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ON

JAPANESE CHEMICAL WARFARE

Volume III

THE MANUFACTURE OF CW MATERIALS BY THE JAPANESE

Office of the Chief Chemical Officer

GHQ, AFPAC

APO 500

TOKYO, JAPAN

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GENERAL HEADQUARTERS, ARMY FORCES, PACIFIC
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ABSTRACT

This report outlines the production of Japanese chemical warfare supplies, both offensive and defensive. Methods of manufacture are briefly discussed in the respective sections of the report. Tables giving the best available production figures on the various agents, munitions, and equipment are also presented. The authors of the report conclude that the Japanese were ill-prepared for modern, large-scale chemical warfare, either offensive or defensive, and that no important technological advances in manufacturing methods were introduced. Yearly breakdown of production does not show any significant trend except for a general decrease in 1944. The table on the following pages summarizes the total production of chemical agents and of gas masks.

Approximate Total Production Of
Chemical Agents and Gas Masks by the Japanese.
1930 to 1945, inclusive.

Persistent Agents	
Mustard	3,610 metric tons
Lewisite	1,381
Total	4,991
Non-persistent Agents	
Hydrocyanic acid	255
Chloracetophenone	172
Phosgene	1,080*
Chlorpicrin	1,000*
Total	2,507
Toxic Smoke Agent	
Diphenylcyanarsine	1,957
Smoke Agents	
Berger Mixture	7,000
HC	4,000
Agents containing SO_3	1,750
Total	12,750
Gas Masks	
Military	5,846,000 masks
Civilian	13,161,000
Total	19,007,000

*Rough approximation. There was little or no shipment of this production to military installations, and the bulk of the material was used as an intermediate in the manufacture of commercial materials.

Flame Throwers	
Portable	6,020 units
Mechanized	100
Total	6,120
Incendiary Bombs	216,500 bombs
Toxic Filled Bombs	50,000 bombs

I. INTRODUCTION.

A. Purpose

The purpose of this report is to summarize the information which has been obtained on the manufacture of chemical warfare materials by the Japanese.

B. Scope

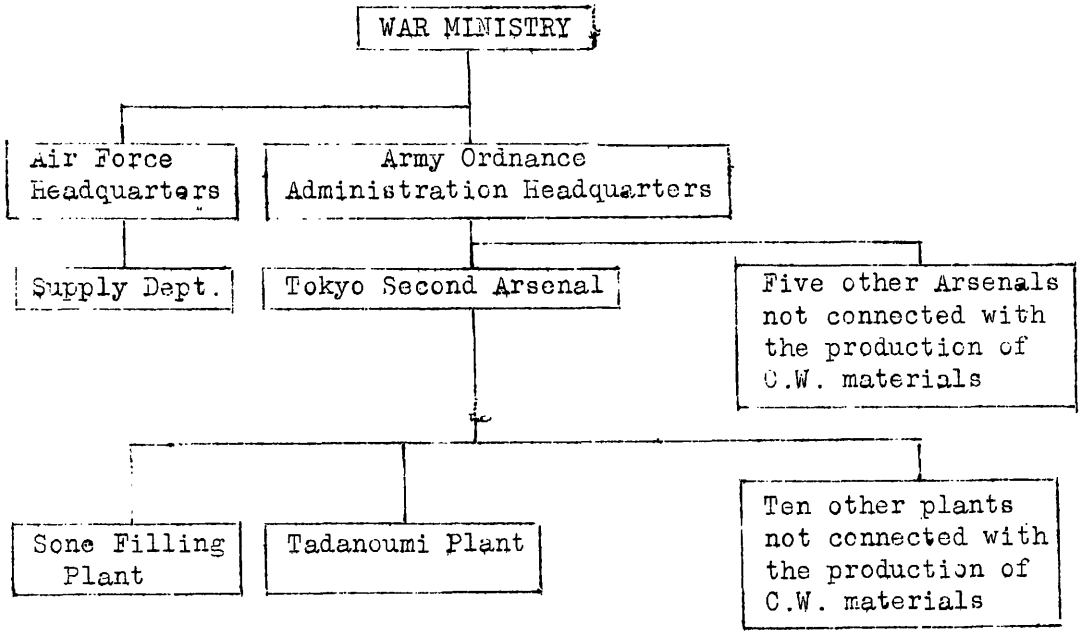
Prior to the writing of this report individual reports have been submitted on each installation which has been investigated by Chemical Warfare personnel. These reports contain detailed information on the manufacturing processes, organization of the arsenals or companies, and rates of production. They should be referred to when complete information is desired.* This report, however, summarizes the information contained in the individual target reports on the materials manufactured; the firms producing the materials; the methods of production; and the rates and quantities produced. Chemical warfare materials are considered to be those for which the Chemical Warfare Service of the United States Army had the chief responsibility in the United States.

*Copies of these reports are on file at the Office of the Chief, Chemical Officer, GHQ, AFPAC; G-2, GHQ, AFPAC; Office of Chief, CWS Washington, D. C.

