokeless Powder.- For shipment of loose smokeless powder for cannon, there are provided two metal lined boxes in which the lining is of zinc or copper, usually the former; one of 110-lb. capacity and the other 140-lb. capacity. The 140-lb. capacity box has been recently redesigned, by sloping the sections of the liner top toward the opening, to facilitate emptying the box. Small steel boxes, or more correctly drums, are used for the shipment of ballistic samples from one arsenal to another.

An all steel propellant powder box of the type used by the Navy Department has been in use for some time in the shipment and storage of powder within the Arsenal, and has recently been adopted for use for inter-plant shipment of propellant powder.

Propelling charges for separate loading ammunition from 155 mm and up are packed in cartridge storage cases for shipment, storage and issue to the using Service. Fiber cartridge storage cases are now standard for the 155 mm Gun and Howitzer charges and 240 mm Howitzer charges. Fiber cartridge storage cases are packed for shipment in 3-round bundles, in the same manner as complete rounds in fiber containers. For the other calibers, steel cartridge storage cases are provided. These have been covered more in detail previously. For packing in the cartridge storage cases, propelling charges are classed as single section, base and increment, or multi-section or aliquot parts. Depending upon the length of container used, size of the charge, etc., the charges are packed in the containers with from five charges to the case to as many as four cases for each charge. The aliquot part and multi-section charges are used with the heavier guns, where, due to the weight and for ease in loading the gun, it is necessary to divide the charges, although single section charges have been used with as high as 16 inch guns.

(b) Black Powder.- For the shipment of black powder, sheet steel cylindrical drums of 25-lb. capacity are provided. These drums have circumferential corrugations in order to strengthen the walls and have an opening on one end for filling and for removal of the powder. The standard type has an oval shaped opening in the center of the end and is fitted with bronze slides, in which the oval shaped cover of steel, with felt paper secured to the lower side, is slid into place and fastened. These containers are formed with a double lock seam running vertically, where the two edges of metal are joined, which is intended to be moistureproof. How-

ever due to the thinness of the metal and rough handling often received, seams loosen up in many cases and allow sifting out of the loose powder and entrance of moisture. To prevent this, a cloth bag is used for powders for the finer granulations, the bag being placed inside the drum, filled with powder and then tied before closing the drum. Regulations prescribe that black powder drums for overseas shipment shall be crated, two drums per crate being the usual method.

Black powder charges in bags, made up as practice charges for bombs or projectiles, are packed sometimes in metal lined smokeless powder boxes of 110-lb. capacity with proper markings to indicate the contents, and are sometimes packed in cartridge storage cases. They may also be shipped in the metal powder container. There may be left in storage some black powder (loose) in 50-lb. metal containers or in the 110-lb. smokeless powder boxes, but after using the powder in these containers, they should not be again used for this purpose.

5. Loose Explosives.- Loose TNT, Explosive "D", or tetryl are usually shipped in a standard packing container for these explosives which consists of a rectangular box of 5/8-inch lumber, corner locked and glued, and complying with I.C.C. Specification No. 14, or in a box of nailed construction, with heavy ends, complying with the same specification. Heretofore, the boxes were lined with strong paraffined paper, or other waterproofed paper, in such a manner that there were no joints at the bottom or sides. I.C.C. regulations now require a strong, sift-proof cloth or paper bag as a liner for these boxes. Some Explosive "D" now in storage, packed prior to the adoption of a standard container, is packed in wooden kegs of 100-lb. capacity, lined with a strong paper bag or in paper-lined boxes of 50-lb. capacity.

IV. MANUFACTURE.

a. Materials Used.- The materials required for ammunition containers and for use in packing are numerous and varied, and to use or prescribe them requires at least a general knowledge of their make-up and uses. The principal materials used in the construction of the containers themselves are: lumber for boxes and crates; plain lumber or plywood for separators inside the boxes;terne plate and tin plate for metal liners of boxes, individual terne plate or tin plate cans for packing components, fiber container ends, etc; steel for cartridge storage cases and other metal containers; zinc or copper for smokeless powder box liners; paper and paper board products as chipboard; kraft paper, waterproofed kraft and chipboards, for manufacture of fiber containers and

cartons. Other materials used as portions of containers or inside the containers or for other purposes connected with packing, and materials used in marking boxes are: strawboard, chipboard, and other paper products used as fillers in packing boxes; paints, inks, and related materials used for marking, waterproofing or protective coatings; paraffin, used for waterproofing; rope for grommets for projectiles and packing box handles; rubber for cartridge storage case gaskets.

Although a few drawings may call for certain proprietary articles or methods, the Ordnance Office has adopted the policy to be applied to new drawings and revisions of old drawings, of omitting reference to a proprietary article or method. Where the possible use of a proprietary article is desirable, a note is added to the effect that "any suitable substitute approved by the Chief of Ordnance may be used".

b. Strategic Materials and Substitutes.— Certain materials used in the manufacture of ammunition and ammunition packing are classed as strategic materials. Where possible, substitutes are to be provided for these strategic materials which will be suitable for use in their place. If no substitute is entirely satisfactory, a material will be provided where possible for use in place of the strategic material if, during a period of emergency, the strategic material becomes unavailable. On the drawings the substitute may be called for as the standard with the strategic material as alternative, or vice versa, depending on whether the two are on about equal terms, or the strategic material much better. A study has been made, and some work has been done in the past, towards eliminating strategic materials in connection with packing, or determining suitable substitutes.

Materials used for packing of ammunition which are classed as strategic are: Antimony, tin, rubber, shellac, sisal, jute, and manila fiber. Tin is used in soldering and in tin plating on ferrous sheets. Principal uses for tin plating are box liners, fiber container ends and rings and metal cans. One of the substitutes proposed in the place of tin plate, and specified as the standard on drawings, isterne plate. Another substitute is shellecking or parkerizing of the black metal sheets, or use of some other protective coating which will prevent rusting. Tin as a component of solder, has not been entirely eliminated, though its proportion is reduced by using a solder of low tin content. Antimony, which is sometimes used in solders, can be eliminated by the use of solders not containing this material. Manila fiber, jute, hemp, and sisal are used in the manufacture of rope which is used as rope grommets or packing box handles. Rope handles on packing boxes may

be eliminated by using cotton wobbling, metal handles, undercut grooves, or cleats, though the grooves and cleats are not in some cases suitable substitutes. An investigation was conducted on a fiber grommet for projectiles as a substitute for the rope grommet but this particular material investigated was not suitable for this purpose. Possible substitutes for this type of grommet are heavier cotton rope grommets, although this type grommet is not considered very satisfactory. Shellac varnish is used over the paper seals in the seal recesses of packing boxes, and as a protective coating on such items as data tags and labels. Following investigation to determine a suitable substitute for shellac varnish which included investigation of commercial varnishes of a non-strategic nature, phenol formaldehyde resin (bakelite) varnish has been adopted as standard, to replace the shellac varnish, with the latter as an alternative.

V. PACKING, SEALING AND MARKING.

a. Packing and Sealing Containers.- Under the latest system, the packing and marking drawing will give instructions covering the packing and sealing of the containers. Where the arrangement of the contents is not complicated detailed instructions are not given, the arrangement of the material being obvious. The contents are placed in the container in the prescribed manner, and in the case of boxes principally, the necessary fillers are added to insure tight packing of the contents. Where the packing is complicated, detailed instructions are given, and if necessary, a delineation of a portion of the contents in place to supplement the instructions is added, to insure proper placing of the contents.

Individual metal containers for components, metal cans and liners for a number of components, and other metal containers for materials, where such packing is intended to be moistureproof and airtight, are tested for airtightness after sealing the containers, by means of an air testing apparatus and gauge, using a small air test hole in the container. After the test, this hole is sealed with solder, or a plug. The usual pressure used in testing is 2 pounds per square inch. Fiber containers and fiber cartons can not be air tested, but methods are used for sealing them which are based on procedure established after experimentation.

Each container, after the contents are properly packed, is sealed in some manner which will indicate, before it is opened for issue or use of the contents, whether or not the container has been tampered with. The method of sealing depends upon the type and construction of the container. With screw top and hinged top boxes, paper seals are placed in large counterbores in the top and bottom

of the box and covered over with shellac. A screw under the seal fastens the top or bottom boards, and it is access to this screw without indication which the seal prevents. Where metal strapping is used around boxes of these types, the paper seals are not necessary and will not in future be used.

Hinged top boxes are also sealed by means of car seals, one with each swivel and hasp, which principally serve the purpose of securing the hasps in place. These seals are used also with end opening boxes, for sealing the loose end, these boxes having strapping around the sides which serves the purpose of a seal there. Car seals are used also with cartridge storage cases and packing bundles.

b. Marking of Containers.- All outside containers, or items of ammunition shipped without packing (as the larger bombs shipped with shipping bands), must be properly marked by painting, stamping, or stenciling. This marking is for the purpose of furnishing certain essential information "to permit an intelligent handling, storage and issue of the round or component", and to do so must properly identify the contents. Such information includes the following name or nomenclature of the items or materials packed with proper descriptive information, quantity packed, lot number, month and year packed, gross weight of container and contents, cubical displacement, Ordnance Insignia (indicating Ordnance property), Ordnance Escutcheon and inspector's stamp (to indicate proper inspection), marking to comply with the I.C.C. Regulations for proper classification of the contents, and shipping addresses.

Boxes and crates are marked as follows: A complete description of the contents with lot number and date packed is given on one side. The other side is used for shipping addresses and other shipping data and the lot number is also included. The ends are marked with lot number, Ordnance Insignia, and as complete a description of the contents as space will permit. This should be as complete as possible, as boxes are generally stacked in stores with ends out. The marking on the top consists of lot number, Ordnance Escutcheon and inspector's stamp, and I.C.C. identification marking. This identification marking must be identical with one of the items in the lists of explosives given under each classification, but may be amplified - by adding after the proper I.C.C. Marking. Steel cartridge storage cases are marked in a similar manner.

c. Data Cards.- Data cards are prescribed for use with all items of ammunition containing explosives, except loose explosives in bulk, and are usually required by specifications for

non-explosive materials procured for use with ammunition. One data card is placed in every box (two in metal lined boxes, one inside and one outside the liner) and one attached to every crate, or large item inclosed in a crate. Cards attached, which would be exposed to the weather, are inclosed in a waterproof envelope. The data card gives all necessary information for proper and complete identification of the item or component - lot number of the metal part or parts and lot numbers of the various components, manufacturer of each, date manufactured or loaded, name of loader, date assembled or loaded, etc., number in lot.

VI. CONCLUSION.

An endeavor has been made to cover the subject of the packing of ammunition and ammunition components in all phases, with the standard and accepted methods of packing more or less given in detail, to present a view of this broad subject as comprehensive as possible in the time allotted. Experimental packing has been given also where it helps to amplify the subject or to stress certain points. General methods of packing the ammunition and specific methods and types of packing are indicated and prescribed in several places - Ordnance Safety Manual, Standard Nomenclature Lists, different regulations - but to determine the exact nature and construction of the packing used for a specific item, it is best to refer to the latest drawings covering the packing of the item, and to the drawing covering marking of the container for the proper and exact marking.

REFERENCES

Lecture: "Past and Present Practice of Packing Complete Rounds of Artillery Ammunition",- S.P. Lewis.

Regulations for Transportation by Rail of Explosives and Other Dangerous Articles in Freight, Express and Baggage Services, Including Specification for Shipping Containers", I.C.C. Regulations, (or "Agent B.W. Dunn's Freight Tariff No. 2"; Bureau of Explosives Publication.)

Army Regulations 30-1270, "Transportation by Water of Explosives, Inflammables, and Chemical Warfare Materials".

Ordnance Safety Manual, Pamphlet 7224.

Complete Round Charts.

Technical Regulations TR 1370 A "Miscellaneous Ammunition-Ammunition, General".

"Service Markings of Ammunition and Ammunition Containers" Pamphlet #2036.

Sketch GA 1360 - "Packing Data for Bombs and Bomb Components - Complete Round or Component Shipment".

Sketch GA 1370 - "Standard Packing for Standard Service Rounds".

Standard Nomenclature Lists.

Training and Technical Regulations.

SECTION XIII. PACKING, STORAGE AND SHIPMENT OF AMMUNITION.

2. Storage of Ammunition.

Regulations governing the storage of explosives and ammunition at Ordnance Depots are contained in the Ordnance Safety Manual No. 7224, 1931. However, paragraph 45 b, Section IX, "Storage" of the Manual, states that Manufacturing Arsenal, which have the older type of magazines and which cannot comply with the regulations set forth in the Manual, will comply with the spirit of the regulations and endeavor to obtain the maximum protection against fire and explosions, and to limit deterioration to the minimum, provided, however, that the Commanding Officer must make a specific written report of any mandatory requirements which he may consider impossible of application at his establishment. Further, he is authorized, in fact urged, to prescribe and enforce such additional safety regulations as may be needed to meet local conditions which are not covered by the general Safety Regulations.

The Quantity--Distance Tables contained in the Ordnance Safety Manual as well as the Storage Chart, which shows the explosives, ammunition, etc. which may be stored together, are unconditionally followed by Picatinny, although the "Types" of magazine prescribed for the storage of various commodities cannot be used as they do not exist.

Safety measures, which are considered especially vital in connection with the storage of explosives and ammunition, are as follows:

- (1) Containers must not be opened or repaired in a magazine. This work must be done either in a building specifically set aside, or in the open at least one hundred (100) ft. from a magazine.
- (2) Explosives and ammunition in open or damaged containers must not be stored in a magazine.
- (3) Loaded material must be protected against extremely high temperatures, (over 85°F.) and as far as possible against sudden changes in temperatures. (The latter may damage air tight containers or may result in excessive condensation of moisture in the air.) If the temperature in a magazine exceeds 100°F. for

a period of more than twenty-four (24) hours, the magazine must be cooled by wetting the exterior of the building with water or by opening doors and ventilators after sunset and closing them in the morning. If this method fails the Commanding Officer must decide whether the stores are to be removed and if so report such case to the Chief of Ordnance.

- (4) Containers must be free from dirt and grit before being placed in a magazine.
- (5) Dry grass, leaves, and underbrush, capable of being ignited by sparks from locomotives, smoking, etc., must be cleared for a space of fifty (50) ft. around all magazines.
- (6) Inflammable dunnage, crates, etc., will be eliminated or reduced to the minimum in magazines containing separate loading, unfixed shell and demolition bombs.
- (7) As Black Powder is regarded as one of the worst known explosive hazards, the following rules should always be kept in mind.
 - a. Never use tools or equipment made of metals which may cause sparks, in a Black Powder Magazine.
 - b. Wear safety shoes or rubbers. (When handling loose Black Powder rubbers are prohibited, due to the probability of building up body charges of static.)
- (8) High explosives in boxes must be handled with care and personnel should wear safety shoes although the use of same is not definitely required in regulations.
- (9) Smokeless Powder should be closely observed for signs of deterioration, as it will ignite spontaneously after deterioration has progressed to any marked degree. The odor of ether or alcohol is a normal one, but the acrid odor of nitrous oxide fumes is a certain indication of advanced deterioration.
- (10) Remove spilled grains of Smokeless Powders, especially of small calibers, as many small arms powders are nearly as sensitive to friction as Black Powder.
- (11) Do not expose Smokeless Powder to direct rays of the sun for any long periods of time.

