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From: Chief, Naval Technical Mission to Japan.
To : Chief of Naval Operations.

Subject: Target Report - Japanese Propellants, Article 3 - Research on Non-Volatile Solvent Powders.

Reference: (a)"Intelligence Targets Japan" (DNI) of 4 Sept. 1945.

1. Subject report, dealing with Target O-10 of Fascicle O-1 of reference (a), is submitted herewith.

2. The investigation of the target and preparation of the target report were accomplished by Comdr. R.A. Cooley, USNR. The body of the report was prepared by Japanese Army personnel at Tokyo No. 2 Army Arsenal, Research Station, and translated by Major Alex C. Soper, USMCR.

C. G. GRIMES
Captain, USN

RESTRICTED

O-10-3

JAPANESE PROPELLANTS - ARTICLE 3

RESEARCH ON NON-VOLATILE SOLVENT POWDERS

"INTELLIGENCE TARGETS JAPAN" (DNI) OF 4 SEPT. 1945

FASCICLE O-1, TARGET O-10

DECEMBER 1945

U.S. NAVAL TECHNICAL MISSION TO JAPAN

SUMMARY

ORDNANCE TARGETS

JAPANESE PROPELLANTS, ARTICLE 3
RESEARCH ON NON-VOLATILE SOLVENT POWDERS

This report consists entirely of a translated Japanese document, "Research on Non-Volatile Solvent Powders for Use in Various Types of Ordnance". The Japanese report is complete in itself, being summarized at the outset of each new chapter and therefore no effort nas been made to summarize the report as a whole.

THE REPORT

Start text here.

ORDNANCE RESEARCH

RESEARCH EXPERIMENTATION
REPORT NO. 388

A-R-M-Y S-E-C-R-E-T

RESEARCH ON NON-VOLATILE SOLVENT POWDERS
FOR USE IN VARIOUS TYPES OF ORDNANCE

REPORT NO. 1

(A summary of the experience leading to the standard adoption of non-volatile solvent powders; together with an account of the formal standardization of propellant charges for ordnance use Nos. 9, 13, 16, 20, 26, 30, 42 Cylindrical Powders, and Nos. 90 and 110 Cord Powders.)

RESEARCH PERIOD: from 1932 to 1942

PREPARED AUGUST 1943

TOKYO NO. 2 Army Arsenal
Research Station

(TN: Two terms appearing in the original, CHIKARA (力) and IKIOI (勢), have been translated "force" and "strength" respectively, without precise understanding of their meaning.)

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F O R E W O R D

Research by the Army on non-volatile solvent powder began in the period of cooperative study with the Navy in 1920 and has continued ever since. As a result of this research, the compositions of present day powders adopted as standard are of two types. One, the so-called G OTSU Mk. I, contains 27% nitroglycerine; the other, G OTSU Mk II, contains 35% nitroglycerine. As regards the types of powders now formally standardized, on 15 May 1937 formal standardization was begun with the No. 110 cord powder, together with the No. 20 and No. 30 cylindrical powders; while as the following table shows the number now exceeds ten varieties. In addition there are the No. 400 Fan-shaped powder and the No. 40 Cord powder, charges used in KE 2 and KE 3, as well as a number of powders used in rockets.

Type of Powder	Shape	Composition	Chief Use	Date of Std. Specification
No.9 Cylindrical	Cyl.	G. OTSU Mk II	Type 94, 37mm gun special artillery	23 Aug. 1939
No.13 Cylindrical	Cyl.	G. OTSU Mk II	Small cal. guns	18 Aug. 1941
No.6 Cylindrical	Cyl.	G. OTSU Mk I	Med. cal. guns Large cal. howitzers	29 Jan. 1938
No.20 Cylindrical	Cyl.	G. OTSU Mk I	Med. cal. guns Large cal. howitzers	15 May 1937
No.26 Cylindrical	Cyl.	G. OTSU Mk I	Med. cal. guns Large cal. howitzers	8 Nov. 1938
No.30 Cylindrical	Cyl.	G. OTSU Mk I	Med. cal guns Large cal. howitzers	15 May 1937
No.42 Cylindrical	Cyl.	G. OTSU Mk I	Large cal. guns Large cal. howitzers	4 June 1942
No.110 Cord Long	Cord	G. OTSU Mk II	Turret 50 cal. 30cm guns	15 May 1937
No.11 Cord Short	Cord	G. OTSU Mk II	Turret 45 cal. 40cm guns	15 May 1937
No.90 Cord Long	Cord	G. OTSU Mk II	Turret 45 cal. 30cm guns	3 May 1940
No.90 Cord Short	Cord	G. OTSU Mk II	Turret 45 cal. 25cm guns and 24cm railway guns	3 May 1940

This report is chiefly concerned with the studies made on non-volatile solvent type powders after August 1932, under such headings as "Research on Interior Ballistics of New Powders", "Research on Powders for Use in Large and Medium Caliber Guns", "Research on Powders for Use in Small Caliber Guns", and "Research on Non-volatile Solvent Powders for Use in Various Types of Ordnance". First of all, in this initial report, we shall give a brief chronological account of the research done in the past by the Japanese Army on non-volatile solvent powders, thereby making clear just how the powder compositions were decided. As regards the charges for use in the gun listed in the foregoing table, we shall summarize the experience which has led to formal standardization, as an aid to future reference.

Abbreviations to be used are as follows:

N/G	Nitroglycerine
M/G	Guncotton
NO	Degree of nitration (cc)
C/L	Centralite (C Chemical)
OTU	Orthotolylurethane
F/D	Formyldiphenylamine (F Chemical)
D/A	Diphenylamine (D Chemical)
Inert Components	Mixture in the proportion: Ammonium oxalate 0.5, Sodium bicarbonate 0.5, Graphite 0.1
W	Weight of Charge (kg)
Vo	Muzzle velocity (m/s)
Ev or rv	Mean or probable error in muzzle velocity
Pto	Absolute chamber pressure (kg/cm^2)
EPto or rpto	Mean or probable error in chamber pressure
Pshi	Measured chamber pressure (kg/cm^2) (non-absolute values)
f	Force of powder (kg)
Q	Heat of explosion (cal/kg)
t	Temperature of explosion ($^{\circ}C$)
V	Comparative volume (lit/kg)
P	Weight of projectile

Chapter I

A SUMMARY OF THE EXPERIENCE LEADING TO THE STANDARD ADOPTION OF NON-VOLATILE SOLVENT POWDERS

Section A: Introduction

The so-called non-volatile solvent powders were discovered in Germany in 1912. At the time the composition was as follows:

Guncotton	63%
(Degree of Nitration 190cc)	
Nitroglycerine	30%
Centralite	7%

(1)

(Number in circle is that assigned to composition)

The pressing need for research on non-volatile solvent powders was recognized by both the Army and Navy about 1920. In February of that year the Navy authorities purchased manufacturing equipment and wwre granted the rights of manufacture and use of such powder from the KOLN-ROTTWELL Powder Co., largely through the efforts of Rear Admiral KATO, Kanji, research emissary to Germany at that time. In addition they engaged four German directors and decided to have the Navy powder depots undertake such research under a committee organization. All preparations went steadily forward to completion, culminating in a beginning of experimental production in July 1921. In April 1922, by dint of zealous research, they were at last able to carry on production without any foreign assistance. Finally, in December 1924 a non-volatile solvent type powder made its formal appearance on the scene, the so-called Type 13 Smokeless powder. It contained the following components:

Guncotton	64.4%
(Degree of nitration 189cc)	
Centralite	4.5%
Nitroglycerine	30.0%
Inert components	1.1%

(2)

Although the Army started research work about the same time as the Navy, for certain reasons (see Section D of this Chapter) standardized adoption by the Army came about 13 years later than in the Navy.

Section B: Summary of Research Experience by the Army

1. Chronological Subdivisions

Chronologically speaking, research done on non-volatile solvent powder by the Army can be roughly divided into the following phases:

- Period of joint research with the Navy (1920-1930)
- Period of the Powder Conferences (1925-1932)
- Period of preparation for standardization (1932-1937)
- Period of formal standardization (1937-present)

Below are set forth general observations concerning each period.

2. Period of Joint Research with the Navy (1920-1930)

Since prospects for research on non-volatile solvent powder by the Army had brightened by 1920, due to the reports of investigations made in Germany at that time by the engineer, FUKAO, Shichiro, and by Lt. Col. CHIAKI Kenji, when the Navy set up its committee for research on such powders, members to participate in joint research were contributed by the Army. The latter in turn found it necessary to do research on its own account

and so there was set up a committee to begin investigations. From then on during the years 1920-1925, however, the progress of research by the Army into non-volatile solvent powders was for various reasons slow. The situation was such that in the spring of 1925 Technical Hq. turned over a part of its research on manufacture of new powders to the Navy. Moreover there were those who maintained that the Army's policy at that time should be to turn over all research on non-volatile solvent powders to the Navy, and simply have its arsenals get materials and manufacturing instructions and carry out manufacture of the powders required. (1)*

However, due to the efforts of leaders in the field, the opportunity finally came for the Army to carry out research on its own powders. Thus we enter the next period, that of the Powder Conferences.

During this period, as a result of research in manufacturing by the Navy, it became possible to confirm the feasibility of manfacturing powder for Army use with an N/G of 25-27% and a stabilizing content of 7-8%.

(Note: Members of the Joint Research Committee from 1920 to 1930 included two men each from the Army Scientific Research Center and the Army Arsenal.)

3. Period of the Conferences for Research on Powder (1925-1932)

As soon as the Conferences for Research were established, research was begun with the following division of labor.

Section in Charge	Research Items
Army Technical Headquarters	Ballistics and Corrosion characteristics
Army Scientific Research	Manufacturing technique (including powder design)
Army Arsenal	Industrial manufacturing methods

Results of research during this period may be summarized as follows:

a. Ballistics, corrosion, compositions, etc.