C. Organization of Japanese Armed Forces for the Production of Chemicals

1. Army:

The Table of Organization of the Japanese Army showing only those organizations connected with the manufacture of chemical warfare materials is shown below:

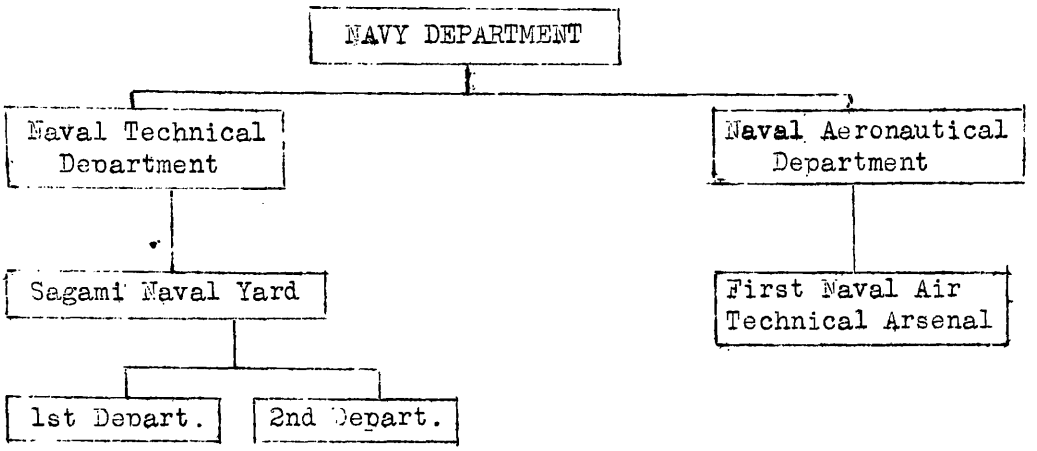


It was the policy of the Army to manufacture all toxic materials in the Army Arsenals. Non-toxic raw materials and chemical warfare equipment and weapons (e.g., flame throwers) were manufactured by industrial concerns who had contracts with the Army. Actually, however, in the case of chlorpicrin and phosgene small amounts were bought from industrial concerns whose production was chiefly for other applications (such as dyes). Toxic and smoke munitions were filled at the Sone Filling Plant. Bomb and shell casings were obtained by this plant from other arsenals.

Except for a few materials, such as the toxic agents which were obtained from Tadanoumi Arsenal, the Air Forces handled the production of their materials and equipment.

2. Navy.

The Table of Organization for the Japanese Navy showing only those organizations connected with the manufacture of chemical warfare materials is as follows:



The First Department had charge of the manufacture of toxic gases, indendiary bombs, and the construction and filling of gas bombs. The Second Department was in charge of the manufacture of protective equipment and smoke weapons. Some incendiary bombs were also filled at the First Naval Air Technical Arsenal.

D. Government Control of Chemical Supplies.

During the war, the chemical industry in Japan was under the control of the Munitions Ministry. The Chemical Bureau of this Ministry was charged with the allocation of raw materials and finished products and formed the over-all policy governing productive capacity. The chemical industries formed the Chemical Industries Control Association which served in an advisory capacity to the Munitions Ministry and aided in the administration of general policies formulated by the Ministry.

Procurement of general chemical supplies for the armed forces passed through normal channels of the Munitions Ministry, which procured these materials for Army and Navy Arsenals or private concerns working on military contracts. Toxic chemicals, however, were classified by the military and were directly controlled by the Army and Navy without passing through Munitions Ministry channels. This control included commercial plants supplying such items as thiodiglycol for the production of mustard gas at Tadanoumi Arsenal, hexachlorethane for the 2d Tokyo Military Arsenal, etc. Neither the Munitions Ministry nor the Chemical Industries Control Association were advised of these transactions, except where shortages or difficulties in procurement arose. In such cases, the Munitions Ministry expedited production, normal channels being involved throughout.

II. MANUFACTURE OF TOXIC AGENTS.

The chief manufacturing and procurement agencies of chemical warfare toxic agents for their respective branches of service were the Sagami Naval Yard at Samukawa, Kanagawa-ken, and the Tadanoumi Branch, Hiroshima-ken, of the 2d Tokyo Military Arsenal. With the exception of phosgene and chlorpicrin, all agents used by the Japanese armed forces were manufactured at either of these two plants. Information contained in this report was collected by field trips to these arsenals, interrogation of their personnel, and reports submitted by these personnel. For brevity the arsenals will be called Sagami Arsenal and Tadanoumi Arsenal in the following report. More detailed information will be found in the individual reports on these installations.

A. Mustard.

Experimental production of mustard using the French* process was begun by the Japanese Army at Tadanoumi Arsenal in 1928. In 1934-37 production of mustard and of non-freezing mustard using the German* process was inaugurated. Pilot plant work and research on mustard by the Navy began in 1923 at the Chemical Warfare Section of the Naval Technical Institute in Tokyo. It was not until 1943 that a full-scale production plant began operation at Sagami Arsenal.