- (12) Handle boxes of Smokeless Powder with care, as seams are easily ruptured in the inner container, thus allowing air and moisture to enter, which are conducive to impaired stability.
- (13) Separate loading Shell will be closely observed for signs of exudate. Fuzed projectiles will be rolled slowly to prevent arming of the fuze.
- (14) Demolition Bombs must be handled carefully. They are regarded as one of the most hazardous type of ammunition to store, because of the tendency to detonate en masse. Look for signs of exudate. Never ship Bombs with primer detonators in place.
- (15) Primers, Detonators, Fuzes, etc. must be handled with extreme care, even when properly packed.
- (16) Pyrotechnics should be handled with extreme care. Boxes must not be dropped or thrown.

Explosives and ammunition when packed and stored in accordance with War Department Regulations are grouped, so far as the hazards due to fire or explosion, into the following general classes.

Class 1--Small arms ammunition and sodium nitrate.

These are principally fire hazards and no limits are placed on the storage of material of this nature.

Class 2--Smokeless powder and pyrotechnics. These materials may become unsafe under extreme conditions of moisture and high temperature. They burn with intense heat but do not usually form missiles or generate pressures which cause serious structural damage to adjacent magazines.

Class 3--Point-detonating fuzes, minor caliber base-detonating fuzes, powder train and mechanical time fuzes packed separately in boxes. The amount of explosives in articles of this class varies from 30 to 250 grains. These fuzes usually explode progressively, not more than a box or two at a time. Pressures which would cause serious structural damage to adjacent magazines are not usually generated, and missiles are small and of light weight, usually falling within 100 yards.

Class 4--Fixed high-explosive shell, 3-inch trench-mortar ammunition, fragmentation bombs, grenades, and shrapnel of all calibers, fuzed or unfuzed, packed in boxes. Articles in this class usually explode progressively, only a few boxes at a time, many explosions of individual rounds being of a very low

order. Pressures which would cause serious structural damage to adjacent magazines are not usually generated and most missiles would fall within 200 yards.

Class 5-- Separate-loading or unfixed loaded shells of all calibers, loaded with explosive D, fuze, or unfuze. These shells usually explode one at a time, and in practically all cases with low order. As only one shell should be involved in an explosion, the missiles are limited both as to number and range and most missiles will fall within 400 yards.

Class 6-- Major and medium caliber base-detonating fuzes, bomb fuzes; and adapters and boosters for high explosive shell, for chemical shell, and for bombs, packed separately in boxes. The amount of explosives in articles of this class does not exceed one-half pound. They usually explode progressively, by piles. The numbers involved in any explosion is limited by making the piles small and separating them by prescribed distances determined by actual detonation tests. Structural damage caused by the pressures generated is usually limited to adjacent magazines and the missiles are light and usually fall within 200 yards.

Class 7-- Separate-loading and unfixed loaded shell of all calibers, except those loaded with explosive D. Shell in this class usually explode progressively by piles. The number involved in any one explosion is limited by making the piles small and separating them by prescribed distances which have been determined by actual detonation tests. Structural damage caused by the pressures generated is usually limited to adjacent buildings. Most missiles will fall within 500 yards.

Class 8-- Primers, detonators, primer-detonators for bombs, grenade fuzes, and blasting caps, packed in metal containers and wooden boxes. The amount of explosives in articles of this class varies from 30 to 110 grains. All in a magazine may explode at one time, but as the total amount of explosives involved is limited and the explosives are not strongly confined, structural damage is usually

limited to adjacent magazines. This class of ammunition forms light missiles which have a very limited range.

Class 9-- Bulk explosives such as black powder, T.N.T., tetryl, and explosive D. The black powder usually explodes, and T.N.T., tetryl, and explosive D usually burn but may explode. Since these explosives are similar to commercial explosives, structural damage should not occur at the distances specified in the American Table of Distances for similar quantities of commercial explosives. Missile hazards are minimized by using a type of magazine construction which breaks up into small fragments in case of explosion.

Class 10-- Demolition bombs. All in a magazine may explode. If this happens, structural damage caused by the pressures generated should not occur at the distances specified in the American Table of Distances for similar quantities of commercial bulk explosives, and most missiles will also fall within these distances.

It is customary at Field Service Depots to assign certain magazines to certain classes of material, i.e., the Magazine Areas are divided into Smokeless Powder Sections, High Explosives Sections, Ammunition Sections, etc. This system is followed not only because of the fact that the various "Types" of Magazines are grouped in the Magazine Area, but because of the practical advantage of having all of one class stored in the same section for safety and supervisory purposes. However, no such arrangement is possible at Picatinny Arsenal as our manufacturing schedules are not uniform with respect to the various types of ammunition manufactured and assembled. This frequently results in an enormous demand for space for one type of ammunition one year and for another type the following, making it necessary to use all available magazines for housing whatever ammunition is being produced.

It will be noted when an inspection tour of the Magazine Area is made that large numerals are attached to the magazines. This is a local arrangement for indicating the degree of hazard represented by the contents of each of the buildings in case of fire or explosion in the building itself, or in adjacent territory. The significance of each of the numbers is as follows:

No. 4 indicates - Bombs, demolition and flashlight;

Black powder in cans or charges;
Dynamite; Explosive "D"; Fulminate
of Mercury; Lead Azide; Nitroglycerine;
Picric Acid; T.N.T. Blocks; T.N.T. boxed;
Tetryl; Flashlight Powder.

(Every effort will be made to prevent fire from reaching this class of material. If this can not be done, the fire fighting forces will withdraw to a distance of at least 800 feet and protect themselves against explosion, by seeking such cover as is available.)

No. 3 indicates - Smokeless Powder in Boxes and in Bulk.
Separate Loading Propelling Charges.

(If a fire is discovered in a building in which smokeless powder is stored, there is little chance of saving the building. Personnel should take shelter against heat wave and protect surrounding property.)

No. 2 indicates - Bombs, Fragmentation; Boosters; Fixed Ammunition, H.E.; Fixed Ammunition, Shrapnel; Grenades, H.E.; Shrapnel, Separate Loading; Shell, H.E. Separate Loading; Shell, H.E. Trench Mortar.

(Every reasonable effort will be made to control the fire and the building should not be abandoned until it is evident that the fire can not be controlled. If fire gets beyond control, personnel should seek cover to protect themselves from flying fragments.)

No. 1 indicates - Acetone; Turpentine; Oil; Gasoline; Paints; Benzol; Ether; Alcohol; Acids; Compressed Gases, etc.; Ammonium Nitrate; Caps, detonating, blasting, and percussion; D.N.T.; Fuzes, time detonating, and grenade; Primers and Primer Detonators; Pyrotechnics; Smokeless Powder in course of manufacture, except in dry houses and blenders; Small quantities of loaded components; Surveillance Magazines.

(Every effort will be made to put the fire out. If the fire can not be controlled the building should be abandoned and efforts of the fire fighting forces should be made to protect surrounding buildings. If fire gets beyond control personnel should seek such cover as is available to protect themselves from light missiles. When fire occurs in building containing inflammable liquids or compressed gases, the possibility of explosion must be considered.)

The Ordnance Safety Manual describes in detail the method of piling which shall be followed for each type of ammunition and each kind of explosives. However, with the exception of separate loading shells which are piled with a view to eliminating sympathetic detonation, the general scheme is to pile material in double rows with stencilled ends facing aisles of approximately twenty-six (26) inches in width, in order that inspection, inventory and handling may be facilitated.

Aside from the physical angle of handling and protecting explosives and ammunition, the surveillance of the chemical changes, which are inherent in all explosives in varying degrees, is of major importance. By the term "Surveillance" is meant; observation, inspection, investigation, and test, (ballistic, chemical, or physical) of explosives and ammunition in storage. The purpose of surveillance is to determine whether deterioration is in progress, and if so the state and nature of such deterioration and the consequent degree of serviceability in order that reliance will not be placed upon munitions which are no longer safe or effective. Also to eliminate the danger of disaster through spontaneous ignition or explosion of materials which have become dangerously unstable.

The surveillance work in the Field is carried on by a Surveillance Inspector who is closely allied with, if not actually under the supervision of the Chief of the Storage activities. However, at Picatinny, due to the presence of a most modern equipped Laboratory and qualified technical personnel, the surveillance activities are conducted by the Technical Group rather than by the Stores Department, the only exception being the yearly N/10 Normal Methyl Violet Paper test on Smokeless Powder, which is conducted by the latter with the understanding that any questionable conditions are to be reported to the Technical Group for consideration and decision. This test consists of inserting a strip of Methyl Violet Paper approximately 5 1/2 inches long in each box of powder of a web size up to and including the 12 in. mortar, provided the powder is more than five (5) years old, for the purpose of determining the stability of the powder.

SECTION XIII. PACKING, STORAGE AND SHIPMENT OF AMMUNITION

3. Shipment of Ammunition.

In order to minimize the dangers to life and property incident to the transportation of explosives and other dangerous articles, by carriers engaged in interstate or foreign commerce by rail, the transportation of such articles within the limits of the jurisdiction of the United States is regulated by Federal Law. Therefore when presented for shipment to a common carrier they must be packed and described to comply with Interstate Commerce Commission Regulations, provided, that shipments of explosives offered by the War and Navy Departments of the United States Government may be packed, including limitations of weights, as required by their own regulations. However, any proposed departure from the requirements of the Interstate Commerce Commission Regulations must be submitted to the Chief of Ordnance for a decision, i.e., where the Ordnance Department is involved.

The services of the Bureau of Explosives are utilized by the Interstate Commerce Commission in the execution of its regulations. This Bureau was organized by the American Railway Association in 1906. Nearly all common carriers are members of the Association, and comply with the rules and regulations issued by the Bureau of Explosives. Inspectors of the Bureau of Explosives are stationed throughout the country to observe, investigate, and report violations to the Interstate Commerce Commission, which prosecutes if conditions warrant. In this connection it is well to dwell on the fact that heavy penalties are provided for the shipper who knowingly solicits the transportation of any explosives or other dangerous articles without complying with the requirements of the Interstate Commerce Commission as well as for the carrier that knowingly accepts and transports same. When the death or bodily injury of any person results from the violation of the regulations the person or persons who shall have so knowingly violated or caused to be violated such regulation shall be fined not more than \$10,000 or imprisoned not more than 10 years, or both.

The Interstate Commerce Commission Regulations governing the transportation of explosives and other dangerous articles describe in detail how shipments must be loaded, braced, placarded, certified, etc., and Bureau of Explosives Pamphlet No. 6 contains data, photographs, etc. on the shipment.

It is impossible to go into the specific details connected with each item of ammunition or explosives shipped from Picatinny, but an example will be given of the requirements in connection with making a shipment of 3 inch A.A. Ammunition.

Such ammunition is classed by the regulations as "Ammunition for Cannon with Explosive Projectiles," and each outside package must be marked accordingly. A "Certified car" is required for shipment. Certified cars must be inspected inside and outside, and must conform to the following specifications:

a - Closed cars of not less than 80,000 pounds capacity, with steel underframes and friction draft gear, must be used when available.

b - Cars must be equipped with air brakes in condition for service.

c - Cars must have no loose boards or cracks in the roof, sides, or ends, through which sparks may enter, or unprotected decayed spots liable to hold sparks and start a fire.

d - The doors must shut so closely that no sparks can get in at the joints, and, when necessary, they must be stripped. The stripping for doors should be on the inside and be fastened to the door frames where it will form a shoulder against which the closed doors repressed by means of wedges or cleats in door shoes or keepers. The openings under the doors should be similarly closed. The hasp fastenings must be examined with doors closed and fastened, and the doors must be cleated when necessary to prevent doors shifting. When the car is opened for any cause, wedges or cleats must be replaced before car containing explosives is permitted to proceed.

e - The journal boxes and trucks must be carefully examined and put in such condition as to reduce to a minimum the danger of hot boxes or other failure necessitating the setting out of the car before reaching destination. The lids or covers of journal boxes must be in place.

f - The car must be carefully swept out before it is loaded. For less-than-carload shipments the space in which the packages are to be loaded must be carefully swept.

Holes in the floor or lining must be repaired and special care taken to have no projecting nails or bolts or exposed pieces of metal which may work loose or produce holes in packages of explosives during transit. Protruding nails in the floor or lining which have worked loose must be drawn, and if necessary for the purpose of fastening the floor or lining, new nails must be driven through other parts thereof.

g - When packages of explosives are to be loaded over exposed draft bolts or kingbolts, the bolts must have short pieces of solid, sound wood with beveled ends (2-inch plank) spiked to the

floor over them (or empty packages of the same character may be used for this purpose) to prevent possibility of their wearing into the packages of explosives.

h - The roof of the car must be carefully inspected from the outside for decayed spots or broken boards, especially under or near the running board, and such spots must be covered or repaired to prevent their holding fire from sparks. A car with a roof generally decayed, even if tight, must not be used.

The carrier must have a certified car examined by a competent employer to see that it is properly prepared, before permitting same to be loaded and must have a "Car Certificate" signed in triplicate, by a representative of the carrier and of the shipper, after same is loaded and properly braced. The original certificate must be filed by the carrier at the forwarding station and the other two (2) must be attached to the outside of car doors, or to the sides of the car, one (1) on each side, the lower edge of the certificate not less than 4-1/2 ft. above the floor level.

In addition to the certificate mentioned above, Explosive Placards, as prescribed in Interstate Commerce Commission Regulations, must be attached to both sides and both ends of the car, (these placards and certificates must be removed from cars by the party unloading same) and Bill of Lading covering the shipment must bear the following notation, "This is to certify that the above articles are properly described by name and are packed and marked and are in proper condition for transportation according to the regulations prescribed by the Interstate Commerce Commission." Care must be exercised to insure that no commodities not authorized to be loaded or stored with Ammunition for Cannon with Explosive Projectiles, as indicated by Loading and Storage Chart shown in the Interstate Commerce Commission Regulations, are placed in the same car. In the particular case illustrated there are no specifications in existence for the type of box to be used, nor any container weight limit. However, in the majority of cases a container, conforming to a certain specification, as outlined in the regulations, must be used, and the weight limit prescribed must be adhered to.

The shipping requirements for any commodity can be ascertained with little effort by referring to the index in the Interstate Commerce Commission Regulations, and if an item is encountered which is not listed in the regulations, contact must be made with the Bureau of Explosives for a decision as to packing and shipping regulations.