(1) Starting with a program of making the force, f, of non-volatile solvent powder approximate as closely as possible that of the then standard C Strip powder, without differences in corrosiveness and other potentialities, a series of experiments was made. These resulted in the selection of composition ⑤ (see table below), which was ordered for experimental manufacture by the Navy as a non-volatile solvent powder for the 14th year Type 10cm gun. This, together with a solvent powder containing nitroglycerine experimentally manufactured by the Army, and the C Strip powder (standard compositions), were used in three radially expanded 14th year Type 10cm guns, under conditions generally similar to those of battle, on four occasions in January, April, August, and November of 1929. After a large number of continuous firings, the non-volatile solvent powder and the C powder showed

*Throughout this translation footnote numbers are used which indicate the source of the information by the Japanese at the time the original Japanese report was prepared. These footnote numbers are explained at the end of the report.

no great difference in corrosive action and in amount of progressive increase in shell base interval. Neither was large. However, the solvent powder containing nitroglycerine demonstrated these qualities in high degree. This last powder, in comparison to the other two types, had a greater force, due to its high temperature of explosion. (2)

Characteristics of powders used were as follows: (3)

Type of powder		Non-volatile solvent powder	Solvent powder containing N/G	C Strip powder
Ammo. Mark		20D27C (RIKU 13)	12G15B (H1 18)	10B Special strip
Shape		Cord	Strip	Strip
Date of manufacture		Nov. 1928	Nov. 1928 and July 1929	Nov. 1928
Composition Percentages	N/G	27.0	15.0	
	M/C (No.cc)	63.9 (190cc)	79.0 (204cc)	98.5 (204cc)
	C/L	5.0		
	OTU	3.0	5.5	
	Inorganic D compound	1.1	0.5	1.5
Composition No.		(5)	—	—
Powder thickness (mm)		1.97	1.20	1.01
Special thermochemical calculations				
Explosive force (kg)		10096	10630	10030
Explosive calories Q (cal/kg)		751	882	764
Explosion temperature (°C)		2480	2840	2500

(Note: As a result of eight tests since October 1925, the powders listed in the table were manufactured with suitable dimensions and ingredients for the 14th year type 10cm guns.)

As a result of these tests, although the solvent strip powders containing N/G had no research value for Army gun use, the C Strip type and non-volatile solvent powders (cord form) were suitable, and it was recognized that there was urgent need of research regarding the division of use between the two and their gradual organization. Subsequently, therefore, a certain amount of research was conducted on these aspects.

(2) At the Army Scientific Research Bureau, cord powder with the following components was experimentally manufactured as powder for the Type 45, 15cm gun and was fired in March 1927.

N/G	25.0%	③	25.0%	④
M/C	66.9%		65.9%	
(NO)	(190cc)		(190cc)	
C/L	7.0%		5.0%	
OTU	—		3.0%	
Inert Component	1.1%		1.1%	

As a result of this firing, these decisions were reached: that a diameter of about 2.8mm was proper for cord powder: that although the N/G content from the standpoint of reduction of corrosion should be as low as possible, it should be kept around 25% for manufacturing purposes; and that a proper stabilizing ingredient content was from 7 to 8%. (4) Thereafter further research was carried out. Based on the Scientific Research Station's plan of June 1929, (5) industrial production was initiated in November and December of 1929 at the IWABANA Arsenal, of the three types, strip, cord, and cylindrical; using two composition types ③ and ⑤ as analysed below, corresponding to the ③ and ⑤ compositions mentioned above; in a relationship of two batches of the ⑤ compositions and one batch of the ③ compositions for each powder type, making 9 in all, 180kg of each. Firing was carried out in March 1930.

③ (1) Corresponding compositions			⑤ (1) Corresponding compositions	
N/G	25.0%		27.0%	⑤ (1) differs only slightly in the degree of nitration.
M/C	66.9%		63.9%	
(NO)	(189cc)	③ (1)	(189cc)	
C/L	4.0%		5.0%	
OTU	3.0%		3.0%	⑤ (1)
Inert Component	1.1%		1.1%	

As a result of experimental manufacture as well as firing tests the following facts were learned: (6)

(a) Powders were experimentally manufactured in accordance with the general specifications shown in Table No. 1. In September 1939, the nitrification of the gun cotton was completed and in October, the refining.. From November to December, the forming of the powder was done. As a result, the following facts were learned:

(i) As the gun was industrially produced at the IWABANA Arsenal for the first time, a search for equipment was carried out beforehand, and the desired Gottman submersible type nitrator was obtained. Although in the general specifications table the degree of nitration of weak nitrocellulose to be used was set at 173±3cc, and that of composite gun cotton at 189±1cc a trial run was made of weak nitrocellulose with a degree of nitration of 180cc. (the degree of nitration of composite gun cotton was kept at 189cc). Thus, extension and extrusion were made somewhat easier and 25D25B manufactured.

(ii) The manufacture of composition No. ⑤ was quite easy. Extrusion pressure as well as firing ratio were small.

(iii) The strip type (extruded) was the most difficult to produce. The cord type was easiest in making possible a fixed powder thickness.

(b) The f of composition ③ was slightly greater than that of ⑤. Moisture was 0.7%. Special thermo-chemical figures obtained from the mixed composition were as follows:

Composition	f(kg)	Q(cal/kg)	T(°C)	V(lit/kg)
③ (1)	10010	744.7	2460	767.7
⑤ (1)	10000	730.9	2432	776.9

(c) Under uniform maximum compression, the cylindrical type had the greatest muzzle velocity, the cord type the least and the strip type came in between, conforming with interior ballistics theories.

(d) Although the trajectories of the strip and cylindrical types were nearly the same, as factors pertaining to the speed and pressure of the cylindrical type were somewhat superior and moreover the manufacture was easier, it was recognized that of the two, research on cylindrical powder would be more fruitful. With the existing components, production of cord powder of the desired powder strength seemed difficult to accomplish. Furthermore, in December 1931, cord and cylindrical types made experimentally in conformance with ⑤ (1) were used in a Type 45 15cm gun; comparison of corrosion characteristics due principally to the difference in shape gave nearly the same results in both. (7)

(3) In 1928, the Navy ordered the experimental manufacture of cord-shaped smokeless powder containing the same ingredient as Navy Type 13 powder, and of strip powder of the composition listed below. (8) Both were for use on 24cm railway guns.

These powders were fired in May of 1929

N/G	27.0%	⑥
M/C	64.9%	
(NO)	(190cc)	
C/L	4.0%	
OTU	3.0%	
Inert Component	1.1%	

On the basis of the results, in October 1930 experimental manufacture was begun at the arsenal of cord-shaped and cylindrical powders containing the components listed in ③ (1) (9). These powders were fired in December of the same year. As a result, since the cylindrical powder seemed to have a greater tendency than did the cord-shaped powder to cause deterioration of the ordnance, it was decided that in the future cord-shaped powder should be immediately used when there was need for powder for this type of ordnance. Moreover, it was found that, instead of the proportions listed in ③ (1), those of ⑤ (1), which were the same as those used for the Type 45 15cm gun, gave the best results.

(4) In 1927, plans were made for powder of composition ⑥ for use in the 41cm howitzer. (10)

In addition, experimental manufacture and research were carried out on powder for use in small cal. guns.

(5) In May 1929 research was conducted on the composition, shape and characteristics of field gun type, non-volatile solvent powder, with the following results: (12)

(a) Composition: Difficult to judge as to the superiority or inferiority of ③(1) or ⑤(1).

(b) Shape: The shape of the cord-shaped powder was best and that of the strip powder worst from the standpoint of manufacturing, but in terms of strength, the cylindrical powder was best and the cord-shaped powder worst.

(6) From the end of 1930, repeated experiments were made in the manufacture of a cylindrical powder composed of the components ⑤(1) or ⑦(1) below, for use in the 14th year Type 10cm gun. Research was conducted on the relations between the size and the strength of the cylindrical powder, with the result that it was found that its strength diminished as its interior diameter became larger. (13)

N/G	27.0%	⑦(1)
M/C	63.9%	
(NO)	(189cc)	
F/D	8.0%	
Inert Component	1.1%	

In addition to the above a certain amount of research was also conducted on such matters as changes in the strength of the powder with the passage of time (14) and under-water storage testing. (15)

b. Manufacture

(1) Because the Army Scientific Research Station pressed for the establishment of research in non-volatile solvent powders in the Powder Conferences and pushed forward the completion of manufacturing equipment with great vigor, it was possible to begin experimental manufacture in July of 1926. Instruction in manufacturing techniques was received from the Navy, and independent manufacture became posssible from the beginning of 1928. From that time until 1932 basic research was conducted in manufacturing techniques and plans for the composition, shape, size, and type standards of powders ranging from field gun type powder to powder for use in large calibre guns. (16)

(2) Research in manufacturing on a production basis was being carried out by the Army Arsenal at the ITABASHI Mfg. Co. in accordance with the division of work laid down by the Powder Conferences. But from 1927, installation of equipment for the manufacture of non-volatile solvent powder was begun at the IWABANA Powder Mfg. Co., and in 1928, production research was moved there. The installation of equipment was completed in

(Note: From about 1930 for manufacturing purposes ⑤(1) and ⑦(1) used 27% N/G and 8% stabilizing compounds.)

May 1929 and at the end of that year manufacture of powder for the Type 45 15cm gun was begun on a production basis. (See chapter 1, section B). Following this, experimental manufacture was tried of cord-shaped smokeless powder for the 14th year type 10cm gun, on powder for railway guns, etc.

c. Summary of results

(1) The Powder conferences selected the standard composition ⑤ (1) for powders used in Army ordnance.