The primary manufacturing process used by the Army, and the only method employed by the Navy, was the so-called German* process. Actually, the Arsenals only employed the last step of this process, as thiodiglycol obtained from industrial concerns was bought as a raw material. The HCl used in the chlorination of thiodiglycol to produce mustard was also obtained from private sources. The chlorination equipment at both Arsenals was made of porcelain throughout to resist corrosion.

*The Japanese named their processes after the equipment manufacturers. The "French" process is a modification of the Levinstein process, while the "German" process is the thiodiglycol process.

The chlorination consists of the gradual addition of HCl to thiodiglycol at 85°C., the reaction requiring four hours. The reactor contains brine cooling coils and a propeller agitator. Upon completion of the reaction, the batch is cooled and the agitation is discontinued. The mustard settles to form a lower layer and is drawn off from the spent acid layer, which is decontaminated and drained to the sewer. The acid in the mustard solution is neutralized with soda ash, the product is filtered and sent to storage tanks.

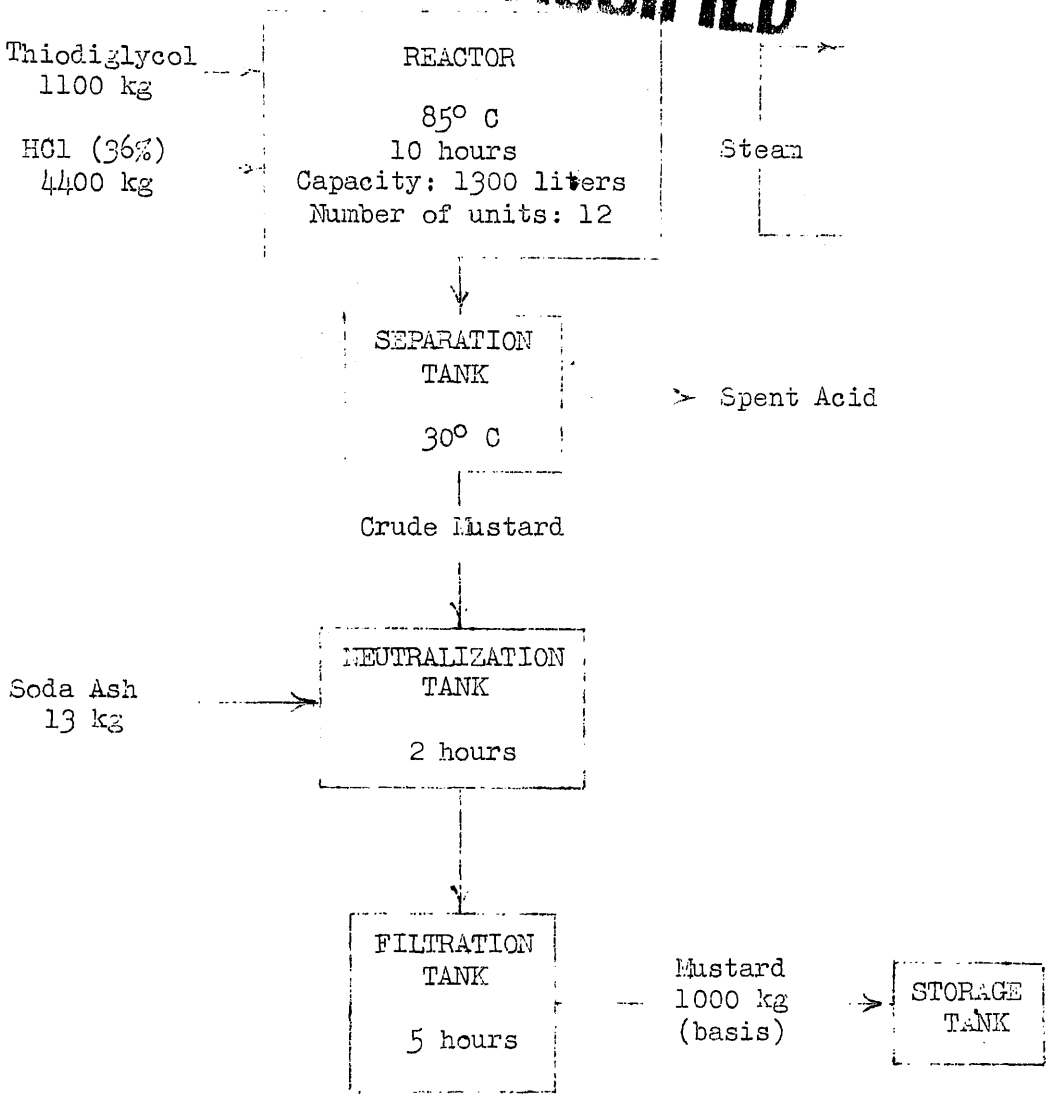
The same method, equipment, and operating conditions were used by the Army for the production of non-freezing mustard, which differed only in raw material. Instead of pure thiodiglycol, a mixture of approximately the following composition was used:

$S(C_2H_4OH)_2$	57.5%
$S(C_3H_6OH)_2$	18.0%
$S(C_2H_4OH)(C_3H_6OH)$	13.5%
H_2O	10.0%
Impurities	1.0%

For the production of mustard by the French process, manufacture was carried through at Tadanoumi Arsenal from basic raw materials. Ethylene was produced from ethyl alcohol by heating and then scrubbing the water from the generated gases. The ethylene was further dried by bubbling through a sulfuric acid tower. The other raw material in the process, sulfur dichloride, was produced at the Arsenal by the chlorination of sulfur monochloride, bought from a commercial firm. Carbon tetrachloride, used as a solvent in the process, was also purchased from private concerns.