In view of the fact that all stations are called upon frequently to ship samples of explosives and ammunition for chemical analysis and other investigational purposes, it is deemed advisable to briefly cover the requirements in connection

with express shipments. It is to be understood that most explosives and ammunition are classes as "Forbidden explosives" so far as shipments by express is concerned. However, exception is made (not including nitroglycerin) in the case of properly packed samples for laboratory examination. It must be understood, however, that "Laboratory examination" does not include ordinary use or demonstration. Samples of explosives for laboratory examination must be placed in well secured metal cans or glass bottles, or in strong waterproof paper or cardboard packages; each sample must not consist of more than one-half pound of explosive, and the interior package must be placed in sawdust or similar cushioning material, at least 2 inches thick, in a wooden box, complying with Interstate Commerce Commission Specification No. 14. Whenever these samples of explosives for laboratory examination are contained in a metal envelope or receptacle, this receptacle must be properly cushioned with sawdust or similar cushioning material in a strong wooden box and this interior box must be placed in a wooden box specification 14, with at least 2 inches of cushioning material separating the boxes. Not more than 100 blasting caps may be shipped in one outside package for laboratory examination and they must be packed and cushioned as just described. Not more than 20 half-pound samples of explosives for laboratory examination may be placed in one outside box or transported at one time and the net weight of the explosive contents must be plainly marked by the shipper on the outside of each box offered for transportation. In this connection it is advised that when components of ammunition are being shipped, the net weight of the explosive content is the guiding factor with respect to the half-pound limit.

SECTION XIV - COMPLETE ROUNDS

1. Visit to Complete Rounds Division at Picatinny Arsenal.

The Complete Rounds Division was designed so that empty components could be received at a given point for necessary preliminary work such as thread cleaning or painting of shell before they entered the line for loading and assembling. The Complete Rounds Division as established covers a straight line of buildings and connecting ramps approximately 2400 feet long. Other buildings, in which explosives or other materials are stored also those in which preliminary preparation of materials is accomplished, are spaced along the main loading and assembling line. All buildings in this division are spaced and arranged to provide a smooth flow of materials and explosives into the line and at the same time maintain safe distances between buildings from the standpoint of hazard to employees and other buildings in the event that an explosion might occur.

The auxiliary buildings required for operating this line are:

- High explosive storage magazine
- Ammonium nitrate storage building
- Ammonium nitrate drying and screening building
- T.N.T. screening building
- Paint storage building
- Black powder storage building
- Fuze, primer and booster storage building
- Smokeless powder storage building
- Air compressor and motor houses.

This line was established to load, assemble and pack for shipment various calibers of complete rounds, as well as, shell for semi-fixed rounds, separate loaded shell, and fragmentation and demolition bombs. The following items were loaded and assembled in this Division:

- a. Shell from caliber .90 to 240 m/m Howitzer, inclusive.
- b. Bombs, fragmentation and demolition from 17 pound to 2,000 pound inclusive.
- c. Rounds, shell, complete, from caliber .90 to 105 m/m inclusive.
- d. Rounds, shrapnel, complete, 75 m/m and 3 inch A.A.

Arrangements are now being made to transfer the loading of bombs, large shell and trench mortar shell to another location.

The various explosives used and their compositions are listed below:

- a. T.N.T.
- b. 50/50 Amatol - 50% Ammonium Nitrate and 50% T.N.T.
- c. 65/35 Amatol - 65% Ammonium Nitrate and 35% T.N.T.
- d. Trimonite - 88% Picric Acid - 12% Mononitronaphthalene.
- e. Ammanol - 67% T.N.T. 22% Ammonium Nitrate - 11% Flake Aluminum.
- f. Black Powder.

Explosives and other materials are received and stored in buildings designated until required for use.

Various methods of loading are used depending upon the item to be loaded and the explosives used as the filler. The methods for filling shell and bombs are casting, pellet, and lob as indicated below:

- a. The casting method is used when the explosives are in a liquid or molten state. T.N.T., 50/50 Amatol, Trimonite and Ammanol are loaded by this method.
- b. The pellet method is used principally for filling 100 pound bombs and those larger in size. The loading is accomplished by filling bombs with molten T.N.T. and preformed T.N.T. pellets. (Some shell were loaded by this method but the practice has not been adopted as standard).
- c. The lob loading method has not been used in production but has been developed for loading large bombs. It is used in connection with 65/35 Amatol. The explosive mixture is similar to thick cement when being loaded.
- d. Shrapnel are base charged with black powder. The powder is poured in funnels and the shrapnel vibrated until it lodges in the space provided in the base.

This plant is equipped for crushing, drying and screening ammonium nitrate when these operations are necessary. However, it has been found that ammonium nitrate can be procured with a moisture content below the required .20%. The crusher in operation breaks up all lumpy material. It is then fed directly into a long cylindrical dryer. The dryer rotates and the ammonium nitrate passes through it to a screen used for removing lumps and foreign material.

The explosive or explosive mixtures are heated or melted in the building designated for the purpose. This building is

equipped to handle some of the explosives previously listed.

T.N.T. LOADING

The equipment installed at the present time for melting T.N.T. is of two types, i.e., melting kettles and continuous melt units.

In use the T.N.T. kettle (steam jacketed) is partially filled with T.N.T. and as it melts additional granular T.N.T. is added until the kettle is filled to capacity, which is 1200 pounds. During the melting process the TNT is agitated or stirred by moving agitators.

The continuous melt unit is equipped with steam coils and a catch pan underneath for holding the molten TNT until it is required for use. This unit has a capacity of more than 3,000 pounds per hour.

When the TNT is melted and ready for use it is drawn off in galvanized iron cooling tubs equipped with baffles. The cooling is accomplished by a mechanical agitator which keeps the entire quantity of molten TNT circulating in the tub. This process is continued until determination is made that sufficient cooling has taken place. The TNT is then transferred to the pouring room where it is stirred manually with wooden or aluminum paddles. Portions of the material are poured into pails of various compositions. Those now commonly in use are made of either black iron or aluminum. The pails are equipped with pouring spouts so that the molten material can be readily poured into the shell.

Shell or bombs are placed on lift truck platforms in quantities varying with the size to be loaded. Pouring funnels are placed in the shell for greater ease of loading and to prevent explosives from getting into threads; also for use as a riser to prevent cavitation in the explosive charge. Shell are not always filled in one pouring, the controlling factors being sizes and shapes of cavities. Thus, the present 3 inch A.A. Shell, M42, can be filled in one increment, while the 75 m/m Mark I is better filled in two increments. The restricted neck of the 75 m/m Mark I shell causes TNT to solidify quickly and prevents the TNT trickling through from the riser to fill the cavities caused by shrinkage of the charge, while with the 3 inch A.A. shell this condition does not occur. In all cases it is necessary to break down charges, that is, the crust which forms over each increment must be broken to permit the molten material to feed down and fill the cavity caused by shrinkage. Large shell and bombs are filled in two or more increments. All TNT recovered from funnels,

pails or tubs called "clean scrap" is remelted. Floor sweepings and other dirty scrap is packed and stored for recrystallization.

50/50 AMATOL LOADING

The pouring of 50/50 Amatol follows the methods of pouring TNT. The Amatol is prepared by preheating the ammonium nitrate in a steam jacketed dough mixer while the TNT is melted in a continuous melt unit. Equal proportions of TNT and ammonium nitrate are mixed together in a steam jacketed mixing kettle until a homogeneous mix is obtained. Since 50/50 Amatol is used in large shell and bombs partial filling is accomplished directly from the kettle by means of the draw-off pipe and valves. The advantages of this arrangement are, more explosives can be produced in a given time as the kettle will not be used for both melting and mixing but will be used as a mixer only. It also provides facilities for having additional materials ready for mixing as soon as the 50/50 mix is drawn from the mixer. Considerable handling of explosives also will be eliminated.

TRIMONITE LOADING

The kettle at present being used for mixing Trimonite is one previously used for melting TNT. The Trimonite ingredients melt at different temperatures and constant agitation is necessary to provide a thorough mixing. The steam pressure used for Trimonite is 8 to 10 pounds in the jacket of the kettle. The temperature for pouring this explosive is between 90 and 100°C. It can be poured directly into shell from the mixing kettle or can be poured from pails. Shell can be poured in one pour and a "top-off". The "top-off" is made in the pouring and cooling room.

DRILLING AND BOOSTERING

The explosive charges in shell and bombs are drilled for booster or fuze cavities. This is accomplished on either vertical or horizontal drilling machines depending upon the size of the item being drilled. Small shell and bombs are drilled on the vertical machines while large caliber shell are drilled on the horizontal machine. Excess explosives are cleaned from the threads with brass, bronze or steel picks depending upon the explosives loaded in the shell or bombs. Final cleaning of the threads is done by wiping with a cloth dampened with acetone.

Booster cavities are gaged to determine if correct drilling has been done. Fuze well cups are inserted in some shell before the booster is put in place. In others, the booster is assembled directly into the shell.

COMPLETE ROUNDS ASSEMBLY

The complete rounds assembly consists of putting live primers in cartridge cases, weighing smokeless powder charges and check-weighing, assembling projectiles to cartridge cases, gaging for profile and alignment of the round, inserting fuzes and assembling waterproofing covers.

For anti-aircraft ammunition distance wadding is used in the cartridge cases. This consists of two discs and a pasteboard tube which are assembled on top of the propelling charge in the cartridge case.

The primers are assembled in cartridge cases with hand mandrel presses. The primed cartridge cases are transferred to the powder weighing room for the powder charge. The powder charges are weighed and checkweighed. The loaded cartridge cases are transferred to the assembling and crimping machine where the shell and cartridge case are assembled together by means of an air operated machine. The assembling machine now installed is equipped to handle more than one size of round, that is, it will assemble and crimp rounds from 75 m/m to 105 m/m inclusive. Each assembled round is gaged in a chamber gage to insure that they will enter the gun chamber freely. The rounds then go to the fuze assembling room when the fuzes are inserted and staked in place. If powder train time fuzes are inserted in the rounds a waterproofing cover is assembled. The rounds are then transferred to the painting and packing room.

PAINTING, STENCILLING, PACKING AND SHIPPING

All rounds are painted with two coats of paint or shell lacquer. The present practice is to do this by hand. The complete rounds are packed in fiber containers and boxes or are bundle packed. The complete round fiber containers are sealed with colored adhesive tape indicating the kind of round, that is, yellow tape for high explosive rounds, red tape for shrapnel rounds, blue tape for practice rounds. The tape is stencilled with the pertinent data to identify the round, the lot number and the date of assembly. Packing boxes are stencilled while bundle packing requires the use of an identification disc for this purpose. Paper labels have also been used for bundle packing.

SECTION XV - MISCELLANEOUS SUBJECTS

3. Safety

The Safety program at the Arsenal is organized to conform with well directed plans of American Industries wherein great success has been attained in efforts to eliminate accidents. Industrial Safety programs have been pronounced successful from both humanitarian and money saving aspects. It is extremely gratifying to review statistics which show a great reduction in loss of human life and number of lost time accidents in recent periods as contrasted to statistics which reveal the dangerous conditions which existed in industry only a generation ago. The money cost of accidents is tremendous. The opportunity to eliminate this expense has given impetus to industrial safety movements. Insurance is furnished to cover risk of compensation payments provided inspectors of the insurance companies have access to the plants to assist in maintaining safe conditions. It is estimated that the non-insurable cost to industry of lost time accidents is four times as great as the insurable loss of compensation payments for medical service and lost time. The non-insurable loss caused by accidents consists of damage to equipment, lower efficiency of substitute workmen, time required by supervisors to instruct substitute workmen, production curtailment, etc.

The Arsenal Safety work is covered by the three "E"s of Safety which are Engineering, Education and Enforcement.

ENGINEERING:

The term engineering is here used in a broad sense and applied to safety work includes the application of knowledge of the behaviour of explosives and ordnance materiel when manufactured, handled and stored so that safe conditions are established. The contact of explosives with high temperature is carefully avoided. Most explosives are found to be unsafe when exposed to temperatures much higher than the boiling point of water. Especial precautions are taken regarding exposure to open flame, electric sparks, frictional sparks, frictional heat, high pressure steam temperature, light bulbs, soldering equipment and hazardous static conditions. The engineering drawings for new operations and Arsenal operating practices are carefully scrutinized to detect and eliminate conditions which might be hazardous.

In addition to explosives material the Arsenal operations require the use of equipment with various mechanical and electrical hazards. The power house and distribution system with its steam and electric generating equipment require careful engineering control to maintain safe conditions in coal and ash handling, prevention of rupture of high pressure steam equipment and protection of personnel from contact with electrical circuits.

Mechanical hazards exist in the machine shop where metal parts are made, using commercial machine tools. Engineering control of safety in the machine shop includes studies of the use of belt and machine guards, protection from exposure to electrical equipment, slippery floors, and foreign objects in eyes of operators. These machine hazards are present in other departments of the Arsenal, sometimes in conjunction with explosive hazards.

Inflammable liquids are used in the manufacture of explosive materials and various operations in loading and packing. The storage and use of inflammable liquids are carefully controlled to prevent fires and explosions that might occur from ignition of these materials alone or in conjunction with explosive material.

The transportation system consists of a railroad, cranes, shovels, tractors, automotive cars and trucks. The use, maintenance and repair of transportation equipment involves dangers which may be overcome by safety engineering studies.

EDUCATION:

The properties of explosive materials are well understood and the details regarding their proper use have been learned by operating personnel from many years of experience. Foremen and supervisors give needed information to new employees and carefully oversee all work to eliminate unsafe conditions and practices. The number of accidents which are caused by unsafe practices are far greater than the ones which are caused by unsafe conditions which can be corrected by safety engineering. Therefore, it is recognized that the Arsenal's safety program should emphasize strongly the elimination of unsafe practices. The education of the individual workers to appreciate the importance of safe practice should be undertaken by management with the cooperation of the Safety Division. It is not likely that many new conditions will be discovered that cause accidents because practically all of our accidents of a conditional nature are catalogued under some well known heading, but new ways are being developed for getting workers to function more safely and eliminate unsafe working procedures.

ENFORCEMENT:

The enforcement of safety regulations contained in Ordnance Safety Manual No. 7224 and in Arsenal Regulations is a function of management. The successful maintenance of safety consciousness in an industrial group requires the utmost skill in human engineering. Supervisors are prone to emphasize production and might be lax regarding utmost precautions regarding safety of the plant. Workmen may regard the following of safety regulations as effeminate especially those of minor importance and prefer to appear brave and ignore precautionary advice. The enforcement of safety regulations to induce workmen to follow proper and safe practices which they know they should follow requires diplomacy of the highest type.

In addition to the three "Es" the Arsenal is restricted regarding the quantity of explosive material permitted in each area, building and room. In storage of explosives the maximum quantity is set for each magazine based upon distances from other buildings so as to limit loss of government property if an explosion should occur in one locality. The quantity-distance tables are given in the Safety Manual. The data is collected from reports of many explosions and furnishes a basis for limiting the storage of explosives so that too large a quantity will not be placed too close to other material. The personnel are limited in storage operations to a reasonable number required for doing the work. The various kinds of explosive materials are segregated in storage so that the greatest ultimate safety can be maintained.