(2) Although the cylindrical powder had been found superior to the cord-shaped powder from the point of view of interior ballistics, it was impossible to ascertain which was better from the standpoint of corrosion. Accordingly, no decision was reached on whether to adopt the cylindrical-shaped or the cord-shaped powder.

(3) It was decided that cord-shaped powder of composition ⑤(1) would be manufactured as needed for use in railway guns.

(4) Besides the completion of the basic research in manufacturing, a certain degree of progress was evidenced in physio-chemical problems.

4. Period of Preparation for Standardization (1932 to 1937)

Since there was a change in the administration of research in non-volatile solvent powder after the dissolution of the Powder Conferences, the Army Arsenal Gunpowder Factory Research Bureau became the authority in charge. It worked closely with the IWABANA Powder Mfg. Co. and vigorously fostered preparations for standardized adoption of the powder.

However, the situation at that time was such that the need for a non-volatile smokeless powder was less keenly felt than by the Navy and because of the expense required to make changes in equipment, there was no opportunity for its standarized adoption. Therefore, the Research bureau continuously encouraged research, laying particular emphasis on the powder composition which would give a superior non-volatile smokeless powder. An outline of research results and progress follows:

a. F/D was discovered to be superior to OTU as a stabilizer(gelatinizer). Accordingly, a standard composition was achieved which used the following composition ⑧ to improve the stabilizing agent part of the Powder Committee's standard composition, ⑤ (1):

N/G	27.0%	⑧ (called G OTSU Mk. I)
M/C	63.9%	
(NO)	(189cc)	
C/L	4.0%	
F/D	4.0%	
Inert Component	1.1%	

Moreover, when the stabilizing agent was made 8% of F/D as in ⑦ (1) above, there was no difference in strength, stability, or difficulty of manufacture. (Confirmed by investigations of changes caused by the passage of time, carried out in 1934 and later.)

b. In 1933, research was begun on KE type charge. The following year witnessed the actual use of KE 2 and KE 3 charges of No. 400 Fan powder and No. 40 Cord powder. (Both using ⑧, i.e. Mk I, composition.) This was the first sign of adoption of non-volatile solvent powder by the Army. (Formal standardization came on 9 June 1937.)

c. At the end of 1934, research was begun on powder for use in naval revolving turret guns. Because it was required that the powder strength be nearly identical with Navy 2nd Year Cord powder (C2 Powder), research was conducted in the manufacture of powder whose components were as noted in ⑨ below. This was completed about the end of 1935. As a result, the manufacture of the previous ⑧ type became impracticable, and small size or granulated powder could be made.

N/G	35.0%	⑨
M/C	58.9%	
(NO)	(204cc)	
C/L	2.5%	
F/D	2.5%	
Inert Component	1.1%	

d. In addition, research was conducted on powders of various composition, such as flashless powder, etc. However, it was decided for the present to adopt the two types of compositions ⑨ and ⑧ (or ⑦) listed above.

e. From about 1935

(1) Defects in ordnance arising from increases in the strength of C Type 4 and 5 Strip powder with the passage of time.

(2) Coolants were developed in succession for Type C 3, 4, and 5 Strip powder.

(3) The Army became self-sufficient in turret gun powder, which had previously been provided by the Navy. (Research conducted from the end of 1934.) Other questions arose one after the other, and the opportunity presented itself to adopt non-volatile solvent powder as the charge for ordnance use. As a result of vigorous experiments, by 1937, it was possible to set standard specifications first for No. 110 Cord powder, and then for No. 20 Cylindrical powder, No. 30 Cylindrical powder, etc. Thus, the so-called period of formal standardization was reached.

5. Period of Formal Standardization (From 1937)

Continuing the aforementioned standardization, standard specifications were successively fixed for powder used in small cal. guns, i.e. No. 9 and No. 13 cylindrical powder, as well as for No. 16, No. 26, and No. 42 cylindrical powder and No. 90 Cord powder. There are some people engaged in such research at present. Furthermore, it is to be expected that new powders will be developed by the research in process on compositions, shapes, etc.

Section C. Compositions

1. Composition Nomenclature

Powders containing N/G are broadly designated as Smokeless Powder G.

The solvent powders belonging to these are called Smokeless Powder G KO, while such non-solvent powders are called Smokeless Powder G OTSU. The composition ⑧ which has already been mentioned, is commonly referred to as Composition G OTSU, Mk I, while the composition ⑨, likewise mentioned is commonly referred to as Composition G OTSU, Mk II.

2. Composition G OTSU, Mk I

Foregoing sections have shown how this composition was decided on. From the standpoint of minimizing corrosion, the N/G content was reduced as much as possible within the limits of preparation needs and manufacturing possibilities; in its place was added an amount of a stabilizing compound (gelatinizer) which will not produce too much smoke from the guns and yet will facilitate powder manufacture. With such ideas in mind, the compound was designed for general ordnance use. The following table has been prepared for reference in comparing characteristics of composition G OTSU, Mk I, which were obtained through thermo-chemical computations, with C powder. Data on Composition G OTSU Mk II are included. (See page 17.)

3. Composition G OTSU, Mk II

A brief account has been given in Section B/4 of this chapter of how this composition was decided on. The subject has also been discussed in detail in "Army Powder Laboratory Research Report 201, Turret and Gun Propellants Research (Report 1, Research Dealing with Cord-shaped Powder 110 and Cord-shaped Powder 90), Laboratory 2, TOKYO, August 1940".

The decision was primarily made for use with ordnance requiring striking power. Thermo-chemical characteristics appear in the foregoing table.

4. Standard Formula

The compositions discussed above (⑧ and ⑨) show "combined compositions". According to analyses made of actual powders, the inert component is normally 0.6 to 0.8%, or 0.7% on the average. This reduction, ie. 0.4% at the maximum in the case of gun cotton, makes a composition called "standard formula". This is the term used in the "Outlines of Powder Manufacture".

STANDARD FORMULAE

Composition G OTSU, Mk I		Composition G OTSU, Mk II	
N/G	27.0%	N/G	35.0%
M/C	64.3%	M/C	59.3%
(NO)	(189cc)	(NO)	(204cc)
C/L	4.0%	C/L	2.5%
F/D	4.0%	F/D	2.5%
Inert Component	0.7%	Inert Component	0.7%

Section D: Reasons for Difference Between Army and Navy in Rapidity of Adopting Non-Volatile Solvent Powders as Standard.

The principal reasons are as follows:

NAVY

1. Cord type was almost unanimously decided on as the type suiting the capabilities of naval ordnance. Furthermore, conversion from the then Navy standard 2nd Year Type Cord powder (C2 powder) was considered to be a simple matter.

2. Non-volatile solvent powder (Type 13 powder) was recognized to be superior in all general features (time of manufacture, storage, corrosion) to C2 powder (particularly superior in storage).

COMPARATIVE COMPOSITION
(See Section C, paragraph 2)

Comp.	Type	Itemized Data										
		M/C (No. cc)	N/G (%)	C/L (%)	F/D (%)	D/A (%)	Inert Compnt. (%)	Vol. or Moist. (%)	Q (cal/kg)	Uo (lit/kg)	T (°C)	f (kg)
C Powder	Mk 3 Strip Powder	98.0 (204)				1.5	Camelia Oil 0.5	3.60	773	956	2515	10087
G OTSU Mk I	Combined Comp.	63.9 (189)	27.0	4.0	4.0		1.1	0.85	726	979	2410	9946
	Standard Formula	64.3 (189)	27.0	4.0	4.0		0.7	0.85	734	980	2427	10016
G OTSU, Mk II	Combined Comp.	58.9 (204)	35.0	2.5	2.5		1.1	0.60	960	892	3006	11077
	Standard Formula	59.3 (204)	35.0	2.5	2.5		0.7	0.60	967	893	3025	11148

ARMY

3. Army powder was dominantly of smaller types. Not so much importance was placed on it as by the Navy. Corrosion was also a question which caused concern.

4. Conversion to non-volatile solvent powder (cord or cylindrical in shape) from strip type powder C was difficult because of such problems as cost of equipment, etc.

Different rates of standardized adoption were thus due to the problems peculiar to the Army and the Navy.

Section E. Motives for Standardized Adoption of Non-volatile Solvent Powder and the General Policy Regarding Such Adoption.

1. Motives

The various preliminaries to the manufacture of this powder were already practically completed by about 1935. Thereafter as described in Section B/4/e of this chapter, a series of problems developed one after another. Since ballistic changes with the passage of time were small, the primary reason leading to standardized adoption of non-volatile solvent powder was the demand for a charge with superior storage qualities. In addition, however, "the adoption of non-volatile solvent powder in a cylindrical shape(powder C is extremely difficult to prepare in a large sized cylindrical shape) would be in response to the requirements of the high-powered weapons that will appear in the future". "Then, when the necessity arises of increasing the force of powder for this purpose, non-volatile solvent powder will be easier to use." It was such ideas as these which, because they originated with the persons concerned with the project at the time, probably produced the important psychological motives.

2. General Policy Regarding Standard Adoption

No sooner was the movement for this standard adoption well under way than the men on this project at Technical Headquarters and at the Ammunition Works Research Bureau laid down roughly the following general policy. Then they set about research to bring about adoption.

General Policy

a. Composition

Composition G OTSU, Mk I will be used as the powder for general ordnance purposes. Composition G OTSU, Mk II, will be used particularly as the powder for ordnance requiring high explosive power.

b. Shape

Cylinder-shaped powder is admittedly superior as regards interior ballistics and will as a matter of practice be adopted for general ordnance. Cord shaped types or others will be adopted for special ordnance needs.

c. Powder strength

The strength of powders which are to correspond to strip type powder C now used will be made to conform as nearly as possible with that of said powder. It will be advisable to leave the amounts of propellant designated by firing tables unchanged as far as it is possible.

d. Powders: Types and nomenclature

Powder types will be fixed on the basis of a graduated series. Nomenclature will be given so as to indicate thickness (diametric) and shape, e.g. No.20 Cylindrical powder is so designated on the basis of thickness and shape.

e. Chamber pressure

The chamber pressure will be expressed in absolute values.