Sulfur dichloride, dissolved in carbon tetrachloride, was introduced at one end of a series of five reactors. Ethylene flowed countercurrently through the reactors. The temperature of the reaction remained from 30° - 35° C. The effective contact time was about 45 minutes in each reactor. The resulting crude product was batch distilled to recover the solvent and then pumped to another still where the mustard was distilled from free sulfur and sulfur polymers. This residue was decontaminated by combustion in a furnace. The product contained 90% or more mustard.

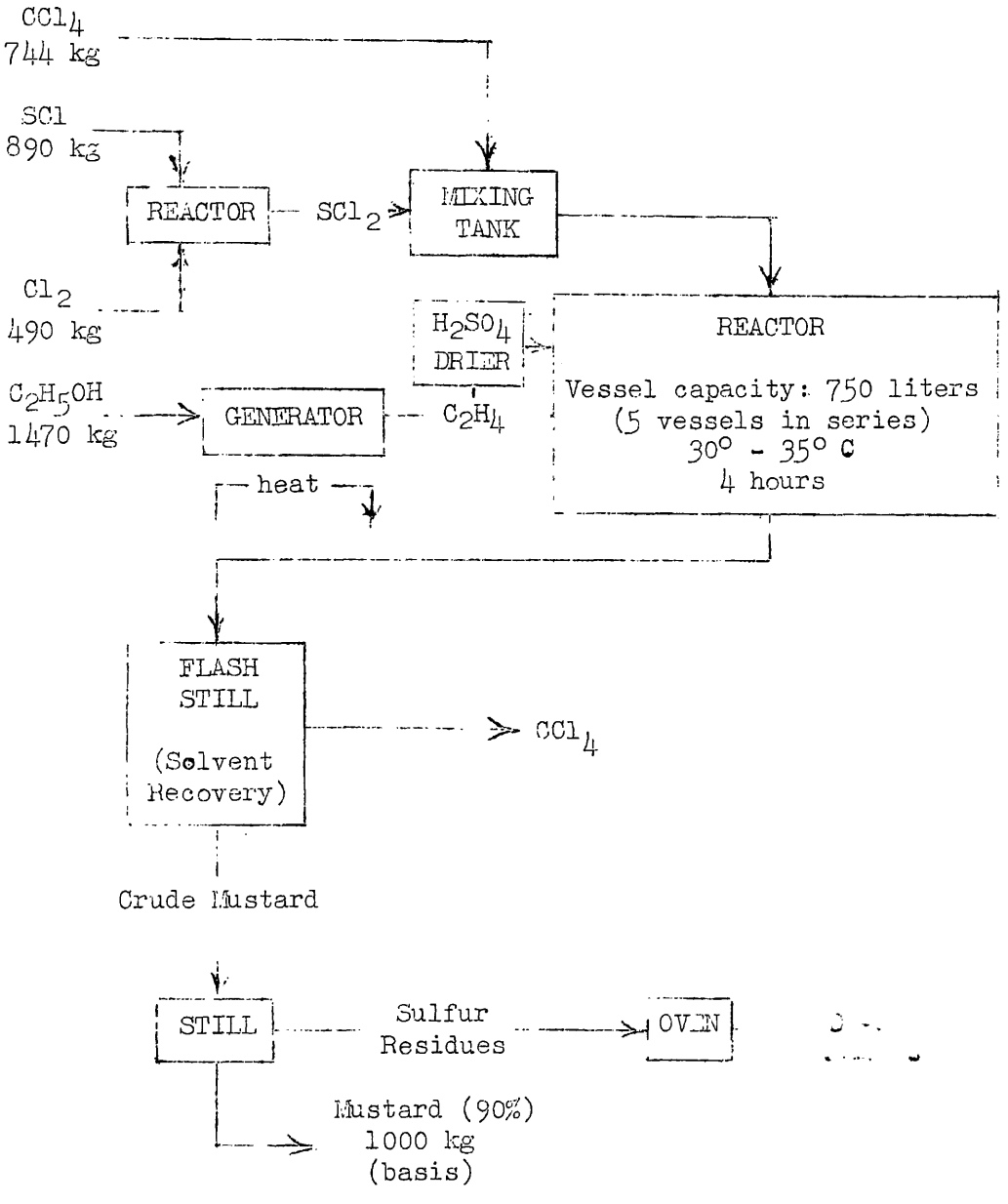
The processes described above are illustrated in the accompanying diagrams, Figure I: Flow Diagram of the Production of Mustard at Tadanoumi Arsenal, German Process, and Figure II: Flow Diagram of the Production of Mustard at Tadanoumi Arsenal, French Process.