In addition to elimination of unsafe practices and conditions in explosives manufacture, the quantity of explosive material is limited regarding each building and each room of the manufacturing buildings. Safety studies include quantity necessary for the job, contacts between rooms, proximity of service magazines, and allowances for freight cars. The properties of explosives such as sensitivity, rate of burning, stability and possibility of fire or detonation are included in safety studies. The personnel allowances for each room of manufacturing areas where explosives are handled are posted upon the wall in plain view with the explosives allowance for the room. The quantities of inflammable liquids are carefully regulated throughout the Arsenal so as to conform to necessary amounts for each location.

New and unusual operations where explosives are involved, or new modifications of existing procedures are carefully scrutinized by the Safety Division. It is the unusual operation that may allow for unsafe conditions or practices to appear.

Because the subjects of sanitation, toxicity, health and ventilation involve personnel safety, they are also covered by the activities of the Safety Division.

A complete set of records are maintained in the Safety Division concerning accidents in connection with which property is destroyed or injury is sustained by personnel. An individual report is made for each injury, minor or lost time. Unusual accidents are investigated by the Safety Division and a special report made with all details. These endeavors are valuable to help prevent recurrence of accidents. Monthly reports include "frequency rate" of disabling injuries which is given as the number of injuries per million man hours of exposure and the "severety rate" which is the number of days lost per thousand man hours of exposure. These figures are directly comparable to records of industrial plants connected with the National Safety Council.

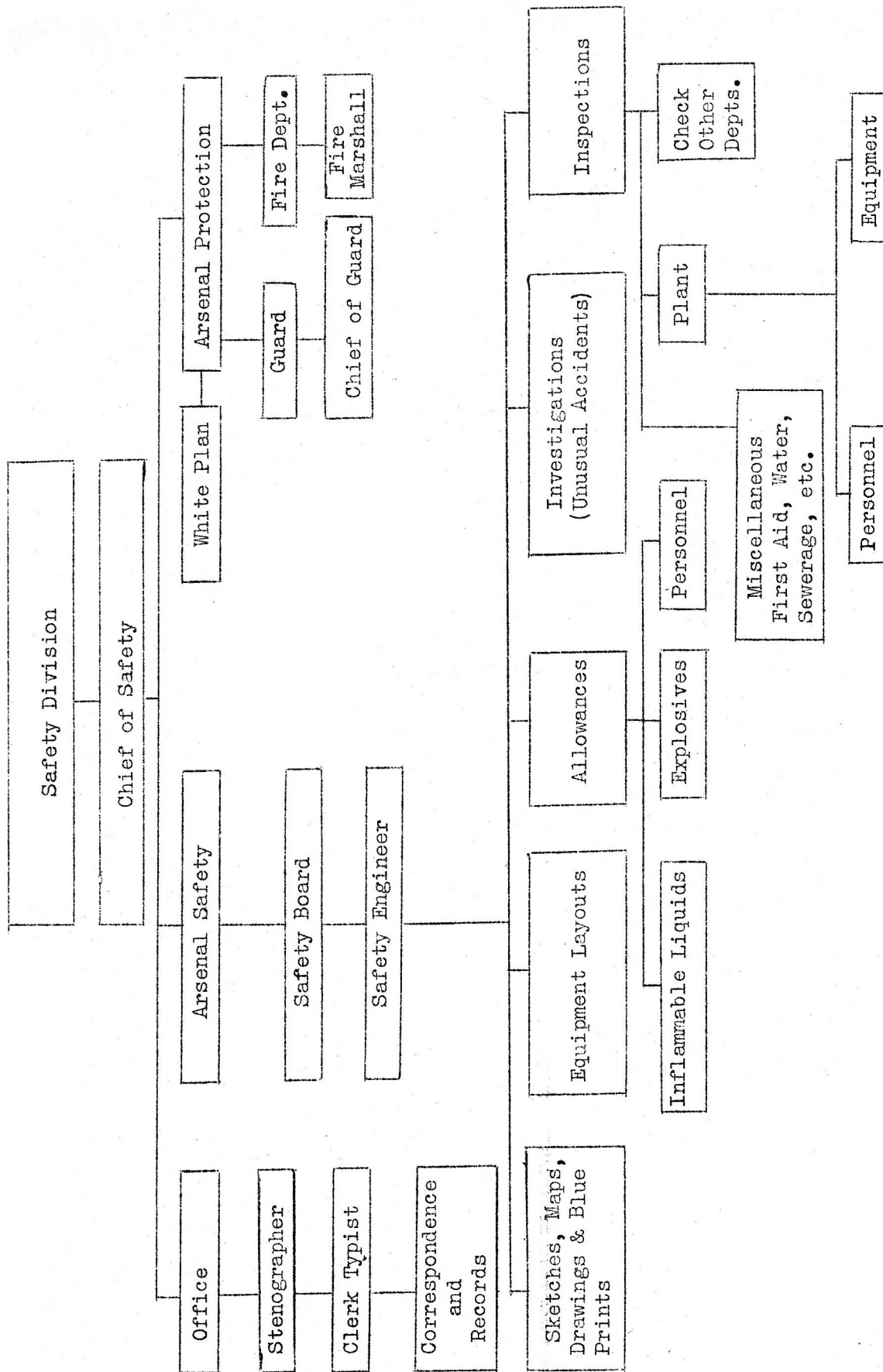
The records of the Arsenal showing lost time accidents in the various departments furnish evidence to show that safety programs are only as effective as the management of the department desires. Our records show that explosives departments on the Arsenal have better records than the non-explosives departments. This proves that under conditions admittedly more hazardous, intensive safety control produces a reduced accident rate.

The enforcement of traffic regulations and protection of personnel on the roads of the Arsenal is a function of the Guard force, a part of the Safety Division. Police duty to protect the Arsenal property is performed by the Guard force. Fire protection is a function of the Safety Division.

The type of shoe required for use in explosive buildings is selected so that the production of sparks caused by charges of static electricity may be prevented and abrasive friction between shoe and floor to cause heat will be reduced to a minimum. The shoe should have a leather sole, sewed; rubber or leather heel with no exposed metal in heel or sole. Nail holes in heel should be plugged with rubber cement to prevent carrying pebbles into buildings.

Visitors are instructed to leave buildings in an orderly manner in cases of fire or fire drill. Where danger of high explosive detonation exists personnel should be 850 feet from the hazard.

The accompanying chart shows the organization of the Safety Division and lists the major activities involved.



SECTION XV - MISCELLANEOUS SUBJECTS

5.- Ammunition Plant Inspection-Organization-Functions-Responsibilities

No two things in the world are exactly alike. This may seem an astonishing statement, but we execute a murderer in perfect confidence that we have the guilty party if his fingerprints match the fingerprints left on the murder gun. Research and experience have shown that of all the billions of fingers in the world, no two are exactly alike. Two fine target pistols of the same model may look exactly alike. The manufacturer tries to make the rifling alike in all his pistols of the same model and the marksmen who purchase them are reasonably satisfied that this is the case. However, ballistic experts have shown that the minute markings left by the rifling tool in each barrel, are different for every gun in the world. Corresponding scratches are left on the bullets fired from a given gun. Thus a murder bullet may be identified as having been fired from a certain gun, and juries commonly accept this as conclusive evidence.

It is not necessary that components of artillery ammunition be exactly alike. The Ordnance engineers have determined to what degree it is necessary that they be alike and placed these tolerances on the drawings. It is therefore the function of inspection to insure that all parts used shall be exactly alike only within these limitations.

During the World War, many contractors complained they were being required to conform to much more rigid inspection than the Government Arsenal. To meet this criticism, the Ordnance Department established an independent inspection system in the Arsenal corresponding to its inspection in contractors' plants, independent of the Arsenal Commander and responsible only to the Chief of Ordnance. This was in addition to the inspection system of the Arsenal.

A similar inspection system is now in force at Picatinny Arsenal except that both inspection organizations are now under the Arsenal Commander who thus acts in a dual capacity. Naturally, as Arsenal Commander, the Shop Inspection comes under him, thru his Chief of Manufacture and the latter's various department shop officers. This inspection is not a separate organization, but constitutes a part of each shop production organization. We may refer to it in this article as Production or better, Shop Inspection. The Inspection Department inspection however is entirely independent of the production organization and is responsible directly to the Arsenal Commander, who is the Inspector of Ordnance and as such is responsible that each article purchased, manufactured or repaired, and all other work performed, complies with the drawings, specifications and other requirements. Naturally he cannot supervise this work

personally and therefore delegates it to his Inspection Department Chief, who acts for him except in matters of sufficient importance to warrant reference to him for decision. It is with the functions of this Inspection Department that this article primarily deals. Its organization, duties and responsibilities correspond very closely to those of the Army Inspector of Ordnance in the plant of a private contractor, except that in the plant of a private contractor, production would not cover such a wide field nor include general procurement such as coal and building materials nor gage checking.

At first thought this may seem a rather complicated organization, but the general principle is quite common in the best commercial plants as well as Ordnance establishments. Its primary purpose is to render the organization responsible for final inspection independent of considerations of production so far as possible. In operation, this dual inspection system aims toward preventing the manufacture of defective work rather than merely detecting work that fails to meet requirements. We will first deal briefly with the so-called Shop Inspection, which as stated above, is conducted by the various production departments and corresponds to the inspection force of the contractor in a private plant.

Shop Inspection. Every machine operator is provided with all the gages necessary for him to periodically inspect the work that his machine produces. He gages about every tenth piece, if the speed of his machine is not too great. The shop also has a number of checkers who move about among the machines, checking the work as produced. These checkers use gages and micrometers. When it is found that pieces do not gage, it is necessary to use micrometers to determine to what extent the piece is off in order that the machine or tool may be adjusted to make parts which will gage. Such work as requires further inspection is transported by electric shop trucks to a centralized inspection department. Here inspection is divided between a "spot" or "sampling inspection" and "one hundred percent inspection" of the contents of the tote boxes depending on the necessity for holding close tolerances.

Inspection Department Inspection. This Department functions in general in accordance with the instructions of the "General Inspection Manual" prepared under the direction of the Chief of Ordnance. At the present time, it consists of a total personnel of forty-one, organized into the following Sections with the duties indicated.

a. Administrative Section - (Number of personnel, 11). Prepares and answers correspondence. Maintains files of drawings, specifications, expenditure orders, data cards, surveillance reports, and inspection reports. Assists Technical Group in the preparation and revision of specifications.

b. General Procurement Inspection Section - (Number of personnel, 6). Inspects all purchased materials, including metals, cloth, machinery, coal, building supplies, etc., purchased by this Arsenal both for use here and for other government establishments. Formal acceptance is indicated by signature on Inspection Certificate on the Receiving Report prepared by the Stores Department. Makes monthly spot checks of Stores Department Inventories, in such buildings as are designated by the Chief, Administrative Group.

c. Explosives Manufacture and Procurement Section - (Number of personnel, 3). Inspects all powder and explosives manufactured at Picatinny Arsenal as well as that procured from private manufacturers, necessitating frequent trips to plants of the duPont, Hercules and other manufacturers.

d. Metal Parts Inspection - Process and Final Section - (Number of personnel, 27). Inspects metal components produced at Picatinny Arsenal and received from other sources, to insure that they comply with applicable drawings and specifications. This consists of a spot check on all shop inspection, with final acceptance or rejection of sets of parts by Lots as indicated by the Inspector's signature on the Data Cards. It also includes such tests of metal components as may be required by the specifications.

All metal components manufactured in shops on experimental orders for the Technical Group are inspected one hundred percent by the Inspection Department with micrometers, etc. If components are later standardized and made on a production basis they are then inspected by shops with gages which will be made available.

e. Loading Inspection - Process and Final Section - (Number of personnel, 10). Inspects tests and accepts or rejects all loading plant production at Picatinny Arsenal in accordance with applicable drawings and specifications. This includes a spot check on all Shop Inspection as well as conducting or witnessing such final tests as are conducted at this Arsenal and the selection and forwarding of such samples as are required for Proving Ground Test.

f. Gage Laboratory Section - (Number of personnel, 8). Inspects and checks all gages, tools and fixtures used by the Inspection Department, and by the Manufacturing Group on its request. Also inspects all similar material manufactured here or procured from outside sources. Stores same and maintains records. Assists in the design of gages for new articles to be produced.

Inspection of Material purchased for other Establishments

Practically all Ordnance Department material is procured and inspected by the various arsenals regardless of where it is to be used, the procurement being allocated to the arsenal most familiar with that kind of material. For example, the procurement and inspection of Powder, Explosives, most components of artillery ammunition and kindred items, is performed by Picatinny Arsenal regardless of whether it is for use here, or is to be shipped to some other establishment. In recent years this has become a very large job and in addition approximately \$2,500,000 of Reserve Powder Manufacturing and First Phase Loading Plant equipment has been procured or is in process of procurement. This inspection of all this material, the value of which is now running into extremely large figures, is either performed directly by the Inspection Department of this Arsenal, or is administered by it.

Until recently all such inspection was performed directly by inspectors from this Arsenal, or delegated by this Department to personnel at other government establishments located nearer to the contractors' plants. For example, the inspection of T.N.T. manufactured by the Hercules Powder Company at its California plant, was delegated to personnel from the Benicia Ordnance Depot, who acted as representatives of this Arsenal and under its administration. Likewise inspection of T.N.T. at Barksdale, Wisconsin, was delegated to the Savanna Ordnance Depot.

With the recent large increases in procurement, active inspection forces have been established in the various Ordnance District Offices, and inspection on contracts let by this Arsenal is now delegated to the District in which the contractors' plants are located, except in exceptional cases where plants are located nearer to this Arsenal than to a District Office. The Commanding Officer of this Arsenal has, however, remained the Contracting Officer and such being the case, inspection remains the responsibility of the Inspection Department of this Arsenal, the District Inspectors being merely its representatives, or in other words, they work under the administration of this office so far as inspection matters on its contracts are concerned. As one of the contracts for equipment for the manufacture of nitric acid, involved sub-contracts and sub-sub-contracts covering plants all over the country including Boston, New York, Philadelphia, Pittsburgh, Cincinnati, Atlanta and San Francisco, it can readily be appreciated that the administering and coordinating of this inspection was a rather complicated job.

In order to secure proper material, particularly on such items as fuze components, powder boxes, etc., it has been found essential to bring District Inspectors to this Arsenal for a course of instruction. Personnel unfamiliar with the use of material, otherwise do not appreciate that in some cases a small burr will prevent the proper functioning of a fuze, while in other cases matters which look important to an inexperienced inspector may be unimportant. Furthermore, in order to establish uniform standards of inspection at widely scattered plants, it has been found essential that personnel be sent out from this Arsenal to coordinate standards. Otherwise, contractors complain that inspectors in some other district are much more lenient than those at their plant, etc.