Chapter II

SUMMARY OF STANDARD SPECIFICATIONS FOR NON-VOLATILE SOLVENT POWDER FOR EACH TYPE OF GUN

In this chapter we shall give a summary of the standard specifications for each type of powder already established as a charge for guns.

Section A: Propellant Charge for Turret Guns (No.110 and No.90 Cord Powders)

1. Formerly, as a propellant charge for turret guns, the Navy 2nd year Type Cord powder (C2 powder), procured from the Navy, was used. By agreement with the Navy, this powder was supplied to the Army from the Navy on order. However, after the Navy adopted non-volatile solvent type powder as standard, this powder was manufactured only when ordered by the Army. Thus, in times of emergency, there was much mutual inconvenience. Eventually, shortages arose in the C2 powder which the Army had in storage. This and the fact that coolants were separately produced, led to the Army's deeming it advisable to seek means of supplying itself with powder. From November 1934 they engaged in research, and developed the G OTSU Mk II composition. Finally, in May 1937, No. 110 Cord Long powder was decided upon in place of 2nd year Type No. 110 Cord powder Long, as propellant for the 50 cal. 30cm turret gun; and No. 110 Cord Short powder was decided upon in place of 2nd year Type No. 110 Cord powder Short as propellant for the 45 cal. 40cm turret gun. Then in May 1940 No. 90 Cord Long powder was decided upon in place of 2nd Year Type No. 80 Cord powder Long as propellant for the 45 cal. 30cm turret gun; and No. 90 Cord Short powder was decided upon in place of 2nd year Type No. 80 Cord powder Short and Mark 6 Strip powder (used in Mark II propellant charge) as propellant for the 45 cal. 25cm turret gun. Data concerning the above has already been reported in detail in the KAKEN KEMPO, No. 201, March 1940 ("Research on Propellants for Turret Guns: First Report on Research Concerning No. 110 and No. 90 Cord Powders").

2. Tests were conducted in the early part of July 1942 on a powder for use as a propellant in the 45 cal. 20cm turret gun, with the following results. Powders tested were the No. 90 Cord Short and an experimentally manufactured No. 35 Cylindrical (powder thickness 3.5mm, inner diameter 3.5mm, length 350mm, G OTSU Mk. I composition) as well as an experimental No. 75 Cord Short (actually intended as a No. 74 with diameter 7.4mm, length 355mm, and G OTSU Mk II composition) i.e. three in all.

a. Opinions and decisions

(1) Experimentally manufactured No. 75 Cord Short powder has good interior ballistic qualities and is suitable for use as a charge in the 45 cal., 20cm gun, the amount of propellant being 26.40 kg.

(2) Experimentally manufactured No. 34 cylindrical powder burns too slowly.

(3) Although test type No. 90 Cord Short powder burns rather slowly, it can be used as a normal charge without creating a burning residue.

(4) Accordingly, although the No. 75 Cord Short powder can be used satisfactorily in the 20 cm. gun, it is administratively advantageous for the time being to use the present No. 90 Cord powder.

b. Evaluation of tests

45 cal. 20cm gun - AP, subtitute shell (P=113.4 kg)

Piece		Left Turret				Right Turret	
		Left #2 Gun			Right #2 Gun	Right #1 Gun	Left #1 Gun
		Test Mfd. No. 75 Cord Short	Test Mfd. No. 34 Cylindrical	No. 90 Cord Short	Test Mfd. No. 75 Cord Short		
Powder Amount (kg)		26.400	30.600	29.400	26.400	26.400	26.400
Observed muzzle velocity (M/S)	Muzzle Velocity	765.9	761.5	748.7	768.1	772.5	768.2
	Mean Variation	0.9	3.7	1.2	0.3	1.0	1.7
Observed chamber pressure (kg/cm^2)	Chamber Pressure	2442	2161	2269	2483	2522	2490
	Mean Variation	12	23	30	1	17	2
No. of Rounds		4	2	2	2	2	2
Composition		G OTSU Mk II	G OTSU Mk I	G OTSU Mk II			

Note: Muzzle velocity and chamber pressure figures include corrections for powder temperature and gun age. No allowance was made for correction of the volume of the pressure gauge.

On the basis of the above it was decided for the time being to use the No. 90 Cord Short powder in place of the Navy 2nd year Type No. 70 Cord powder, long and short, and the No. 6 Strip powder hitherto used for the 45 cal. 20cm turret gun. In such case, a 30 kg amount of propellant will do. A standard muzzle velocity of 760 m/s and a standard chamber pressure of 2500 kg/cm is aimed at, and research has been directed to this end.

Section B: Propellant Charges for Use in the 24cm Railway Gun and the 41 cm Howitzer (No. 90 Cord Short and No. 42 Cylindrical)

1. Propellant for Railway Gun Use

a. On the basis of the firing tests of May 1929 (17) and December 1930 (18), in connection with the propellant for use in the Type 90, 24cm railway gun, it was decided by the Powder Conference to manu-

facture and use a cord powder of composition ⑤. However, due to the subsequent adoption of the non-volatile, solvent powder composition ⑧, an improvement over ⑤, i.e. the present so-called G OTSU Mk I composition, plans were made, for the second time, in 1935, with specifications for a muzzle velocity of 1050 m/s at a chamber pressure of 3600 kg/cm² or less. No. 74 Cord powder (7.4mm diameter, 380mm length, G OTSU Mk I composition) was found to be suitable and was test produced (19). In firing tests in the later part of November of the same year, the following results were obtained, satisfactory on the whole although the chamber pressure was somewhat high.

Projectile	Cyl. shell (P = 165 kg)
W	98 kg
Number of rounds	3
Vo	1030.9 m/s (1050 m/s)
Evo	2.17 m/s
Pto	2427 kg/cm² (2640 kg)
Ep	26 kg/cm²

Note: These results correspond to a gun age of 66; those in parentheses to a gun age of zero.

b. Later, however, there was a change in specifications for the railway gun to make its chamber pressure 3600 kg/cm² at the maximum and about 3350 kg/cm² standard. This, and the fact that it was advantageous to use (if possible) the same powder as that in the propellant for the 41cm howitzer, on which research was begining anew, made the cord powder completely impractical in the future. In March 1938, consequently, new plans were made for cylindrical powder, and No. 42 Cylindrical powder (thickness 4.25mm, inner diameter 4.25mm, length 350mm, G OTSU Mk I composition) was obtained. After experimental manufacture, the later was test fired in the latter part of April 1938, with the results given below. Although the chamber pressure was somewhat higher than had been hoped for, in general acceptable results were obtained. However, it was necessary that the powder length be 340mm. (Since it was limited by the size of the propellant charge container.)

Projectile	Cyl. shell (P = 165 kg)
W	84 kg (86 kg)
Number of rounds	4
Vo	1039.9 m/s (1050 kg)
G	2.9 m/s
Pto	3365 kg/cm² (3460 kg/cm²)
Epto	23 kg/cm²

Note: These results correspond to a gun age of zero. Items in parentheses, correspond to a muzzle velocity of 1050 m/s.

Accordingly, when the No. 42 Cylindrical powder was used in the 51cm howitzer, very good results were obtained. (See below)

c. The results obtained on the two occasions mentioned above came from firing guns of the age range 67 - 99. Since the gun age correction factor was not reliable, too much confidence cannot be placed in the results. However, in 1940, the railway gun tubes were replaced at the OSAKA Arsenal, and in November and December of that year these new barrels were used in firing tests. The propellants used were the experimentally manufactured No. 42 Cylindrical powder, with the same dimensions as before (except for a powder length of 340 mm.); and a No. 90 Cord Short powder, expected to be usable on the basis of ballistic calculations (produced experimentally with a powder

length of 340mm for purposes of this test, although the standard length of powder at the time was 355mm). Later, in September 1941, the occasion of the tests of AP-HE shells for use in the same gun was taken to measure the velocity and pressure of the No. 90 cord Short powder, and the result of November 1940 were confirmed. The results of these two tests are as shown in Table No. 2, and greater reliance may be placed on them than on the previous results.

On the basis of the results recorded in Table No. 2, the following conclusions have been drawn: (Table 2 is on page 36.)

(1) No. 90 Cord Short powder as a propellant for use in the Type 90, 24cm railroad gun (has the following characteristics):

$W = 78$ kg, $Vo = 1050$ m/s, $P\underline{to}$ 3500 kg/cm^2

The diameter of the binder of powder bundles (20 kg) is 238mm and even an increase of 5 kg (a total of 20 kg for 4 bundles) will not exceed the limit valve of 270mm. Thus the No. 90 powder is considered satisfactory both as to powder strength and binder diameter (See note below).

(2) No. 42 Cylindrical powder has the following characteristics:

$W = 88$ kg, $Vo = 1050$ m/s, $P\underline{to} = 3250$ kg/cm^2

While the chamber pressure is better than that of the No. 90 Cord Short powder, the diameter of the binder is large (about 270mm for one 22 kg bundle).

Considering the powder amount correction (see note below) accompanying the reduction in muzzle velocity based on gun age, this powder is not suitable for railway gun use.

(3) The amount of propellant in the No. 90 Cord Short powder for railway gun use is as follows:

Mark I propellant amount	78 kg
Mark II propellant amount	60 kg

(4) It is necessary to correct the length of the Cord Short powder to 335 ± 5mm. (Although the present 355mm is made 335mm this does not interfere with the results of the investigation.)

Notes

(a) The following essential points were decided upon relative to corrections for gun age as the result of the deliberations in November 1940 of officials on the spot (the TOMIZU Firing Grounds). Details were determined at the time of the compilation of the firing records:

(i) **First**, correct for angle of departure.