Note: All units at slightly reduced pressure from exhaust fan. Off gases treated with $KMnO_4$ and vented to atmosphere.

Figure I

Flow Diagram for the Production of Mustard at Tadanoumi Arsenal, "German" Process.



Note: Off gases treated with $KMnO_4$ and vented to atmosphere.

Figure II.

Flow Diagram for the Production of Mustard at Tadanoumi Arsenal, "French" Process.

The production of mustard by both the Army and the Navy was intermittent and spasmodic. None of the equipment was kept in continuous use for any extended period of time. A summary of production figures appears in the following table:

Table 1.

Yearly Production of Mustard by Japanese Forces.

Source	Metric Tons Prior to 1942	1942	1943	1944	1945	Total
Navy -- German Process	30	80	200	190	0	500
Army -- German Process	337*	170	169	114	0	790*
French Process	450*	100	102	43	0	695*
Non-freezing	475*	180	100	0	0	755*
Total	1,292*	530	571	347	0	2,740*

*These figures do not include production for 1941. In that year, Tadanoumi Arsenal produced 1,138 tons of all types of mustard and Lewisite.

Mustard produced at Tadanoumi Arsenal was stored at the arsenal or shipped to the Hiroshima Supply Depot. That produced at Sagami Arsenal was stored at the Samukawa Branch of the arsenal.

B. Lewisite.

Lewisite was manufactured on a production basis at Tadanoumi Arsenal only. Production began in 1934 at a rate of 0.2 metric tons per day and continued until 1937. From 1937 until August 1944, two tons per day of the agent were manufactured at this installation. The Japanese Navy only produced Lewisite on a pilot plant scale and the product was utilized for experimental purposes only. During the closing years of the War the Lewisite produced by the Navy was converted to its oxide for use as an anti-fouling paint.

Raw materials for producing Lewisite were manufactured by the Arsenals. Acetylene was generated by the action of water on calcium carbide and run through a series of drying towers under its own pressure. Arsenic trichloride was made from arsenous oxide and sodium chloride. These solids were thoroughly mixed in a blender and then added to a kettle containing sulfuric acid. The reagents were heated and agitated until the reaction was completed. The water and arsenic trichloride were then distilled and separated in a settling tank.

Lewisite was produced from acetylene and arsenic trichloride in a porcelain reactor at a temperature of 85°C. Copper chloride dissolved in hydrochloric acid was used as a catalyst, and the reaction required approximately six hours. The resulting product was batch distilled to a concentration of about 85%. All equipment was constructed of porcelain throughout. The process is shown in the accompanying diagram, Figure III: Flow Diagram of the Production of Lewisite at Tadanoumi Arsenal.

Production figures are shown in the following table. Inasmuch as the Navy consumed all Lewisite produced, only approximate figures of the production at Sagami Arsenal are available. The Army produced all of its Lewisite at Tadanoumi Arsenal and stored it either at the Arsenal or at the Hiroshima Supply Depot.

Table 2.

Yearly Production of Lewisite by Japanese Armed Forces.
Metric Tons

Source	Prior to 1942	1942	1943	1944	1945	Total
Army	662*	150	194	87	0	1,093*
Navy	5	5	5	5	0	20
Total	667*	155	199	92	0	1,113*

*These figures do not include production for 1941. In that year Tadanoumi Arsenal produced 1,138 tons of all types of mustard and Lewisite.