The administration of this inspection of this material purchased for the Ordnance Department at large, heads up to the proper section in this office; for example, powder, T.N.T., detonating caps, etc. to the Explosives Manufacturing and Procurement Section; bomb bodies, bomb crates, bomb fin assemblies, to the Metal Parts Section; loading machinery, nitric acid manufacturing equipment, fiber containers for complete rounds, etc. to the General Procurement Inspection Section. Personnel of the various sections have been carefully selected from men having training as specialists in the various lines of work. Occasionally, an inspection job comes up for which qualified personnel are not available in this Department. In such cases, experts in the particular field are borrowed from the Service Department, War Plans Division, Technical Group, etc., depending on location of a qualified man.

District Office inspection is not confined to material being procured by this Arsenal for other establishments, but applies as well to material being procured from commercial contractors for direct use here.

More detailed information regarding the functions and responsibilities of the Inspection Department is given below:

Principles of Inspection: The sphere of influence of inspection service is far greater than its numerical relationship would indicate, for it reaches into every department and touches all the detailed plant operations having to do with creating and maintaining quality standards. But its dominating capacity as an instrument for assisting in controlling quality, may lead to the serious mistake of placing the responsibility for quality upon the Inspection Department.

That such an attitude toward the Inspector and his Department is untenable is proved by a moment's reflection on the fact that the Inspector never puts his hand to the work except to inspect visually or to measure dimensions. He enforces quality by refusing to

accept poor work, but this act of rejection is passive as regards enforcing the production of good work. Quality or lack of it must necessarily be worked into the material by the production department which controls production processes. This principle may be summarized by stating that the inspector does not make the goods, consequently the responsibility for quality rightly rests with the manufacturing departments. It is a particular rule in our plant, however, that the presence of an inspection force does not in any way relieve the foreman from responsibility as to accuracy of product.

The functions and responsibilities of the Department are as follows:

a. To see that all procured and War Reserve materials received and each article manufactured or repaired, comply with drawings and specifications and other requirements, before they are accepted.

b. To determine the grade or quality, workmanship and dimensions of all materials and parts. Where physical or chemical requirements are stated in specifications for material, tests are made by the Arsenal or other approved laboratory, on samples selected by the Inspector.

c. To inspect the packing and crating of ammunition.

d. To inspect and release ammunition to storage or for shipment.

e. To make necessary inspections, at commercial establishments, of materials and processes before authorizing manufacture. Whenever practicable and economical, the services of the District Ordnance Offices and the Naval Inspectors of Ordnance are utilized.

f. To check specifications and drawings in connection with the provisions that relate to matters of inspection, and make recommendations as to changes necessary therein.

g. To make recommendations for changes in drawings and specifications as may be found desirable from experience in inspection.

h. To assign ammunition lot numbers to all ammunition, except experimental items, manufactured at Picatinny Arsenal.

i. To prepare test program requests for the test of ammunition on production orders, and submit to the Office of the Chief of Ordnance.

j. To report, by letter, shipments of ballistic samples of ammunition of standard types, to the Chief of Ordnance and to the Commanding Officer, Aberdeen Proving Ground.

k. To maintain a complete file of inspection reports, acceptance sheets, lot numbers, and laboratory reports of all standard ammunition.

l. To check the design of inspection gages for components of ammunition and complete rounds.

m. To maintain a gage laboratory for the inspection of all gages: to be responsible for measuring and checking gages to see that they are satisfactory for use with the components or the complete rounds of ammunition, in accordance with drawings specified in expenditure orders or contracts.

n. To inspect all tools, jigs and fixtures to be used for manufacture of ammunition and components.

o. To check for accuracy, upon request, all measuring instruments used throughout the Arsenal in manufacturing operations.

p. To make a report of all peculiar conditions in the progress of manufacture and inspection on production orders which require special attention of inspectors in the method of testing and inspection of manufacturing processes or dimensions of finished parts.

Inspection and Work Gages: Work gages are in use throughout the Manufacturing Shops. These "work gages" do not permit as much tolerance in the piece being made as is permitted by the final "inspection" gages. By this means, pieces which are slightly outside the "work" limits as a result of worn tools, machines out of adjustment, etc., may still be within the inspection gage limits and thus reduce the number of rejects. The use of "work" gages encourages the cultivation of accuracy in operators.

The size of work gages are always inside or outside the inspection gage tolerances, inside on Ring Gages and outside on Plug Gages, so that after the piece is manufactured to work gage size, the Inspection gage will always gage the piece without any interference.

Gages are manufactured with wear and toolmakers tolerances. The wear allowance varying from .0000 to .0006 and the toolmakers tolerance from .0001 to .0010 for the "GO" and from .0000 to .0010 for the "NOT GO" end, depending upon the component tolerance.

For reference two (2) types of gages are referred to, as shown on attached photostats, DE Plain Plug and Comb. Ring & Snap. DE Plain Plug (Work Gage), Dwg. AP-16533, DE Plain Plug (Insp.), A-53438, Comb. Ring & Snap (work Gage) Dwg. AP-16514 and Comb. Ring & Snap (Insp.), Dwg. A-53421. It will be noted that by comparing the sizes of one gage against the other, that the inspection gage will always function if the component has been manufactured to the Work Gage Sizes.

Inspect for Proper Materials.

To inspect successfully, the Inspector must have the latest information pertaining to all materials used and be versed on the latest test requirements of the materials, which in all cases are described in the applicable specifications. In order to facilitate inspection, he should be or make himself so familiar with these various materials as to be able to recognize them at sight. He should know and understand their characteristics, properties, use and purpose, in order to be able to prevent possible misapplications or to suggest substitutions. He should determine when and where allowances can be made for slight defects in materials, which will not affect the finished product. Raw and finished materials must be inspected in general for conformity in quality, dimensions and appearance, in accordance with information given in one or more of the following sources:

- General Specifications for Ammunition
- Federal Specifications
- Detail Specifications
- Manufacturing Information
- Finish Charts or other Documents

In some cases materials must be inspected by comparison with materials on hand, or by actual trial in machine or shop as well as subjected to a close scrutiny for imperfections that are likely to impair the finished product. When necessary, secure tests of chemical and physical properties. When inspecting material at a commercial establishment, the Inspector must assure himself that adequate facilities and equipment are available at the plant, to properly inspect and test the product or material from which the product is manufactured. Also during the process of manufacture, he must check the product, to determine that conformity with all conditions stated in the proposal or contract, in regard to the material from which the product is made, are being adhered to.

The Inspector should check for proper authorization in case of substitution and for proper amounts when the system so provides. He should check samples and test pieces and their respective forgings, castings and blanks, for agreement in identification with each other and see that materials bear the necessary markings and identifications. All questionable cases, and damaged or otherwise defective materials should be reported promptly to the Chief Inspector and the Manufacturing Agency, in order to effect a speedy correction.

All materials found defective are rejected. The Inspector advises all persons concerned and either scraps the condemned materials according to the prescribed method or he can recommend salvage of the usable components, if in his or his superior's opinion, this action is advisable and the materials can be brought up to requirements.

Inspect for Proper Workmanship.

In order to be able to perform the foregoing duties thoroughly, the Inspector will secure or establish inspection limits in accordance with prescribed drawings, specifications, and general inspection manual, or in line with his knowledge of the work. He must, of necessity, be thoroughly familiar with the interpretation of his manufacturing information in order that he may be able to tell whether or not manufacturing processes are being properly followed.

He should know the proper sequences in which operations must follow one another for best results and be familiar with working conditions, manufacturing methods and requirements. It is his duty to see that the right materials and proper information are used and that workmanship is up to standard in quality. He should not, however, insist upon work that is unnecessary.

The Inspector should see that necessary and proper means are used for checking manufacturing operations, such as measuring instruments, gauges and templates. The use of these should have for its aim, the elimination of the human element as much as possible.

For parts manufactured in quantities, the Inspector should endeavor to devise methods enabling rapid and sure inspection. For best results, work should be inspected during the different stages of manufacturing. This inspection is the responsibility

of and is performed by the contractor, however, occasional check inspections are made by the inspector, as well as final inspections after the work has been completed.

According to the needs of the case, the Inspector might apply a general inspection, such as inspection for proper information, adherence to information, character of workmanship and quality of finish, or a detail inspection obtained in the following methods:

a. Checking of the first piece of each operation in a lot in order to prevent repetition of possible defects, or to prevent further work being done on defective parts.

b. Checking of a sufficient number of pieces in a lot to determine if the contents of the lot are satisfactory.

c. Checking for accuracy of dimensions (observance of proper tolerances).

d. Submitting work to tests after the conclusion of various operations.

To do these things, the Inspector must make a study of the parts manufactured, in order to be familiar with defects typical to the work.

There are many things which the Inspector can do in order to prevent defective work, such as the following.

a. Examine and check the inspection equipment for correctness and effectiveness, at regular intervals.

b. Check the work from new tools, jigs and fixtures as soon as possible.

c. Check the important dimensions on large work before removing it from the machine,

d. Be sure that the latest manufacturing information is being used, also that the drawings are of the latest or correct revision.

e. Make sure that the latest changes known to him are embodied in the work.

f. See that markings and stampings are clear and identify the parts properly.

g. Be sure that the special features which appear on the drawings from time to time are not overlooked and are properly taken care of.

h. Have all testing apparatus properly checked to assure accuracy.

Maintain Daily Routine

For his routine work, the efficient Inspector will have a daily program which should consist of a logical and methodical arrangement of procedure. Among other things, this will include the following:

a. Inspection of work and materials at such times and with such frequency as best suits the conditions of the manufacturer, as well as his department.

b. Checking of tools, fixtures, operations, information, reports, tests and troubles at stated times during the day.

c. Approving and signing of data cards, test programs and time and cost sheets.

d. Reporting results, finding and experiences. Receiving results of laboratory tests and answering general correspondence.

Such a program will of necessity vary to conform to the line of work, the location and the conditions. One of the most important things about his daily routine, however, is that he, himself, be regular and prompt in attendance. He should also impress upon those under his supervision, the fact that it is their duty to be on time. In case of pressing work, he should have no difficulty in maintaining his interest in his problems, even beyond the quitting hour or to the extent of extra shifts. He should have assistants who can take each others place, as well as his own, during absence, without causing any handicap to his department. In other words, he should have two men capable of handling the same job, in order that his organization may function properly at all times.

He should also practice and preach Safety First.

Maintain Morale.

The Inspector should help maintain morale in the organization with which he is connected. He should be fair and impartial to all. Make just decisions and give unbiased opinions on questions submitted to him. He should make workmen feel that he thoroughly understands the quality of the work required and insist that this quality be met. Show appreciation for suggestions made. Recommend to foremen, employees who do good work as well as calling their attention to those whose work is of a poor quality.

He should use tact:

a. When making decisions where opinions govern the case in hand.

b. In using only constructive criticism.

c. In avoiding arguments with the workmen. He should confine himself to concise statements in explaining why work cannot be accepted and point out defects in a friendly manner.

He should:

Promote good will by working in harmony and cooperating with all supervisors with whom he has dealings.

The Inspector should never make an issue about points that are of little importance. He should extend encouragement and help to new men by showing appreciation for good work.

He should be trustworthy, consistent in his approvals and rejections, and should control his temper. He should display a proper dignity, yet be friendly and pleasant.

SECTION XV. DESTRUCTION OF AMMUNITION

8. Destruction of Ammunition and Hazardous Ammunition Components.

In this lecture the destruction of ammunition and ammunition components will be considered from the viewpoint of the Ordnance Officer who will be called upon to actually accomplish the destruction or to give technical advice to the Commanding Officer of a post, camp or station with regard to destruction of ammunition. Matters which are fully covered in the Ordnance Safety Manual and in Technical Regulations 1370-A will not be repeated here; and, for convenience of arrangement, the subject matter is divided into a General Discussion, Destruction of Artillery Ammunition and other large components, Destruction of Small Ammunition Components, and Handling and Destruction of Duds.

GENERAL DISCUSSION

Items for destruction occur in four ways:

- a. Un-accepted manufactured components.
- b. Obsolescence of material.
- c. Deterioration in storage.
- d. Duds.

The procedure involved is most decidedly influenced by whether the destruction is to take place at an Ordnance establishment or at a post, camp or station. In the first case, adequate facilities and trained personnel are usually available; a routine procedure is established; and even though the material is of an unusual or experimental nature, the necessary technical advice is usually available. The officer has only to assure himself that adequate safety precautions are being taken and that the general principles outlined in T.R. 1370-A and the Ordnance Safety Manual are not being violated.

At a post, camp or station, the situation is vastly different. The Ordnance Officer is the technical expert and must shoulder the entire responsibility; the personnel are untrained; and the facilities negligible. Each specific case presents a different problem and it is only possible to outline the general principles.

At posts, camps, or stations, the only items requiring destruction are obsolete or deteriorated ammunition (which may be considered together), and duds. Duds will be omitted from the discussion for the present for they present an entirely different problem from ammunition of known condition. Prior to destruction, all obsolete or deteriorated ammunition will necessarily have been placed on Inventory and Inspection Report and its disposition recommended and approved. The disposition, directed by the Inventory and Inspection Report will show what parts, if any, are to be salvaged. However, the post Ordnance Officer is almost invariably the inspector for all Ordnance property; so both the responsibility for the disposition and the actual destruction rests upon him. It should be noted that regulations prescribe that destruction be accomplished by burning, exploding, or dumping at sea, and specifically forbid dumping in inland streams or waterways, numerous regrettable examples to the contrary notwithstanding.

In any destruction project the major consideration is SAFETY. It is impossible to over-emphasize the importance of safety for the way explosives can exceed one's most carefully considered estimates is surprising beyond belief. Every hazardous operation should be fully covered by safety devices. It is highly advisable to test all safety devices before hand by subjecting them to the severest test they may be called upon to withstand, provided such test is reasonable and practicable. For example, a safety tube to protect against the accidental explosion of a primer should be tested. On the other hand, a baffle wall to protect against the accidental ignition of several boxes of smokeless powder should not be tested, for it is not generally feasible to expend the maximum quantity of powder and boxes for test. After all, good judgment is the deciding factor both in the design and testing of safety devices. After all the requirements of safety have been fully satisfied, then, and only then, may salvage and economy be considered.

At a post, camp or station, it is generally necessary to improvise one or more pieces of apparatus. Protective walls, complete round presses, burning pits with secure covers, etc. are generally not available. The apparatus can generally be provided by modification of existing facilities by the local Ordnance or Quartermaster shops, in accordance with a pencil sketch furnished by the Ordnance Officer. The salvage yard is a fruitful source of supply for old armor plate, boiler plate, and all sorts of things that just suit the purpose. Each piece of improvised apparatus should not only be safe beyond a reasonable doubt, but also assure protection to the careless, indifferent, childishly curious, and just plain brainless. It is well to remember that the private soldier is not paid to think; and the I.Q. rises only gradually with the non-commissioned grades.

It is therefore necessary that the officer do all the necessary thinking before the first phase of operations is begun. It is urgent that he make a detailed analysis of his problem, and plan the entire procedure step by step.