(ii) Since, after a certain number of shots, it is difficult to assume a reduction of muzzle velocity, the muzzle velocity should be measured in order to increase the powder charge, if required.

(b) Even with a chamber pressure of 3500 kg/cm^2 there is no difficulty.

(c) The aforementioned conclusions were reached as the consideration of the records from the above standpoints.

2. Propellant Charge for Use in the 41cm Howitzer (Type 100 Heavy Howitzer)

a. Powder design and experimental manufacture:

The powder was designed in accordance with the following specifications (March 1938):

Projectile ..... AP-HE shell (P = 1000 kg)
Standard muzzle velocity ..... 580 m/s
Standard chamber pressure ..... 2500 kg/cm^2
Powder composition ..... G OTSU Mk I Composition
Powder shape ..... Cyl. (No.30 cyl. powder type)
Propellant bags .... In 4 bags, bag dia. 420mm or less

This powder is intended for ordinary use in 24cm railway carriage guns.

In accordance with the above the designed dimensions and the actual measurements of the experimental powder are as follows:

Type of Powder	Symbol	Dimensions (mm)				Amount exp. mfd. (kg)
		Outside Dia.	Inside Dia.	Thickness	Length	
No. 42 Exp. Cyl. (1)	42D27T(1)	12.75 (12.63)	4.25 (4.09)	4.25 (4.27)	350 ±5 (349)	3000
No. 42 Exp. Cyl. (2)	42D27T(2)	13.50 (13.25)	5.00 (4.74)	4.25 (4.25)	350 ±5 (349)	3000

Notes: 1. The bundle diameter of 120 kg of the proposed charge of 42D27T (1) is 310mm 42D27T(2), which has a greater inside diameter, was experimented with for the special use in 41 howitzers because there was a surplus.

2. Actual measurements are shown in parentheses.

b. In the first part of December 1938, a powder strength test was carried out with the 41cm howitzer. The following results were obtained:

Type of Powder	Projectile	W (kg)	Vo (m/s)	Evo	PF (kg/cm^2)	EPto	No. of rds.
No. 42 Exp. Cyl. (1)*	Cyl. shell (P = 1000 kg	120	585.1		2418		2
No. 42 Exp. Cyl. (2)*	AP-HE P = 1000 kg	120	583.1	0.92	2385	30	4

* Manufactured March 1938

Both types gave good results. Because the difference of powder strength, which is based on the difference in the inside dia. of the powder, was small, the measurements adopted were those of the No.42 Experimental Cylindrical powder with the smaller inside dia. for general purpose and railway gun use.

c. August 1940, Experimentally Manufactured No. 42 Cylindrical Powder

Advantage was taken of the opportunity furnished by a shell test, to use this powder (inner diameter and thickness in subparagraph(a) above, length 340mm). The results of the previous occasion were confirmed, and it was decided to adopt the No. 42 Cylindrical powder as propellant charge for the 41cm.

(This test was first carried out in July 1940, using powder made in November 1938. It was halted, however, due to a failure of the breech block on the second round. Repairs were made, and the test was carried out in August.)

Powder amount, strength, etc., were decided on as follows:

Projectile - AP-HE or capped armor-piercing shell (P = 1000 kg)
W - 120 kg (Mk II charge or less is furnished; use one type of charge)
Vo - 580 m/s
Pto - 2400 kg/cm^2
(However, the length of the powder may be 330 ± 5mm)

d. Decisions on test requirements, etc.

The decision having been made to alter the standards for No. 42 Cylindrical powder, tests were first carried out with a 36 cal. 27cm gun in December 1941 and January 1942. It was discovered, however, that the 27cm gun was unsuitable as a test gun for this powder. Then in February 1942 the test was made with a 45 cal. 25cm turret gun and the following results were obtained:

Type of Powder	Projectile	W (kg)	No. of rounds	Vo (m/s)	Evo	Pto
No. 42 Cyl.*	AP substitute shell 235 kg	76.00 (78.88)	3	786.1 (810)	3.43	2253 (2420)
No. 42 Cyl.** (medium)	AP substitute shell 235 kg	76.00 (79.34)	3	782.2 (810)	0.90	2244 (2439)
No. 42 Cyl.** (fast burning)	AP substitute shell 235 kg	76.00 (77.24)	1	799.7 (810)		2430 (2502)
No. 42 Cyl.** (slow burning)	AP substitute shell 235 kg	76.00 (80.44)	2	769.6 (810)	2.30	2140 (2423)
Averages	AP substitute shell 235 kg	78.98		810		2446

* Manufactured in Feb. 1942
** Manufactured in Jan. 1942

Note: Figures in parentheses correspond to a muzzle velocity with the standard figure 810 m/s. Conversions derived from firing.

Although the 25cm turret gun was a suitable gun for No. 42 cylindrical powder, it is to be used as a supplementary testing gun since its complete combustion point is somewhat early. The main testing gun will be the 45 cal. 30cm turret gun. Powder performance tests using these guns will be carried on and conclusions drawn as soon as possible.

For reference, the requirements which would be established, based on the above results are as follows:

Proposed requirements for No. 42 cylindrical powder tests

No. 1 Physiochemical Test

Item	Requirements
Diameter of Bundle	$\frac{1}{4}$ weight of fixed charge of 41 bundles Diameter 420mm or less
Moisture	0.85 ± 0.25
Length of Powder	330 ± 5mm
Heat resistance	Test in 100° red flames for over 20 hours

Note: Determination of moisture is made after at least five days exposure to wind.

No. 2 Firing Test

Item		Requirements		
Testing gun		45 cal. 30cm turret gun (omitting No. 3 & 4 turrets) (primary)	45 cal. 25cm turret gun (supplementary)	
Type of shell		Capped AP shell for 45 cal. 30cm turret gun	Capped AP shell for 45 cal. 25cm turret gun	
Weight of shell		400 kg	235 kg	
Standard weight of charge		See note 1 below.	79.00 kg	
Weight of igniter		800 g	560 g	
No. of rounds per time		3-10	3-10	
Standard muzzle velocity		810 m/s	810 m/s	
Mean error in muzzle velocity		40 m/s or less	40 m/s or less	
Mean Chamber Pressure	Maximum	See note 2 below	2600 kg/cm^2	Control figures
	Standard	See note 3 below	2450 kg/cm^2	
	Minimum	See note 4 below	2300 kg/cm^2	

Notes: (1) The weight of the charge at time of firing must always depend on a standard propellant charge weight, corresponding to the strength of the powder.

(2) The weight of the fixed charge is based on results of firing tests, and it is calculated so as to give a standard muzzle velocity of 810 m/s by methods noted in testing requirements.

(3) An average chamber pressure corresponding to the fixed charge weight is calculated by methods noted in testing requirements.

(4) Firing tests should be carried out after powder has been exposed to wind for at least five days.

As noted above, actual firing results are based on the 30cm turret gun as main testing piece. Though the numerical strength value of the powder has not yet been decided, a temporary standard strength will soon be set to facilitate preparation. The standards for this powder (see table) were determined on 4 June 1942. (Test requirements, etc., will be published soon.)

Section C: Powder Equivalent to Nos. 5,4, and 3 Strip Powders (i.e. Nos. 30, 20, and 16 Cylindrical Powders)

1. Aims of Study

Research on these powders not only covered powders to be used in turret guns, but also was the precursor of the standardized adoption of non-volatile solvent-type powders for ordnance use by the Army. The reasons behind this research were primarily two: "Ordnance failures due to an increase in powder strength in Mk 4 and 5 strip powders, based on the passage of time; and the continuous production of coolants."

The detailed program of the research was as follows: (see chapter 1, Section E/2)

a. A powder strength as nearly as possible like that of the then standard C Strip type.

(1) To select a powder which should agree as closely as possible with the firing table values which correspond to the then standard C Strip type, in charge amounts (primarily of Mk I) for actual ordnance use.

(2) The strength of the powder in the testing gun depends on the following:

(a) Most desirable is the duplication of W, V, and P of the present strip powder.

(b) If (a) is impracticable, choose that (powder) which duplicates Wto and Vo.

(c) If both (a) and (b) are impracticable, choose that duplicating only Vo.

b. The composition derived from prior research, will be G OTSU Mk I.

c. The shape will be cylindrical (with the necessity of increasingly greater muzzle velocities in the future, selection has been made in recognition of the superiority of the cylindrical type in interior ballistics).

2. Powder Corresponding to Mk 5 Strip Powder (i.e. No. 30 Cylindrical Powder)

Since it had been found in previous research that No. 26 experimental cylindrical powder (2.6mm thickness, 2.3mm internal diameter, 340mm length) is generally suitable as a powder corresponding to the Mk 5 Strip type, a powder with the same dimensions was manufactured experimentally.

When firing tests were made in the latter part of December, 1936 with a 7th Year Type 15cm gun and a KRUPP Type 30 cal., 24cm gun, it turned out to be a little too fast burning.

With those results as a basis, plans for experimental manufacture of the following powders were made:

	Absolute Measurements (mm)				
Type of Powder	Outer Dia.	Inner Dia.	Thickness of Powder	Length of Powder	Remarks
No. 30 Exp. Cyl.	8.48	2.49	3.00	340	Mfd. at IWABANA Feb. 1937
No. 28 Exp. Cyl.	8.17	2.50	2.84	340	
No. 7 Exp. Cyl.	7.88	2.52	2.68	340	

The following powders were tested in February 1937 with a KRUPP 30 cal. 24cm gun as the testing gun for Mk 5 Strip powder. Results are shown in the following table:

Type of Powder	Weight (kg)	No. of rds	Vo (m/s)	Evo	Pto (kg/cm^2)	Epto
Mk. 5 Strip (requirement)	30.000	3-10	492 ±5	2.5 or less	1670 ±140 (1780 ±150)	
Mk 5 Strip* (U No. 26)	30.000	7	489.9	2.16	1733	22
No. 30 Exp. Cyl.	30.000	7	492.2	0.94	1735	84
No. 28 Exp. Cyl.	29.500	7	493.0	0.73	1783	22
No. 27 Exp. Cyl.	28.000	1	481.7		1714	

Note: The required chamber pressure value given in parentheses for the Mk 5 Strip type is converted to Pto by multiplying Pshi by the copper cylinder coefficient 1.043 and the pressure gauge coefficient 1.021.