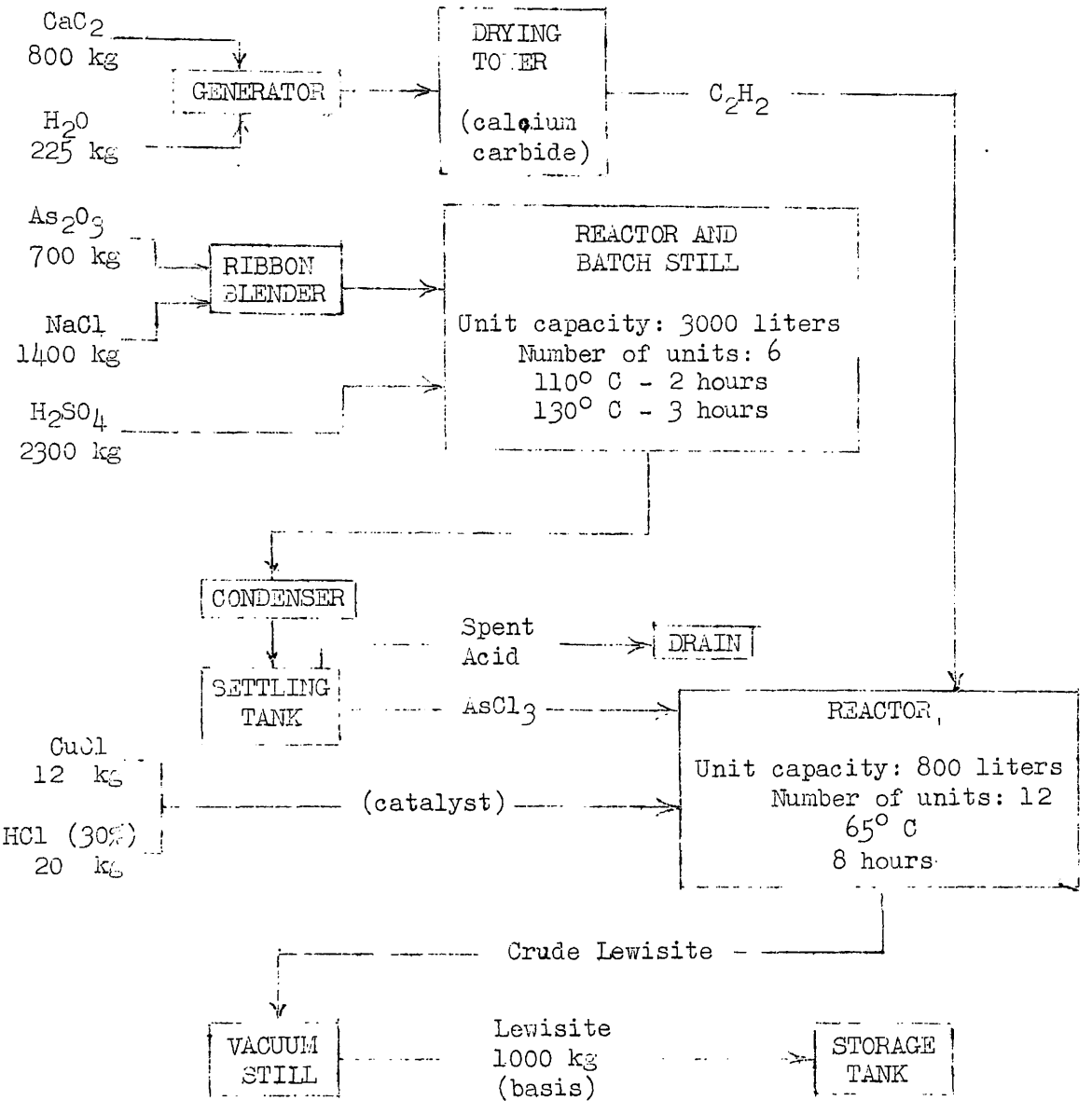


Figure III.

Flow Diagram for the Production of Lewisite at Tadanoumi Arsenal.

C. Hydrocyanic Acid.

The Navy did not produce hydrocyanic acid on any scale whatever. The Army began production of this agent at Tadanoumi Arsenal on a small scale in 1939 and continued production until August 1944.

Hydrocyanic acid was produced by the reaction of sodium cyanide solution and 50% sulfuric acid. These raw materials were introduced into a lead-lined steel reactor and heated to 40°C. The HCN gases evolved were condensed in a brine heat exchanger and the liquid product piped into cylindrical containers. These cylinders had tubes of copper mesh which served as a stabilizer. The produce was stored at the Arsenal or at the Hiroshima Supply Depot.

Production is outlined in the following table;

Table 3.

Yearly Production of Hydrocyanic Acid by Japanese Armed Forces
Metric Tons.

Source	Prior to 1942	1942	1943	1944	1945	Total
Army	138	103	1	13	0	255

D. Diphenylcyanarsine.

Small-scale production of diphenylcyanarsine began at Tadanoumi Arsenal in 1934. Manufacture was increased in 1938 with the installation of equipment capable of producing two tons per day of the agent. Production on this scale continued until the cessation of hostilities. The Navy only produced diphenylcyanarsine on a pilot plant scale at Sagami Arsenal and that only during the decade from 1933 to 1943.

The process used by the Army started with the conversion of diphenylarsenous acid to its oxide by the action of sodium bisulfite. The oxide was then chlorinated with hydrochloric acid and the resultant diphenylchlorarsine converted to diphenylcyanarsine by the action of a saturated solution of sodium cyanide. The process is illustrated in Figure IV: Flow Diagram of the Production of Diphenylcyanarsine at Tadanoumi Arsenal.

The Japanese Navy produced its own diphenylarsenous acid and manufactured diphenylcyanarsine in a slightly different manner. Raw materials for the initial stage of the process were aniline and hydrochloric acid, which were reacted in an agitated kettle to form aniline hydrochloride at a temperature of 0° - 3° C. Sodium nitrate was slowly added while the batch was held at that temperature. The resulting benzene diazonium chloride was then added slowly with agitation to a solution of sodium arsenate to form sodium phenyl arsenate. This was then neutralized with HCl and filtered into a kettle where further treatment with hydrochloric acid yielded phenylarsenic acid. The latter was then raised to a temperature of 75°. C and reduced to the arsenous acid by sodium bisulphite. Phenylarsenous acid was crystallized out and reacted with 36% hydrochloric acid for about four hours at 80° C. The batch was then allowed to settle and the lower layer drawn off to another reactor where diphenylchlorarsine was obtained by reaction with phenylarsenous oxide in the presence of concentrated sulfuric acid at 95°C. The product was then cooled at 8° C and centrifuged. The crystals were transferred to an aqueous solution of sodium cyanide in another kettle and allowed to react at 45° C for one hour. After settling and decantation, the crude diphenylcyanarsine was distilled under pressure. The process is illustrated in Figure V: Flow Diagram of the Production of Diphenylcyanarsine at Sagami Arsenal.