DESTRUCTION OF ARTILLERY AMMUNITION

Whenever complete rounds are to be destroyed, whether or not some parts are to be salvaged, it is almost always necessary to divide the work into two distinct phases; viz; disassembly and actual destruction of hazardous components. In general, these two phases have no mutual relation other than the fact that the first governs the supply for the second; consequently, they should be considered separately.

If the work is of any considerable magnitude, a detailed list of operations for each phase of the work should be prepared in writing and copies furnished to the non-commissioned officers and posted at the place of work. The method used by the Artillery in the service of the piece can be admirably adapted to this use. Assign each man a number, and a few simple operations to perform, e.g., number one will open the ammunition box, remove the lid from the box, and place the open box on the roller conveyor. Number two will push the box along the conveyor from number one to number three, etc. This method has three distinct advantages: first, each man knows exactly what he must do, and knows that he should do nothing else; second, it provides a ready vehicle for avoiding excessive muscular fatigue, by the mere expedient of having the men change posts once or twice a day; third, it provides a prompt method of re-organizing the demolition crew each morning when there is a partial or complete change of personnel. In addition to the list of operations, a list of general and special safety rules should be prepared and posted at the place of work, in order that no man can fail to know what he should and should not do.

The entire program should then be checked against T.R. 1370-A and the Ordnance Safety Manual to see that all applicable principles are being carried out and none violated.

As an illustration, in 1933 it became necessary, due to obsolescence, to dispose of 6,000 complete rounds of Fixed 4.7 inch H. E. Shell, unfuzed, at Fort Sill, Oklahoma. The instructions of the Chief of Ordnance were to save the smokeless powder for exchange for new FNH powder, save the brass cartridge cases for scrap brass, and destroy the rest of the complete round.

In this case, the breaking-down operation was performed in the magazine area (but at least 100 feet from the nearest magazine) in order to save a long haul on the complete rounds from the magazine to the place of work and an equally long haul on the salvaged components back to the magazine area. Furthermore, since it was impracticable to carry on both the breaking-down phase and the demolition phase simultaneously, due to lack of personnel, the projectiles were temporarily stored in the magazine.

The breaking-down phase required the improvising of three pieces of apparatus (see sketch); a machine for pulling the projectile from the cartridge case; a baffle wall with a chute going through it to safely deliver the powder to the storage containers; and a device for firing the primers. All of this apparatus was constructed in the Ordnance shops. During the period of destruction, the Ordnance shops had to get along without one of its large arbor presses, as it was necessary to convert it, by means of attachments, into a breaking-down machine.

The apparatus was set up as shown by the accompanying sketch; a sheet of operations made out showing the duties of each man; a set of safety rules provided; and the work proceeded without the slightest mishap.

After separating the projectiles from the complete rounds, they must all be destroyed. Neither T.R. 1370-A nor the Safety Manual furnishes an adequate method for accomplishing this task. The regulations contemplate destroying only a few deteriorated rounds; and it is presumed that an Ordnance Officer will devise a safe and reasonable working plan to meet the local situation and submit it to proper authority for approval. To destroy 6,000 projectiles individually with blasting caps would be an expensive and time consuming task.

Fort Sill is amply supplied with wide open spaces and natural ditches. An area was selected about 1-1/2 miles distance from the inhabited area that was adjacent to a road and through which ran a very crooked ravine. By locating the points of destruction in the acute crooks of the ravine, all the benefits of a trench could be obtained, without the labor of digging. It should also be noted that after a few blows the digging is done automatically by virtue of the deepening of the crater and the problem becomes one of filling rather than digging.

The first operation in preparing a field for demolition work is to take out a good fire-fighting crew armed with wet burlap sacks, and burn off an area of at least a hundred feet radius from each point of destruction. More should be burned off if

practicable, for hot shell fragments occasionally cause grass fires. As an additional precaution, empty sacks and a water supply should always be kept on hand when destruction is under way.

Shell fragments could be expected to travel up to 800 yards. This is too great a distance for personnel to retire to between explosions. Hence, a small shanty, similar in design to the dug-out used by a baseball team, was constructed of old tractor armor plate at a distance of 100 yards from the ravine. (See Sketch). The shanty was connected with the three crooks in the ravine by means of old Signal Corps communication wire.

To insure safety, a knife switch was installed on top of the shanty with a white semaphore attached. When the switch was open the semaphore was automatically displayed; and no one was allowed out of the shanty, unless the semaphore was up. A guard was placed on the road at a point of advantage, who allowed no one to pass unless the semaphore was up, and then only after informing the officer in charge of his intention by signal flag communication. In like manner, the officer in charge used a signal flag to inform the guard when another truck load of ammunition was required.

The personnel were divided into a fusing crew who connected the blasting caps and tamped them into the booster cavities; a truck crew, a loading crew, and a guard. The throwing of the switch and operation of the blasting machine were functions reserved to the officer in charge, who saw that the field was clear and all men were in the shanty, before closing connection.

Operations were begun with one shell, then three, then six, etc. up to twenty. Twenty worked so well that two or three blows of forty were tried; but this resulted in jarring a loose window out of the Ordnance shops (2 miles distance), and the Commanding General claimed that he was blown out of his office chair, so twenty became the standard practice.

In blowing the twenty shell, they were arranged with six in the bottom row, five in the next, four, three and two on top. No. 8 electric blasting caps were placed in the top two only. It would be unwise to place the blasting caps in other than the top shells, as this would tend to increase the scattering of fragments and might result in scattering un-exploded shell. By initiating the explosion from the top, its force was made to work downward, and in no instance did a shell fail to explode.

Perhaps this may appear to be a rather tedious and involved procedure to accomplish an end that so readily takes place, almost of its own accord. However, it should be borne in mind that systematic organization is not only a potent factor in avoiding hazardous blunders; but it lends proper courage to personnel, quiets devil-may-care bravado, and actually speeds up production enough to pay its own way - besides, this is a peace-time job, and it is better to waste a considerable amount of time and labor than have one soldier injured.

The methods for destruction of artillery shell apply equally well to bombs, trench mortar shell, and any other fairly large component which contains high explosive. It should, however, be noted that whereas artillery shell contain only about 15% by weight of explosive, bombs and trench mortar shell contain up to 60% explosive, and the number of units destroyed at one blow should be reduced accordingly. Where the booster cavity is not accessible, it may be necessary to put one or more TNT blocks on the component which is to initiate the mass detonation.

The destruction of shrapnel can not be accomplished by mass detonation. When only a few obsolete or deteriorated shrapnel are to be destroyed, it is generally easier to unscrew the fuze, soak the shrapnel in a barrel of water for several days, and then disassemble under water, rather than accomplish destruction by explosion. When the number to be destroyed renders this method too laborious, other means must be devised.

No specific method is described in either the Safety Manual or T.R. 1370-A, other than the general method of destroying artillery ammunition by placing several TNT blocks on the projectile. This method would doubtless shatter the shrapnel case and scatter the balls; but gives no positive assurance of destruction of the base charge. The remaining portion of the shrapnel still might cause an accident. It is therefore highly desirable to destroy the base charge.

By way of illustration, it is well to go back to the Fort Sill project, previously referred to. At the same time that the 6,000 rounds of shell were being destroyed, it was also necessary to destroy a considerable number of fixed 4.7 inch shrapnel.

The shrapnel was broken down in identically the same manner as previously described for the shell. The same system and set-up was also used for the destruction, except that a 110 volt line from a Mobile Ordnance Repair Shop was used for a source of electricity instead of the blasting machine.

The shrapnel, with time fuzes removed, were laid in a row in the blowing pit. A No. 8 blasting cap was slipped down the flash tube of each shrapnel, and sand piled up in front to force the explosion to the rear. Only ten shrapnel were blown at a time for the reason that ten blasting caps connected in parallel were all that could be successfully initiated by the current available. Although not as fast as the destruction of the shell, this method worked very successfully. The shrapnel cases were available for salvage, but the recovery of the balls was too tedious to be worth while. It should be noted that when a shrapnel is exploded in this manner, the case recoils with a tremendous velocity and will escape from the blowing pit unless backed up by a solid perpendicular surface.

The method used at Picatinny Arsenal for removing the base charge is safe, simple, and effective. An armor plate barricade is erected with about a 3/8 inch hole drilled through it at an angle of 45 degrees with its face. A wooden jig is placed behind the barricade which holds the shrapnel at just the correct angle so that a brass rod pushed through the 45 degree hole will proceed straight down the flash tube and push out the disc and packing, driving them down into the base charge. After the obstructions are removed from the flash tube the operator steps behind the barricade and gets the shrapnel. The black powder is then removed by inverting the shrapnel case and shaking. The broken disc and the packing are allowed to remain in the base cavity.

At one time it was the Arsenal practice to wash out the base cavity with water, and then dry it by introducing a jet of compressed air down the flash tube. This method also succeeded in removing the fragments of the disc and packing as the compressed air was sufficiently violent to blow them out through the clearance between the flash tube and the compressed air tube. However, the purpose of the removal of the old base charge is replacement by a serviceable base charge; not destruction of the projectile, and the use of water was found objectionable and was therefore discontinued.

The Arsenal method of removing the base charge can very readily be adapted for use in the field where the quantity of shrapnel to be destroyed justifies it. The obstructions in the tube can be removed from behind an armor plate barricade as described above. Then a small rubber tube connected with a water supply can be introduced down the flash tube and the black powder removed by floatation. After the apparent removal of all the black powder by floatation, and while the cavity is still wet, the balls and matrix can be removed by as violent means as the situation demands. This can generally be accomplished by

violently striking the case against a heavy iron bar. This method has been successfully used and has the advantage of making both the case and the shrapnel balls available for salvage.

DESTRUCTION OF SMALL AMMUNITION COMPONENTS

Instructions for the destruction of primers, fuzes, detonators, etc. are given in T.R. 1370A, and the prescribed method is burning in a pit about 6 feet square and 4 feet deep. Several means that do not require so much digging are described in the Safety Manual. For the destruction of limited amounts of grenade fuzes, primers, and other small components, a very suitable stove can be improvised from two old tractor armors bolted cowl to cowl. A fire will burn in these old armors much better than in a pit as baffled drafts are already provided by the protected vents through the radiator guard. Add a baffled chute to one of the top doors for the introduction of explosives, and the stove is completed. The explosions in this stove do not scatter the fire as is the case in a pit or trench and the apparatus can be preserved for future use without offering the hazard of a pit fall.

When the use of a pit becomes unavoidable, as is the case when powerful detonators or hand grenades are to be destroyed, it is sometimes possible to avoid several men days of labor by getting permission to use an old abandoned dry well, cistern or cattle dipping vat. A cattle dipping vat is excellent, because it is generally constructed of heavy reinforced concrete, is about 12 feet deep, and is capable of admitting draft from the bottom. The top of the pit must be covered with heavy metal bolted in place in order to keep the fragments in. A roaring fire of salvaged lumber doused with gasoline should first be started in the pit. Do not drop a match in to start the fire. Instead, wrap a small ball of saturated waste with wire; light the waste, and toss it in the pit from a distance of at least 12 feet, if you want to save your hair and eyebrows. As an alternative to the ball of saturated waste, use a small amount of black powder ignited with an electric squib. Explosives should be introduced cautiously, because normal action cannot be expected under intense heat. Three or four detonators for 3 inch Stokes mortar shell will almost ruin a very substantial pit; and the only way to know that all previously introduced components have exploded is to wait and count the explosions. Even such an innocent thing as an unfuzed tear gas grenade which is only supposed to slowly expel its gases through a row of perforated holes, will detonate violently under the influence of heat; and, if the cover of the pit has been partially blown away, the empty grenade case may come out with sufficient velocity to practically decapitate a man. Expect the unexpect-

ed when burning explosives.

SAFE HANDLING AND DESTRUCTION OF DUDS

A dud is any ammunition component that has had an opportunity to function; did not; but may at any time. Every dud must be regarded as a potential accident.

For some quite unaccountable reason duds have a peculiar and sinister fascination for a large number of people. This is particularly true of civilian components who come to army posts for summer training; recruits, and even new officers. Many accidents, and often fatal ones, occur every year from this perverted thirst for military knowledge or fetish for souvenirs. The Ordnance Officer should consider it his duty to recommend to the Commanding Officer that tampering with duds be strictly prohibited by post regulations, and that violation of the prohibition be severely punished.

Duds present three different types of problems to the Ordnance Officer, depending upon their location at the time that they became a subject of his duties: viz; duds on the artillery target range, duds lodged in the bore of cannon, and duds abandoned in populous areas.

With regard to the first and third classes, there is an important point to be observed. The Ordnance Officer in the field is responsible for the storage and issue of ammunition. Once he has completed the issue, his responsibility ceases, unless it is again enjoined upon him by proper authority. The police of the range and safety of the command are functions of the Commanding Officer. Various people will call the Ordnance Office requesting that action be taken with regard to explosives or ammunition on or off the post. All these people should be advised to report the situation to the Commanding Officer. The Commanding Officer may want his range officer, or some other officer, to take charge of the situation; and, except in cases of emergency, the Ordnance Officer is going beyond his jurisdiction, if he takes action with regard to ammunition concerning which he has no responsibility. On the other hand, ordnance ammunition lodged in the bore of cannon is an ordnance responsibility, because the proper functioning of the piece is an ordnance responsibility.

The destruction of range duds is fully covered in the Safety Manual and T.R. 1370-A. Usually a line officer detailed by the Commanding Officer as range officer does this work, instead of

an Ordnance Officer, and the Ordnance Officer has no control of his activities. Flagrant violations of regulations are not uncommon. One of the worst violations is the practice of gathering duds into convenient piles and destroying them by mass detonation. The saving in time and TNT is a poor excuse. No officer has the right to subject himself or his command to such risks.

A dud should be approached with respect, caution, and honest misgivings. The first and most important point to observe is whether or not the dud is fuze. If it is unfuzed it may be safely subjected to all the indignities that the temper of the individual may suggest; but if fuze (time, point or base), it should be treated with the same horrified aloofness traditionally accorded the leper. The condition of its fuze is an unknown quantity. Every safety feature may be shot. Although it has stood the terrific impact of fall, a slight additional jar, the mere changing of its position from the horizontal to the vertical, may cause the firing pin to scratch across the primer and result in taps for the intruder. Leave it where it lays; put the prescribed number of TNT blocks on it; and destroy it as prescribed in regulations. Any other course is a violation of regulations and must be justified by cogent reasons.

In extremely rare cases, it may become necessary to move a fuze range dud before destroying it. In this event, a length of rope somewhat greater than the danger radius of the dud should be obtained. A secure hitch should be carefully taken on the dud. Then it can be dragged to a location where destruction can be safely accomplished.

When a projectile lodges in the bore of a cannon, no trouble is experienced with the usual tendency to troops to attempt unauthorized repairs on ordnance material. They call the Ordnance Officer without delay. This spirit of rectitude is probably not dictated by unusual reverence for this type of dud; but is more likely accounted for by the fact that officers are present when such malfunctions occur, and see that proper action is taken.