*Manufactured in Oct. 1936

No. 27 experimentally manufactured cylindrical powder is fast-burning and is therefore not suitable as a powder corresponding to the Mk 5 cylindrical type.

No. 28 and No. 30 experimentally manufactured cylindrical powders both showed strengths generally equivalent to Mk 5 Strip powder. However, it was necessary to judge which of the two was best fitted to correspond to the Mk 5 from the results of a firing test made with the other testing-gun, the 7th Year Type 15cm gun. Results of the test made of them along with Mk 5 Strip powder are as indicated in the table on the following page. According to the results shown in the table, the Experimental No. 30 Cylindrical powder Mk I charge is acceptably similar to the Mk 5 Strip powder charge. It would be desirable to increase the weight of the Mk II charge by 0.600 - 0.650 kg over that of Mk 5 Strip powder. For this reason, it has been accepted as most appropriate to use the Experimental Type 30 powder as the equivalent of Mk 5 powder. Therefore, as the stand-

ard powder thickness to correspond to the Mk 5 Strip powder, a powder with the same dimensions - namely, 3.00mm thickness - as those of the Experimental No. 30 was adopted. It was named the No. 30 Cylindrical powder and was formally standarized on 15 May 1937.

3. Powder Equivalent to Mk 4 Strip Powder (No. 20 Cylindrical)

A No. 18 Cylindrical (thickness 1.80mm interior diameter 1.91mm, powder length 348mm) and No. 19 Cylindrical powder (thickness 1.98mm, interior diameter 1.86mm, powder length 347mm) were made experimentally as equiv-

Type of Powder		W (kg)	Rds	Vo (m/s)	Evo	Pto (kg/cm^2)	Epto
Mk 5 Strip (firing table values)	Mk I Mk II	16.650 11.100		845.0 600.0		2500 1100	
Mk 5 Strip (U Mk 26) made Oct. 1936	Mk I Mk II	16.650 11.100	6 6	814.2 565.9	2.22 2.52	2261 1039	35 20
Exp. No. 30 Cyl.	Mk I	16.650	6	812.7	1.65	2194	11
	Mk II	11.100 11.700	6 2	535.4 557.1	2.63	891 1051	58
Exp. No. 28 Cyl.	Mk I Mk II	16.650 11.100	2 2	834.5 554.6		2294 898	

Note: Substitute AP-HE projectile (P = 44.7 kg)

alents for the Mk 4 Strip Powder. During the latter part of December 1936 both types were fired in a 7th year 15cm gun and in a KRUPP 35 cal. 15cm gun. The Experimental No. 19 proved to be somewhat slow-burning and the Experimental No. 18 fast-burning. With this in mind, planned experimental manufacture of powders took place as follows:

Type of Powder	Dimensions (mm)			
	Outer Dia.	Inner Dia.	Powder Thickness	Powder Length
Exp. No. 20 Cyl.	5.81	1.88	1.96	339
Exp. No. 19 Cyl.	5.72	1.88	1.92	340
Exp. No. 18 Cyl.	5.50	1.88	1.81	340

Note: Manufactured at IWABANA, in February 1937.

The following table gives the results of tests of these powders conducted in February 1937 on a KRUPP 35 cal. 15cm gun, the standard ordnance for testing Mk 4 Strip powder.

Though the Experimental No. 18 Cylindrical powder burns much too fast, according to the tabulation, the Experimental Nos. 20 and 19 Cylindrical powders taken together fall on either side of the standard value of the Mk 4 Strip powder and come within the limits of the requirements. Accord-

ingly, the average powder thickness, 1.95mm, of these two types has been adopted as the thickness of the powder to correspond to the Mk 4 Strip powder; and said powder has been designated No. 20 Cylindrical powder The powder strength with the testing gun for the No. 20 Cylindrical powder is exactly the same as that of the Mk 4 Strip powder.

Type of Powder	W (kg)	Rds	Vo (m/s)	Evo	Pto (kg/cm^2)	Epto
Mk 4 Strip (required)	9.000	3-10	612.0 ±7		2130±120 2270±130	
Mk 4 Strip U Mk 35*	9.000	7	607.5	0.96	2250	18
Exp. No. 20 Cyl.	9.000	7	610.1	1.03	2224	12
Exp. No. 19 Cyl.	9.000	7	613.3	1.63	2287	22
Exp. No. 18 Cyl.	8.700	1	609.0		2319	

*Manufactured in November 1936

Note: The required chamber pressure value given in parentheses for the Mk 4 strip is converted into Pto by multiplying Pshi by the copper cylinder coefficient 1.043 and the pressure gauge coefficient 1.021.

The following are the results of the tests performed with a Type 89, 15cm service gun on both the Mk 4 Strip powder and the Experimental No. 20 Cylindrical powder. The Mk II charge amount of the No. 20 apparently should be increased somewhat over that of Mk 4 Strip.

Type of Powder	W (kg)	Rds	Vo (m/s)	Evo	Pto (kg/cm^2)	Epto
Mk 4 Strip (firing table values)	Mk I, 9.700 Mk II, 8.000		691.5 610.0		2450 1800	
Mk 4 Strip U Mk 35 Mfd. Nov. 1936	Mk I, 9.700	6	678.3	1.12	2355	30
Mk 4 Strip U Mk 35 Mfd. Nov. 1936	Mk II, 8.000	6	596.7	0.78	1693	16
Exp. No. 20 Cyl.	Mk I, 9.700	6	680.3	0.88	2309	11
Exp. No. 20 Cyl.	Mk II, 8.000	6	592.4	1.31	1606	18

Note: Substitute AP-HE Projectile (P=44.7 kg)

Firing results with a 7th Year Type 15cm gun using Mk. 4 Strip with a Mk. II charge were as follows: In comparison with the Mk. 4 Strip, the No. 20 Cylindrical apparently requires about a 0.200 kg charge increase.

Type of Powder	W (kg)	Rds	Vo (m/s)	Evo	Pto (kg/cm²)	Epto
Mk. 4 Strip (firing table)	8.660		600.0		1100	
Mk. 4 Strip U Mk. 35*	8.660	6	606.6	1.42	1287	15
Exp. No. 20 Cyl.	8.660	6	597.3	2.30	1195	24

*Manufactured in November 1936

Note: Substitute AP-HE Projectile (P = 44.7 kg)

As a result of the above, the No. 20 Cylindrical powder of 1.95 thickness as noted was formally standardized as the equivalent to the Mk. 4 Strip powder. (Standardized on 15 May 1937.)

4. Powder Equivalent to the Mk. 3 Strip Powder (No. 16 Cylindrical)

In the light of past researches it had been found that the Experimental No. 13 Cylindrical powder (powder thickness 1.33mm, internal diameter 1.80mm, powder length 130mm) was in general the most suitable for Mk. 3 Strip. Experiments were therefore conducted on powder of the same dimensions. During the latter part of December 1936, it was found, upon firing with a KRUPP Type 38, 10cm gun, the standard testing piece for the Mk. 3 Strip, that the powder was somewhat fast-burning, and that its length of 130mm was too troublesome in munitions production. Thus further research took place on a form with the same length (340mm) as that of the No. 3 Strip powder.

The first tests of a powder with 340mm length were carried out in June 1937, on a KRUPP Type 38 10cm gun. As may be seen in the following tables, it has not been possible as yet to obtain complete data on the results, dimensions, etc.

Type of Powder	Dimensions (mm)				W (kg)	Rds	Vo (m/s)	Evo	Pto (kg/cm²)	Epto
	Outer Dia.	Inner Dia.	Powder Tks.	Powder Length						
Mk. 3 Strip					2.000	5-10	529±5		1940±150 (2070±60)	
Experimental No. 14 Cylindrical Long	4.67	1.78	1.45	340	1.870	6	529.4	1.40	2108	34
Experimental No. 15 Cylindrical Long	4.89	1.78	1.56	340	2.000	6	533.6	1.30	2079	21

Note: The required chamber pressure value given in parentheses for the Mk. 3 Strip is converted into Pto by multiplying Pshi by the copper cylinder coefficient 1.043 and the pressure gauge coefficient 1.021.

Subsequently, second and third tests were conducted in August and November of the same year, also on a KRUPP Type 38 model, 10cm gun. The results, dimensions etc. are as follows:

Type of Powder*	W (kg)	Vo (m/s)	Pto (kg/cm^2)	Powder Thickness (mm)	Moisture (%)	Gun Cotton Admixture Ratio	Corrected Powder Tks. mm
(large) **	2.000	529.8	1946	1.602	0.73	1.591	1.600
(small) **	2.000	531.5	1996	1.577	0.72	1.591	1.581
(medium) ***	2.050	530.5	1983	1.595	0.68	1.884	1.573
(fast burning) ***	2.000	527.3	2042	1.581	0.62	1.827	1.570
						avg.	1.58

*Exp. No. 16 Cyl. Long was only type used
**Test was conducted in August 1941
***Test was conducted in November 1941

Notes

a. Corrected powder thickness is that when the moisture content is 0.75% and the admixture ratio is 1.60.

b. The powder thickness is that calculated so that W = 2.000 kg, Vo = 529 m/s and Pto = 2030 kg/cm^2.

c. The basic data for computing powder thickness are as follows:

(1) For powder thickness of 0.01mm the corresponding variations are: Δ Vo = 1.6 m/s, ΔPto = 16 kg/cm^2.