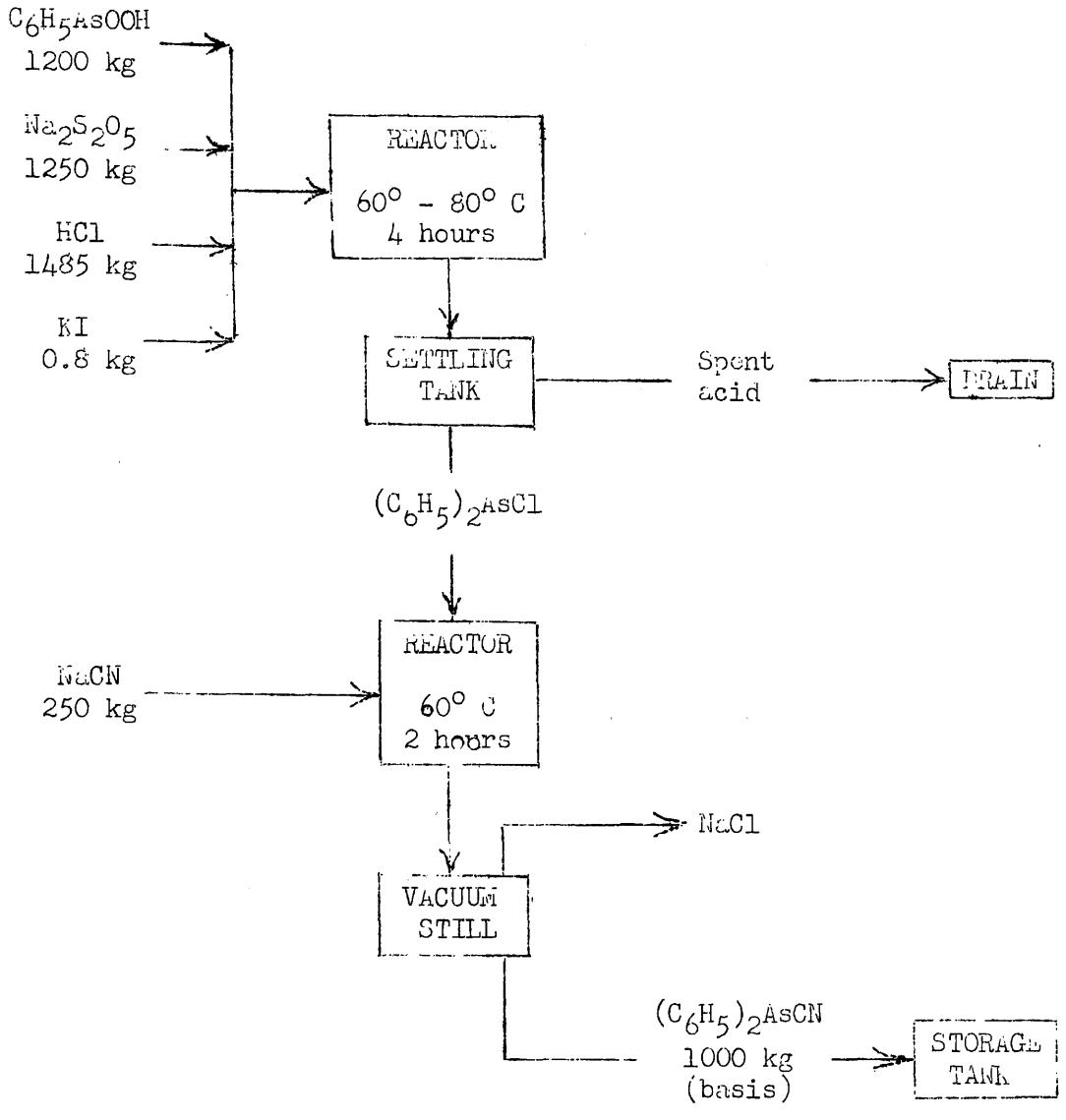


Figure IV.

Flow Diagram for the Production of Diphenylcyanarsine at Tadanoumi Arsenal.