This trouble is not infrequent when 37 m/m low explosive is being fired, and can rather be expected during sub-caliber practices at an Artillery post. The danger points are, of course, confined to the open ends of the gun tube, but even then, it would be inadvisable to try to drive the projectile out. It is better to remove the barrel assembly and press the projectile gently to the rear by means of an hydraulic press of large arbor press. Only the minimum number of persons should be present during this operation.

When duds are abandoned in populous areas, regulations have already been violated and there is no way to remove the hazard without violating them some more. Unauthorized persons sometimes steal duds from an Artillery range; carry them to a nearby city; lose their nerve or enthusiasm, and abandon them on the streets. This generally results in a call from the local police requesting that the Army come and reclaim its own. If the dud happens to be on someone's private property, that should be regarded as the property owner's responsibility; but again that is up to the Commanding Officer. You can't blow up a dud on a city street so, if ordered to take charge of the situation the only thing to do is procure the smoothest riding piece of transportation available; place the dud on a cushion or in a well padded box, being careful all the while to keep it horizontal; and slowly proceed back to the range with it, hoping to God you get there.

SECTION XV - MISCELLANEOUS SUBJECTS.

11. GAGES AND ELEMENTS OF GAGE DESIGN

Definition of the Term "Gage"

1. The term "Gage" in this discussion will be limited to those devices or instruments actually used in the acceptance or rejection of machined components used in the manufacture and assembly of ammunition. This definition precludes all devices such as light ray measuring instruments, measuring machines, optometers, comparitors, Johansson blocks, etc. These devices are used chiefly in the acceptance of the gages themselves. Gage laboratories containing these devices, as well as machines for exact measurement, have been established by the Ordnance Department to assure a supply of trained personnel and for emergency use in the checking of gages. The location and functions of Ordnance Department gage laboratories is described in the Gage Supplemental Procurement Plan, Paragraph 12, Page 4. The location of these laboratories is given in Appendix II for ready reference. Since a knowledge of gage checking is a specialized branch of gage work and not essential to an understanding of gaging metal components, this subject will not be discussed at this time.

2. Prior to the adoption of inspection gages the various parts of mechanism were made by fitting one to the other. The advantage of making component parts such as fire arms, etc., as nearly alike that they could be assembled without fitting, and be interchangeable with other like assemblies, were self evident.

3. Methods of gaging were used as far back as the Revolutionary War, when wood and metal templates were used, however, the first complete system of interchangeable manufacture is credited to a New England mechanic who made a complete system of jigs, fixtures, tools and gages for use in the Colt Armory at Hartford, Connecticut.

4. Considerable progress was made in interchangeable manufacture and gaging during the World War on Ordnance material because of the requirement for extremely large rates of production. The extent to which gages are necessary depends on the quantity of parts to be gaged. A gage should be provided wherever its use is more economical than the use of standard measuring instruments.

5. One of the prime purposes of gages is to "transfer the skill" of measurement from the workman or inspector to the gage, thus making possible the use of relatively untrained labor. As was mentioned previously, mechanisms were formerly made by fitting one part to another. This process required the services of skilled mechanics with long terms of apprenticeship for a continued supply of new labor. This phase of production has passed and now industry is no longer

dependent upon men trained in all phases of machine shop practice. This is true because the skill required is concentrated in the tools and gages which are supplied to the worker before he starts a job. It is, therefore, possible to train men in a very short time to do the bulk of production operations. Therefore, almost any person, male or female, of normal intelligence who can supply sufficient muscular effort, is a potential machine shop producer or inspector.

6. It may not be practicable to design and fabricate tools in advance of an emergency because the type of machine tool equipment on which the components are to be manufactured is constantly changing with changes and improvements in tool equipment. However, since gages are independent of the type of machine used to produce the components, it is possible to design and manufacture gages to be placed in storage for use in the event of war. Thus, with the present policy of gage procurement in peace time, manufacturers will be relieved of a large portion of precision gage work and will be free to concentrate on tool work, which will be urgently needed.

7. The General Inspection Manual of the Ordnance Department states that gages are classified by the Ordnance Department as Inspection Gages and Manufacturing Gages and are defined as follows:

a. Inspection Gages are all gages or special measuring instruments used by the inspector in the acceptance of the final finished product. They are to insure that the product has been manufactured within the component limits specified on the drawings and that the part or unit assembly is acceptable. The supply of these gages is the responsibility of the Ordnance Department, and they are furnished to the inspector.

b. Manufacturing Gages are all gages or special measuring apparatus used by the contractor in the production of the product. The supply of these gages is the responsibility of the contractor.

8. The Manual Gage Inspection of the Ordnance Department gives the following list as the "Types of Gages":

1. Commercial Standard Types
 - Plain Plug
 - Progressive Plug
 - Threaded Plug (straight)
 - Threaded Plug (pipe)
 - Plain Ring
 - Twin Ring
 - Combination Ring and Snap
 - Threaded Ring (straight)
 - Threaded Ring (pipe)
 - Adjustable Snap
 - Adjustable Length

a. These types are commercial and are fully covered in Pamphlet CS8-33 (Gage Blanks) issued by the United States Department of Commerce, Federal Specification GGG-G-61 and GGG-P-351 (for pipe thread gages).

2. Special Types

- Taper Plug
- Alignment Plug
- Flat Plug, Thickness
- Graduated Plug
- Pin or Plate
- Progressive Ring
- Taper Plug
- Plain Snap
- Built-Up Snap
- Shoot Length
- Flush Pin
- Spanner
- Receiving
- Profile or Template
- Thread Plug, Acme Thread
- Thread Ring, Acme Thread
- Thread Plug, Lowenherz Thread
- Thread Ring, Lowenherz Thread
- Thread Plug, Square Thread
- Thread Ring, Square Thread
- Caliper
- Goose Neck

The description of the special types of gages is covered in the Gage Inspection Manual and is attached for ready reference.

9. In the inspection of gages all measurements of gages should be made in a room where constant temperature of 68°F is maintained.

10. Gages received for checking should remain in this room until the gage has attained the same temperature as the room and the instrument used in checking.

11. Care must be exercised, when checking precision gages, that they be shielded from body heat, as this heat is absorbed with greater rapidity by the gage than by the instrument used for checking, which will affect the size. Thus, undue handling of the gage or instrument should be avoided.

12. In the preservation of gages it has been found that No. Ox-Ide, Consistency B, heated to a temperature of 150° to 180°F, offers the best protection for gages in storage. Gages may be immersed in this protective bath, wrapped in moisture and acid proof waxed paper and then wrapped in kraft wrapping paper.

13. Some gages do not permit immersion, such as those having

dial indicators attached, so the protective covering may be applied by means of a brush.

14. The sequence of events in gage designs is that as soon as a new type of material is declared standard, the Manufacturing Division of the Ordnance Department, charged with design, will notify the Gage Division of such fact, and will call upon it to make a complete check of all the tolerances shown on the drawings, with a view to careful analysis of these tolerances and the suggestion of corrections, if necessary. The drawings will be checked over carefully by that section for economical interchangeable mass production, with particular attention to the use of more liberal tolerances wherever possible. The Gage Division will, at this time, prepare or have prepared at an Arsenal, a complete list of all inspection gages required. After completion of the check of tolerances and preparation of the gage list, these data will be referred to the Manufacturing Division for its comment or concurrence. The Gage Division will then proceed, at the proper time, to prepare or have prepared the actual design of inspection and check gages so that all the drawings of such gages will be on hand prior to the date when manufacture of a new standard is expected.

15. A "List of gage drawings" will be made listing each gage drawing, in numerical order, for a type of material. The list of drawings will be made up for the convenience of the file room in getting out a complete set of drawings for any article.

16. An "Index to gage list" will be made, listing each component part of the material, in alphabetical order, showing the gage list number and sheet number upon which the gage for the part is listed.

17. The tolerance or limit system which forms the basis of interchangeable manufacture is applied in different ways by various manufacturers. With a complete system of gaging and inspection, special fitting and assembly is almost, if not entirely eliminated with the manufacturing costs greatly reduced. The practice of making drawings which specify the exact amount of tolerance between different parts eliminates controversy when work is inspected. On Ordnance Department drawings it is required that all dimensions for machined parts will show the basic figure dimension as the maximum metal conditions wherever practicable. The tolerances are unilateral and given in one direction only, i.e., $1.75 + .003$ or $1.750 - .003$. The prescribing of tolerances on interchangeable work is of vital importance and generally does not receive the consideration that it deserves. An interesting publication on tolerance is "Tolerances, Allowances and Gages for Metal Fits," approved by the American Engineering Standards Commission, #B4a - 1925. This publication was adopted by the Ordnance Department in 1927 by Ordnance Department Office Order No. 712. Similar information for screw threads is given in "The Report of the National Screw Thread Commission" and gives all technical data, dimensions, etc., for the American National form of thread adopted as the Ordnance Department Standard.

18. Wear allowances are required on all gages where the component RUBS or presents a wearing action to the gage, with the exception of adjustable snap gages, where no wear allowance is used because the gage may be re-set as soon as it begins to materially wear within the prescribed limit. Tool makers tolerance or "gage tolerance" is applied to all gages between the gaging surfaces. This is necessary since it is impracticable to make any two parts exactly alike. There are several systems of gage tolerances and wear allowances. Perhaps the most simple and yet practical is that used by the Ordnance Department. In this system, ten percent of the component tolerance is taken and approximately divided between the wear allowances and the tolerance. The following tables are taken from the table used for ordnance inspection gages.

TABLE OF WEAR ALLOWANCES AND GAGEMAKERS
TOLERANCES FOR PLAIN PLUG AND PLAIN RING GAGES

From Drawing 27-80-1 Rev. 3-2-38

TABLE I

Component Total Tolerance *	Gage		
	Wear Allowance	Tolerance	
		Go	Not Go
.0005	.0000	.00005	.00005
.001	.0001	.0001	.00005
.002	.0001	.0001	.0001
.003	.0001	.0002	.0001
.004	.0002	.0002	.0002
.005	.0003	.0002	.0002
.006	.0004	.0002	.0002
.007	.0004	.0003	.0002
.008	.0005	.0003	.0002
.009	.0005	.0004	.0002
.010	.0005	.0005	.0003
.012	.0006	.0006	.0003
.014	.0006	.0008	.0004
.015	.0006	.0009	.0005
.016	.0006	.0010	.0005
.018	.0006	.0010	.0006
.020	.0006	.0010	.0007
.022	.0006	.0010	.0008
.024	.0006	.0010	.0009
.025 & UP	.0006	.0010	.0010

TABLE OF GAGEMAKERS TOLERANCES FOR
FLUSH PIN AND ADJUSTABLE SNAP GAGES

From Drawing 27-80-1 Rev. 3-2-38

TABLE II

Component Total Tolerance	Wear Allowance	Gage Tolerance	
		Go	Not Go
.0005	None	.00005	.00005
.001	"	.00005	.00005
.002	"	.0001	.0001
.003	"	.0001	.0001
.004	"	.0002	.0002
.010	"	.0003	.0003
.015	"	.0004	.0004
.020 & UP	"	.0005	.0005

* For component tolerances not listed, use next smaller tolerance.

It should be remembered that the wear allowances and tolerances, derived by taking ten percent of the component tolerance, only apply to the "Go" gage. For example, if ten percent of the .005 tolerance shown in the first column, Table I, is taken, the result is:

$$(1) \quad .005 \times 0.10 = .0005$$

On the same line the wear allowance is .0003 and the gage tolerance is .0002. The sum of these two quantities is .0005 or ten percent of the component tolerance.

19. For tolerances smaller than .002 the ten percent rule gives tolerances which are too small for practical use, so that the system cannot be applied. In these instances, wear allowances and tolerances have been selected as close as possible to practical tool room limits. Note that in the case of .0005 component tolerances, no wear allowance has been applied. Note also that after .016 component tolerance has been reached, the wear allowances and tolerances are constant.

20. The "Not Go" tolerance shown in Table I is selected entirely from practical considerations and bears no direct relationship to the "Go" tolerances or the component tolerances.

21. Table II shows the tolerances for Flush Pin and Adjustable Snap Gages. Note that between .001 and .004 component tolerances, this table has been derived by dividing ten percent of the component tolerance between the "Go" and "Not Go" gage tolerances. For component tolerances outside this range, the gagemakers tolerances are small in comparison with those shown in Table I. The reason for this being that the gages covered by this table are easy of adjustment and repair. In the case of an adjustable snap gage, it is merely necessary to set up Johansson gage blocks to the proper dimensions and adjust the gage to a smooth sliding fit of the blocks between the gaging surfaces. The Manual of Gage Inspection shows clearly the simplicity with which flush pin gages may be measured by the use of gage blocks. From these considerations it is readily apparent that no wear allowance is necessary on these types of gages, and that the small tolerances present no handicap in gage manufacture.

22. In the use of the tables it should be remembered that, in the case of female dimensions, the "Go" gage represents the smallest permissible opening with wear allowance and gagemakers tolerance applied so as to increase the life of the gage. It might be well to point out here that if the gage were made to the minimum size of the female dimension, its useful life would be limited to the first few hundred components gaged. The calculations involved in the design of a cylindrical plug gage for a hole, are shown in Fig. 2. In this instance, the component dimension under consideration is $.500 + .005$. Referring to Table I, the wear allowance opposite .005 component tolerance is found to be .0003. This is added to the minimum component dimension

making the basic gage size .5003. Since the tolerance, as shown under Fig. 2, is to be in the direction of increase in the life of the gage, its sign is plus, making the resulting gage dimension $.5003 + .0002$. The "Not Go" gage for the hole shown in Fig. 2 is the opposite of the "Go" gage, that is, it is a plug representing the largest permissible hole. If the hole is within the limits prescribed, this plug should not enter the hole. Therefore, its name "Not Go" gage. Strictly speaking, however, if the gage enters with difficulty, it is probable that the part is acceptable because parts which are "size and size" can be forced together. In this case then, the basic "Not Go" plug dimension is .5050. From a gaging standpoint, it would be desirable to have the "Not Go" gage exactly .505 and since the plug does not enter the hole, no wear allowance is required. Since it is not economically practicable to produce a plug which is exactly .505 in diameter, some tolerance must be permitted. Consulting Table I again, the recommended tolerance is found to be .0002. This tolerance is applied minus or "in the direction of safety." Thus, the resulting gage dimension is found to be $.5050 - .0002$. In the design of ring gages for the cylindrical piece of work, shown in Fig. 1, the "Go" ring should represent the largest permissible male piece with wear allowance subtracted and gagemakers tolerance applied minus. The wear allowance and tolerances are the same as those used for the "Go" plug in Fig. 2, since the tolerance is the same. Subtracting the wear allowance from the maximum permissible component, the basic gage size is obtained. Viz: $.5000 - .0003 = .4997$. The tolerance is applied minus, giving the resulting gage dimension as: $.4997 - .0002$. The "Not Go" ring should represent the minimum permissible size of the cylinder with the tolerance "in the direction of safety" that is, with the tolerance in the direction of producing a gage that is slightly larger than the minimum size component. Thus, the tolerance would be plus, giving a resulting gage dimension of $.4950 + .0002$.