(2) For moisture content of 0.01% the corresponding variations are: Δ Vo = 0.9 m/s, ΔPto = 8 kg/cm^2.

(3) For gun cotton admixture ratio of 0.01 the corresponding variations are : Δ Vo = 0.5 m/s, ΔPto = 4.6 kg/cm^2.

As a result of the above researches and those conducted at IWABANA, the following dimensions were decided upon for the powder equivalent to the No. 3 Strip:

Outer diameter 5.10mm
Inner diameter 1.94mm
Powder thickness 1.58mm
Powder length 340mm

The powder with these dimensions was thereafter designated No. 16 Cylindrical Long powder.

In a trial manufacture, a rather large quantity of the aforementioned Type 16 Cylindrical Long powder was made available for tests. In January 1938, this powder was fired in the following service pieces used for the No. 3 Strip: Type 45, 24cm howitzer; 11th Year Type, 7cm gun; 14th Year Type, 10cm gun.

With approximately the same charge as that of the No. 3 Strip, it was found that the muzzle velocities of the firing table were attainable.

As cited above, on 29 January 1938 the powder was formally standardized

as the No. 16 Cylindrical Long, the equivalent to the No. 3 Strip.

Another experiment paralleling the above was conducted with a No. 16 Cylindrical Short, the idea being that the following advantages would accrue: that if the powder length could be cut down to 85mm, the chamber pressure could be reduced somewhat; that it would facilitate the manufacture of Mk. I charges for 14th Year Type 10cm gun; and that it would make possible the manufacture of the Mk. I to Mk. V charges, with the same powder as in the Type 45, 24cm howitzer.

Subsequently, however, because it was decided to utilize the long powder by trimming it down (research in trimming method was underway), standandization of the short powder was halted. Since it had been expected that a short powder would be standardized at the same time as the standardization of No. 16, the term "long" was added to the latter in this case only.

(Note: Though experiments were carried out with short powder for the Nos. 20 and 26 Cylindrical, further work on the project was halted for the same reason.)

Section D. Powder of Strength Falling Between No. 20 and No. 30 Cylindrical Powders (No. 26 Cylindrical)

While it had been possible to obtain a series of cylindrical powders with "OTSU" Mk. I composition, corresponding to the C Strip powder, it was only reasonable, from the standpoint of arrangement in graduated series, to provide another type of powder between the No. 20 and No. 30 Cylindrical.

Research was initiated accordingly. First an Experimental No. 25 Cylindrical powder (thickness 2.49mm, internal diameter 2.15mm, length 340mm) was given a trial manufacture. In January 1938, this was fired in a Type 89, 15cm gun and in a 7th Year Type, 15 cm gun with results as follows: though generally suitable as a powder for guns of the 15cm class, in use with the 7th Year Type it developed a rather high chamber pressure, so that it was necessary to correct the measurements for somewhat slower burning.

Gun	Shell	Type of Powder	W (kg)	No. of Rds	Vo (m/s)	Evo	Pto (kg/cm^2)	Σpto
Type 89, 15cm	Substitute (P= 45 kg)	Mark 4 Strip Powder (firing table value)	I 9.65		691.5		2450	
			II 8.60		610.0		1800	
		Experimental No. 25 Cyl. Powder	I 10.46	5	691.5	0.82	2300	39
			II 8.00	5	610.0	0.30	1750	8
7th Year Type, 15cm	Shrapnel Substitute (P 45 kg)	Mark 5 Strip Powder (firing table value)	I 16.65		845.0		2450	
			II 11.10		600.0		1100	
		Experimental No. 25 Cyl. Powder	I 14.80		845.0		2600	
			II 10.00		600.0		1150	

Again, when this was put to a spot check test in the 26 cal., 24cm gun, the results were as follows:

Projectile ..... Cylindrical shell (P = 240 kg)
W ..... 17.500 kg
Vo ..... 430 m/s
Pto ..... 1730 kg/cm^2

Based on the above results, a powder was planned for the 7th Year Type, 15cm gun corresponding to Vo = 845 m/s, Ptc = 2450 kg/cm^2. With a powder thickness of 2.65mm, the No. 26 Cylindrical powder was obtained. Its size is as follows:

Outside diameter 2.65mm
Inside diameter 2.50mm
Thickness 2.65mm
Length 240mm

Using experimental powder with these dimensions, from April 1938 on for several months thereafter, tests of powder strength and tests to determine the amount of temperature correction were carried out in the 26 cal. 24cm gun. Thus the standard powder strength required values, etc., as given at the present time, were determined in the case of the test piece. The strength of the powder was determined to be suitable even when used as the charge of the 30cm long howitzer. Consequently, it was designated No. 26 Cylindrical powder and as of November 8, 1938 was formally standardized.

Section E. No. 9 Cylindrical Powder

Research on charges used in special guns (model KO, MU Shell) began in 1935. In 1936 they obtained an Experimental No. 12 Square powder (N/G 41%, G KO powder), with suitable force. When this powder developed difficulties in the formative stage (bending or cracking of the powder surface) they came to discover G OTSU Mk. II composition simultaneously with the research on powder used in turret guns. Since it was found that with this composition the manufacture even of small size powders was comparatively easy, they investigated powders based on said composition and obtained a No. 9 Cylindrical powder of suitable strength. As of August 23, 1939, this was formally standardized.

This was the first of the cylindrical powders connected with G OTSU Mk. II composition. Then this same powder was found suitable even as a charge for use in the Type 94, 37mm gun, and finally it came to be used as such a charge and even as a substitute for No. 8 Cylindrical powder. At the time of its formal standardization the test gun for this powder became the Type 41 mountain gun, but it is permissible to change over to the Type 94, 37mm gun. Tests connected with the change over were carried out during the year 1940 and requirements were changed to those such as exist at present. In this connection, they have already been published in Report No. 229 on Powder Research Tests: "Research in Connection with Change of Test Gun for No. 9 Cylindrical Powder Together with Determination of Amount of Correction for Charge Temperatures."

Section F. Charges Used in the Mobile 47mm Gun (No. 13 Cylindrical Powder)

This gun first of all used the Mk. 2 Square powder. Then, with plans laid according to the following condition, that the powder chamber capacity (C') should be set at 0.75 liters, they went to work on experimental production of ordnance (1937).

Weight of shell ..... 1500 kg
Muzzle velocity ..... Over 800 m/s
Standard chamber pressure value ..... Under 2600 kg/cm

However among 47mm guns, there are self-propelled guns and AA guns, besides anti-tank guns. Wherever possible it was hoped to keep the capacity of the powder chamber as small as possible (this makes for a better shaped cartridge

case). Therefore, one should use the G OTSU Mk. II composition with cylindrical powder in place of Mk. 2 Square powder. They sought a powder and a powder chamber capacity by ballistic calculations. They were able to obtain the desired results with C'= 0.651 liters when they used No. 13 Experimental Cylindrical powder (thickness 1.29mm, inside diameter 1.21mm, length 10.5mm). In addition to carrying on experimental manufacture of powder on the basis of the above, test production was also carried out on one other gun (a Mark 13 gun barrel with C'=0.75 liters which has been designated as a Mark A Gun Barrel). The results with the two types of guns, A and B, and with various types of cases and projectiles, under controlled experimentation carried out from May 10-31, 1938, were as follows:

1. Powder chamber capacity (C'), 0.660 liters (close to the Mark B gun).

2. Projectile, generally as follows (not settled):

AP shell	P=1.500 kg
Long pointed shell	P=1.480 kg
HE shell	P=1.400 kg

3. Under the following condition, performance of the powder was even further improved:

Vo	800 m/s
Pto	2500 kg/cm^2 or below
Shell	AP (P=1.500 kg)

By referring to the above and to results obtained from firing tests carried out repeatedly during the period 1938 to 1940, measurements of the Experimental No. 13 Cylindrical powder were improved as follows (June 1941):

Outer diameter	3.89mm
Inner diameter	1.25mm
Thickness	1.32mm
Length	11mm

This is our present No. 13 Cylindrical powder. Powder strength is as noted in already published standardization charts or inspection requirements. (Formally standardized as of August 18, 1941.)

Now they have made as the main test gun for this powder the mobile 47mm gun. Although this gun will in principle be used, provision has also been made for the use of the Type 38 field gun as a secondary test gun. Actually, under present day conditions it is with this gun that tests are being carried out.

Section G. Recapitulation

The strength of the various powders listed above, except for the specially noted No. 42 Cylindrical powder, have all been described in already published charts or inspection requirements, and so will not be cited here. However, for reference purposes, powder forces (f) and vivacity rates (A) to be sought from ballistic computations made from them are given in Table III.

Representation in graduated series of cylindrical powders with the G OTSU Mk. I composition by means of degree of vivacity rate is given in appended diagram.

Table I
SPECIFICATIONS OF NON-VOLATILE SOLVENT POWDER FOR
TYPE 45, 15cm GUN
(Evolved June 1929)

Type	N/G	M/C	Component Mixing Ratio				Graph-ite	Dimensions (mm)		wt (kg)	Desig.
			C/L	OTU	Sodium bicar-bonate	Ammonium oxylate soda		Powder thickness (diam)	Powder Width		
Strip	27.0	63.9	5.0	3.0	0.5	0.5	0.1	3.0 2.5	2.8 2.8	180	30D27B
	25.0	66.9	4.0	3.0	0.5	0.5	0.1	2.5 4.0	2.8	180 180	25D27B 25D25B
Cord	27.0	63.9	5.0	3.0	0.5	0.5	0.1	3.5 3.5		180	40D27C
	25.0	66.9	4.0	3.0	0.5	0.5	0.1	3.0	*9.0 **3.0	180 180	35D27C 35D25C
Cyl.	27.0	63.9	4.0	3.0	0.5	0.5	0.1	2.5	*7.5 **2.5	180	30D27T
	25.0	66.9	4.0	3.0	0.5	0.5	0.1	2.5	*7.5 **2.5	180 180	25D27T 25D25T

*External diameter
**Internal diameter

Notes: 1. M/C is a mixture of strong and weak guncottons and the standard point of nitration of the components is as follows:

Strong guncotton No. 210±3 (N÷13.15)
Weak guncotton No. 173±3 (N÷10.85)
Mixed guncotton No. 189±1 (N÷11.85)

2. Water content is determined according to the Navy Type 13 Smokeless Powder Water Content Test and follows the standards thereby prescribed. In these tests it was 0.75 and ±0.20.