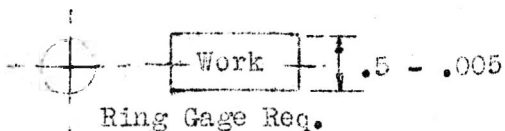


Fig. 1



Fig. 2

Max. size of part	.5000
Wear allowance	- .0003
Gage size	<u>.4997</u>
Tolerance	- .0002
"GO" Gage Dim.	$.4997 - .0002$
"NOT GO" Gage	$.4950 + .0002$
(No wear allowance given)	

Min. size of part	.5000
Wear allowance	+ .0003
Gage size	<u>.5003</u>
Tolerance	+ .0002
"GO" Gage Drg.	$.5003 + .0002$
"NOT GO" Gage	$.5050 - .0002$
(No wear allowance given)	

23. The design of gages for ordnance work is fundamentally the same as that for the manufacture of any other machined metal parts. There are, however, certain principles which apply to ordnance gages

to a greater degree than to other types of manufacture. They are:

- (a) Ruggedness of design. It is assumed that ordnance gages will be used where they are most needed, either on a bench or at the machine where production is taking place. With these conditions imposed it is obvious that gages must be as sturdy as possible in order to withstand all conceivable shop conditions.
- (b) Simplicity of design. Gages are designed whenever possible so that they can be used without a large amount of special instruction of the inspector in their use. This policy leads to a greater number of single purpose gages rather than a small number of combination gages which combine a number of gaging operations in a single gage. It is obvious that here a certain amount of efficiency of operation is sacrificed in favor of simplicity of design. This slight loss in efficiency is balanced by the advantage of being able to employ relatively untrained personnel and also by the advantage of having a flexible system of gaging with the ability to accommodate itself to all manufacturing conditions.
- (c) Low cost of manufacture. The cost of manufacture of each individual gage is kept as low as possible by liberal tolerances, simplified design, and the specification of gage materials in such a way that the manufacturer may choose from any satisfactory material at his disposal. This procedure obviously widens the field of procurement to include many of the thousands of small shops in the country. The advantages of this policy in emergency procurement of gages is obvious.
- (d) Adherence to standard design. The list of standard "types of gages" given in paragraph 8 shows all of the gages for which blanks are maintained in stock by gage manufacturers. These standards are used wherever applicable in ordnance gage design. Thus, the cost of design, procurement and the time of delivery are all materially reduced. As an example of the way in which gage design costs are reduced, there are maintained in the drafting office, standard gage design sheets showing the standard gages without regard to scale. When it is desired to design a standard gage it is only necessary to add the proper sizes and notes to this drawing and the work is complete. The mechanic who makes the gage from this drawing simply withdraws from stock, the proper size blanks and completes the finishing operations of machining, hardening, grinding and lapping. Certain standard items from this list are maintained in manufacturers

stocks and can be purchased without machining operations of any kind. In this category are gages for standard threads, adjustable snap and adjustable length gages. In the case of a thread gage for, say 1/4-20NC-2 thread, this gage can be procured almost as readily as the tap. Adjustable snap gages may be procured, set and sealed to any desired limits. These gages are procurable to cover all sizes from 0 to 12 inches. There is also a small gage for use on small parts procurable in the range from 0 to .76 inches. Ref.: Page 37, Pamphlet CS8-33. The design of gages is moving constantly in the direction of standardization. The form and shape of the so called special gages is specified so that machining is eliminated on the exterior surfaces. As an example, flush pin gages are made from hexagon stock tool steel, which is standard for chisels, tool bits, etc. In addition to this, marking may be stamped without machining of flats.

- (e) Elimination of sensitive special gaging instruments and gages involving proprietary rights. Many gages for rapid inspection are now on the market which involve sensitive mechanical electrical or light ray systems. The question naturally arises as to why the Ordnance Department has not taken more advantage of these for standard War Reserve. There are several reasons why this has not been done, the chief of which is that the accuracy required does not warrant the investment involved in these types of gages, since the majority of ammunition work does not require the extreme accuracy needed in automotive engine work. There is also the factor of storage to be considered. In this connection, there is no assurance that instruments of this type would be serviceable after several years of storage. The design of ammunition gages utilizing visual measuring devices, however, is being conducted. There is an additional disadvantage to some types of the special gages in that they are patented devices which may be procurable only from a limited number of manufacturers.

24. Thread Gages.

As has been mentioned, the best authority on screw threads and gages for screw threads is the "Report of the National Screw Thread Commission," Miscellaneous Publication of the Bureau of Standards, No. 89. Prior to this work, each manufacturer had his own thread standards of fits. Much difficulty was experienced in the fitting of parts together, especially where the holes were tapped by one manufacturer and the male, or threaded bolt, made by another. This condition became very acute during the World War when enormous quantities

of components were manufactured and brought together at one point for assembly. To obviate the difficulties, Congress authorized the National Screw Thread Commission in July 1918. The report gives specific directions as to design, so that gages designed by one manufacturer for a given size screw will be the same as those designed by any other manufacturer. The elements of thread gaging are here treated briefly.

25. There are four gages necessary to the acceptance or rejection of a female thread as follows:

1. Pitch diameter "Go" (thread plug)
2. Pitch diameter "Not Go" (thread plug)
3. Minor diameter "Go" (plain plug)
4. Minor diameter "Not Go" (plain plug)

26. The pitch diameter "Go" gage is a thread plug having threads which simulate the minimum acceptable threaded hole plus wear allowance, and gagemakers tolerance. The pitch diameter "Not Go" represents the maximum acceptable threaded hole with a minus gagemakers tolerance. The minor diameter "Go" and "Not Go" are plain plug gages for checking to see that the tap drill is of the correct size.

27. Three gages are necessary to the acceptance or rejection of a male thread as follows:

1. Pitch diameter "Go" (thread ring)
2. Pitch diameter "Not Go" (thread ring)
3. Major diameter "Go" and (adjustable snap)
"Not Go"

28. The gages named are those which are essential to the inspector for his work.

29. In addition to these gages, check gages are required for acceptance of the thread ring gages and for setting the gages during service. The check gages required are as follows:

1. Check for pitch diameter "Go" (thread plug)
2. Check for minor diameter "Go" (plain plug)
3. Check for pitch diameter "Not Go" (thread plug)
4. Check for minor diameter "Not Go" (plain plug)

30. The pitch diameter "Go" thread ring represents the maximum acceptable thread with the prescribed wear allowances applied. (See N.S.T.C. Report) The pitch diameter "Not Go" thread ring represents the minimum acceptable thread with the prescribed tolerances applied.

31. Concentricity Alignment and Functional Gages.

If an assembly of a group of components must assemble into some other assembly, a functional gage is usually required to determine

whether or not the assembly will fit into its place. The best example of this type of gage in ammunition work is the gage used for a final check of a complete round after assembly of the cartridge case to the projectile. This gage is called a "Profile and Alignment Gage," or "Chamber Gage." This gage simulates the chamber of the gun into which the round must fit, however, it cannot be the exact size of the gun chamber for the following reasons: First, the various elements of the gun chamber may not be in perfect alignment owing to permissible error in manufacture or to distortion which may occur in the metal due to released internal stresses. Second, the round may not be in alignment after assembly. Perfect alignment is no more to be expected in assemblies than perfect machine work is to be expected on the components which make up the assembly. Both should be permitted to vary within limits which permit satisfactory functioning. While the important dimensions on the components which go to make up an assembly are toleranced, it is unusual for the assembly to carry allowances for misalignment of surfaces or eccentricity of diameters. In the design of functional gages, therefore, the gage designer must have a thorough knowledge of the requirements that the assembly must meet. He must design the gage in such a way that it will pass the greatest number of assemblies that will fit into place, but the gage must be designed for maximum useful life. That is, the gage must have a certain allowance for wear, the same as a ring or plug gage.

32. From the conditions outlined it is evident that the gage must be a compromise between the mating surfaces of the assembled parts. With specific reference to the complete round gages mentioned, this compromise is arrived at by making the gage slightly smaller than the gun chamber, yet larger than the round. The method of calculating the interior dimensions of complete round gages has been standardized and a set of rules has been compiled for all interior points of the gage as follows:

A. For Diameters.

1. Calculate the basic clearance, i.e., the difference between the maximum round and the minimum chamber, for all points where corresponding dimensions exist between the round and the gun.

2. Take 60% of the each difference found under 1, except at the bourrelet where 80% is taken.

3. Add the quantities found under 2 to the maximum round dimensions for each point. This is the basic gage dimension.

4. Tolerances on all interior diameters of the gage are the same, and are derived by taking 10% of the basic clearance, as calculated under 1, at the point where the clearance is least. Tolerances of less than .0002 or greater than .0006 will not ordinarily be used. Tolerances are applied minus.

B. For Lengths.

1. Calculate the difference in length between the maximum round and minimum chamber at all corresponding points. In some cases, this will be a negative quantity, that is, the round will be longer than the corresponding dimension of the gun chamber.

2. Where the difference found under 1 is plus, add 60% of the difference in length to the corresponding maximum round dimension to obtain the basic gage length.

3. Where the difference found under 1 is minus subtract 60% of the difference in length from the corresponding maximum round dimension to obtain the basic gage length.

4. Tolerances for lengths are applied minus and will be taken from the following table:

TABLE OF TOLERANCES FOR
LENGTHS OF COMPLETE ROUND GAGES

TABLE III

Component Length		Gage
Above	To	Tolerance *
.0	.25	.0001
.25	1.00	.0002
1.00	2.00	.0003
2.00	4.00	.0004
4.00	6.00	.0005
6.00	8.00	.0006
8.00	14.00	.0008
14.00	20.00	.0010
*No tolerance shall be greater than 1/10 of the component tolerance on the corresponding section of the complete round.		

Tolerances on sections not measuring lengths, such as end sections at the bourrelet, shall have more liberal tolerances than the table permits. There will be some cases where fractional dimensions on lengths will be adequate.

33. In the design of complete round gages, as in the design of all other gages, there arise conditions not covered by the rules. In these cases, the gage designer must exercise his best judgment based on a thorough knowledge of the functioning of the components involved.

34. The life of a gage is governed by many conditions, some of which are:

- a. Permitted wear tolerance.
- b. Condition under which gage is used, that is, number of pieces to be inspected.
- c. Material to be gaged, steel, iron, brass, etc.
- d. Finish of part being gaged.
- e. Finish and hardness of gaging surface.
- f. Care used in applying gages.

Materials such as cast iron and aluminum have a lapping effect and wear the gage more rapidly than either steel or brass.

The wear on gages in a certain plant was .0005 inch for 10,000 aluminum parts and only .0005 inch on 50,000 when made of brass. Gages used for manufacturing purposes have been found to only last one half as long as when used by an experienced inspector.

35. In order to reduce wear, all gaging surfaces should be lapped after grinding. After grinding with a fine abrasive wheel, a surface may appear smooth and polished to the naked eye. Examination with a powerful glass or microscope, however, reveals that the surface, instead of being smooth, is composed of a large number of small scratches. Between these scratches are ridges which wear off rapidly as the gage is used. The most objectionable features, of simply grinding a gaging surface without lapping, is that wear takes place unevenly causing the gaging surfaces to be "grooved" or tapered, depending upon the conditions imposed during use. Wear also takes place on a lapped surface during use, but the rate of wear is much slower than that of a plain ground surface.

36. The process of lapping is performed by rubbing the surface to be lapped upon another surface which has been previously charged with a fine abrasive. This charged surface is called a "lap." Laps may be made from lead, copper, brass, cast iron or any soft porous metal, which will absorb the abrasive used. A complete description of the mechanical process of lapping will be found in Machinery's Handbook (page 1114 in the eighth edition). A good lapped surface should be true and free from scratches. The latter quality may be easily recognized by an examination with a glass. A good test of a flat lapped surface may be made by coating it with a light film of oil and wringing it to another lapped surface. If considerable

effort is required to pull the two surfaces apart, the surface may be considered to be true.

37. There are other methods of decreasing the wear on gages and increasing the life. These consist chiefly of chromium plating the wearing surfaces or resorting to diamond points or cemented carbide inserts. The field for diamond points and cemented carbides does not come within the range of accuracy requirements for ammunition work, therefore, these gages will not be considered. Chromium plate roughly doubles the price of plain plug gages. Manufacturers of chromium plated gages claim three to four times the life of chromium plated gages over that of ground and lapped steel gages. On the surface this appears as a decided economy, however, chromium plated gages used at this Arsenal have shown a decided tendency of the plate to chip off at the entering edge of the gage. Two gages of the same size were placed in service at this Arsenal, one chromium plated and the other made of steel ground and lapped. In this test, to date, neither gage has shown any wear. This is due chiefly to the fact that orders at this Arsenal are not large enough to make it possible to conduct a test in a short time. However, until definite proof exists as to the superior wearing quality of chromium plate, and until the chipping defect can be definitely overcome, there appears to be little justification for the use of chromium plated surfaces for War Reserve gages.

38. The material used for gages is dependent on the number of parts to be gaged. In general, plug and ring gages are made from a good grade of machine steel and carburized. Tool steel may also be used and given the proper heat treatment to obtain the desired hardness gaging surface of Rockwell C63 to 66.

APPENDIX I

LIST OF REFERENCES

Gages, Gaging and Inspection	Industrial Press 1918
Manual of Gage Inspection, prepared by	Frankford Arsenal 1937
General Inspection Manual	Ordinance Dept., March 1938
Gages and Fine Measurements	Mac Millan 1929
Machine Tool and Small Tool Industry	Hirzel Berlin 1931
Report of The National Screw Thread Commission.	Bureau of Standards 1933
Gage Blanks (Commercial Standards CS8-35)	Bureau of Standards 1933
Tolerances, Allowances, and Gages for Metal Fits (A.S.A. B4a)	A S M E 1925
Federal Specification, Gages; Plug and Ring, Plain and Thread (GGG-G-61)	1932
Federal Specification, Pipe Threads; Standard (GGG-P-61)	1934
Machinery's Handbook, Eighth Edition	Industrial Press 1930
Army Extension Courses, Special Text No. 40, Gages, Jigs, and Fixtures	Ordinance Dept., 1931

APPENDIX II

LIST OF ORDNANCE DEPARTMENT GAGE LABORATORIES

Watertown Arsenal for Boston District

Watervliet Arsenal for Rochester District

Frankford Arsenal for Philadelphia District

Springfield Armory for Hartford District

Stanford University for San Francisco District

University of Michigan for Detroit District

University of New York for New York District

Georgia School of Technology for Birmingham District

Carnegie Institute of Technology for Pittsburgh District

University of Cincinnati for Cincinnati District

Washington University for St. Louis District

Armour Institute of Technology for Chicago District

Case School of Applied Science for Cleveland District

Rock Island Arsenal

Picatinny Arsenal