3. Since the cross-sectional and longitudinal dimensions of the form produced by the extrusion process, and the dimensions of the finished powder come out approximately the same, the shape dimensions show that standard. In these tests the powder length in all cases was 350mm.

Table II
RESULTS OF FIRING TESTS OF THE TYPE 90, 24cm RAILWAY GUN

Date of Test	Shell	Type of Powder	kg amt of Charge (Mk Number)	No. of Rds	Age of Gun	Vo (m/s)	Evo	Pto (kg/cm^2)	Epto
29 Nov. 1940	Type 100 Long Pointed (P=165 kg)	*	78 (I)	1	2	1056.9		3499	
30 Nov. 1940		*	78 (I)	4	5-8	1052.8	2.58	3492	34
5 Dec. 1940		*	78 (I)	3	20.5-22.5	1037.5	1.20	3271	32
30 Nov. 1940		*	60 (II)	2	3-3.5	871.9		2293	
5 Dec. 1940		*	60 (II)	3	23.5-24.5	844.3		2094	18
5 Dec. 1940		**	63	1	25	745.8		1555	
5 Dec. 1940		**	75	1	25.5	897.6		2359	
5 Dec. 1940		**	87	1	26	1028.9		3031	
10 Sept. 1941		*	60 (II)	1	27	849.4		2167	
10 Sept. 1941	Type 95 AP (P=200 kg)	***	60 (II)	2	27.5-28	800.2		2269	
10 Sept. 1941		*	60 (II)	1	28.5	805.1		2347	
12 Sept. 1941	Type 100 Long Pointed (P=165 kg)	*	78 (I)	1	45	1022.6		3287	
12 Sept. 1941		*	60 (II)	1	46	855.6		2120	
12 Sept. 1941	Type 95 AP (P=200 kg)	***	60 (II)	2	46.5-47	786.4		2200	

*No. 90 Cord type, short (made Aug. 1940)
**No. 42 Cyl. (made Aug. 1940)
***No. 90 Cord type, short (made Feb. 1941)

Notes: 1. In calculating the age of gun, one round of Mark I powder is figured as 1.0, and one round of Mark II powder (and experimental powder) as 0.5.

2. In these results, corrections for the age of the gun (or corrections for speed and pressure which depend on the length of the shell) have not been made.

Table III
CHARACTERISTIC FIGURES OBTAINED BY BALLISTICS CALCULATIONS
FROM STANDARD TEST REQUIREMENTS
(Examined 1 June 1943)

Kind of Powder	$f \times 10^{-2}$	$A \times 10^{2}$	i	q
# 9 Cyl.	11,000	0.27652	1.07	1.030
#13 Cyl.	11,000	0.17593	1.07	1.210
#16 Cyl.	10,000	0.10395	1.07	1.082
#20 Cyl.	10,000	0.085822	1.07	1.152
#26 Cyl.	10,000	0.062048	1.07	1.095
#30 Cyl.	10,000	0.052600	1.07	1.134
#42 Cyl.	10,000	0.036506	1.04	1.068
#90 Cord	11,000	0.040754	1.0233	1.023
#110 Cord	11,000	0.031016	1.0233	1.043

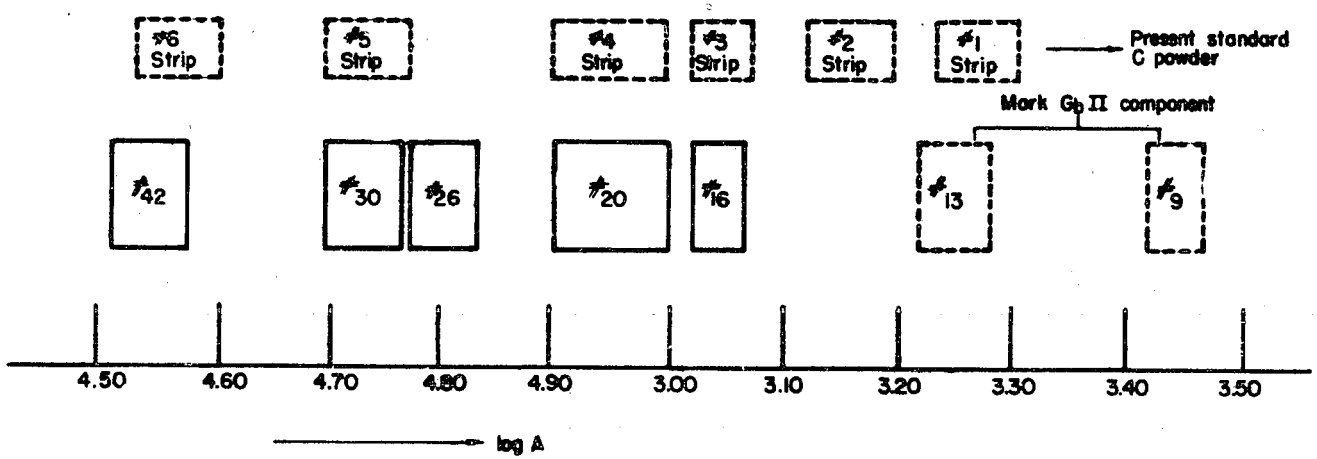
Notes: 1. In the ballistics calculations involving cylindrical powder Technical HQ's "Table of Interior Ballistics (Cylindrical Powder)" was used.

2. In the ballistics calculations involving cord powder Technical HQ's "Table of Interior Ballistics (Strip Powder)" was used.

3. "i" is the coefficient for interior ballistics; "q" is the lateral pressure coefficient.

NON-VOLATILE SOLVENT TYPE POWDER SERIES DIAGRAM
(USING G OTSU MK.I COMPOSITION CYLINDRICAL POWDER)

(The figure in the brackets is the thickness of thin powder in millimeters.)



Explanatory Notes: The diagram illustrates a graduated series of cylindrical powders using the present G OTSU MK.I Composition, by logarithms of the vivacity rate (A).

Their widths are shown by logarithms converting the muzzle velocity allowance of the requirements into A.

Further, the arrangement of the strip powder (present standard powder) is made so as to be equivalent to cylindrical powder.

EXPLANATION OF FOOTNOTES

(1) May 1925, Army Scientific Research Station.
"On Manufacture of Non-Volatile Solvent Powders"

(2) February 1930, Army Technical HQ.
"Second Periodic Report on New Powder Experiments" (January-November 1929)

(3) February 1930, Army Scientific Research Station.
"Research Report Concerning Powders Used in Corrosion Tests" (Scientific Research Report No. 376)

(4) April 1927, Army Scientific Research Bureau.
"Research on Non-Volatile Solvent Powder for Use with Type 45, 15cm Gun"

(5) June 1929, Army Scientific Research Bureau.
"Outline Plans for Non-Volatile Solvent Powder for Use with Type 45, 15cm Gun"

(6) June 1930, Army Technical HQ.
"Experimentation Report on Non-Volatile Solvent Powder for Use with Type 45, 15cm Gun" (March 1930)

(7) May 1932, Army Technical HQ.
"Report on Experimental Firing of Non-Volatile Solvent Type Powder Used in Tvpe 45, 15cm Gun" (December 1931)

(8) February 1928, Army Powder Laboratory.
"Research Report on Plans for Propellant for 24cm Railway Guns Ordered by This Office" (Army Powder Laboratory Research Report No. 222)

(9) October 1930, Army Powder Laboratory.
"Research Report on Plans for Powder to be Used in 24cm Movable Guns" (Army Powder Laboratory Research Report No. 432)

(10) November 1927, Army Scientific Research Station.
"Report on Plans for Manufacture of Powder for the Experimental 41cm Howitzer" (Research Report No. 198)

(11) March 1928, Army Scientific Research Station.
"Research Report on Powder for High Muzzle Velocity Small Caliber Guns" (Research Report No. 226)

(12) May 1930, Army Scientific Research Station.
"Research Report on Composition, Shape, and Characteristics of Field Gun Type Non-Volatile Solvent Powder" (Army Powder Laboratory Research Report No. 399)

(13) August 1932, Army Scientific Research Station.
"Research Report on the Size of Cylindrical Non-Volatile Solvent Powder for Use in 14th Year Type 10cm Guns" (Research Report No. 615)

(14) August 1932, Army Scientific Research Station.
"Research Report on Changes in the Strength of Non-Volatile Solvent Powder with the Passage of Time" (Research Report No. 614)

(15) April 1930, Army Scientific Research Station.
"Research Report on Underwater Storage of Powder Containing

N/G" (Research Report No. 394)

(16) August 1932, Army Scientific Research Station.
"Research in the Manufacture of Non-Volatile Solvent Powder" (Research Report No. 656)

(17) May 1929, Army Scientific Research Station.
"Report of Observation of Firing of 24cm Railway Gun Manufactured by This Office"

(18) December 1930, Army Technical HQ Supplement to 8th Powder Conference.
"Status of Non-Volatile Solvent Powder Firing Tests"

(19) September 1935, Ammunition Works Research Section, Powder Research Report No. 105.
"Research on Interior Ballistics of New Powders" (Research on Powder Planned for Type 90, 24cm Railway Gun)