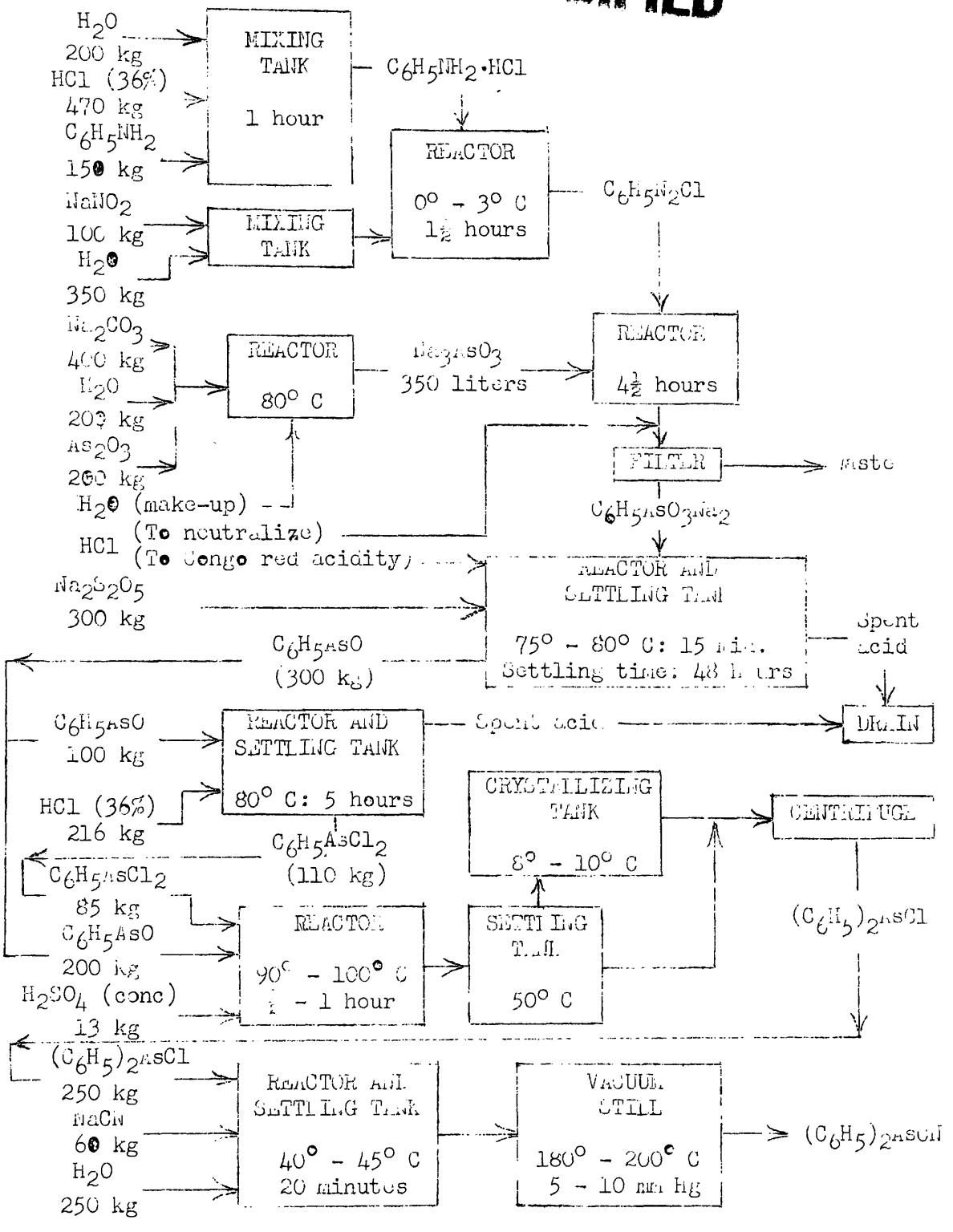


Figure V.

Flow Diagram for the Production of Diphenylcyanarsine at Sagami Arsenal

The finished agent was shipped from Tadanoumi Arsenal to the Hiroshima Supply Depot while Naval production was stored at the Samukawa Branch of Sagami Arsenal. Production figures are shown in the accompanying table.

Table 4.

Yearly Production of Diphenylcyanarsine by Japanese Armed Forces.
Metric Tons

Source	Prior to 1942	1942	1943	1944	1945	Total
Army	1,067	433	246	91	0	1,837
Navy	30	50	40	0	0	120
Total	1,097	483	286	91	0	1,957

E. Chloracetophenone.

The Army produced chloracetophenone on a small scale at Tadanoumi Arsenal from 1939 until the end of the war. The Navy started trial production at Sagami Arsenal in 1931 and continued until the early part of 1944. Early production by the Navy consisted of the chlorination of acetophenone manufactured from benzoic acid. However, a shortage of that raw material lead them to adoption of the same process as the Army, described below.

Acetic acid was first converted to monochloracetic acid by the addition of chlorine in a reactor. Choracetylchloride was produced from the monochloracetic acid in a reactor by the addition of chlorine and sulfur monochloride in the presence of zinc chloride. The product was distilled and then reacted with benzene using aluminum chloride as a catalyst. The resultant chloracetophenone was crystallized in a centrifuge containing ice water and separated by centrifuging. The process is illustrated in the accompanying diagram, Figure VI: Flow Diagram of the Production of Chloracetophenone at Tadanoumi Arsenal.

Production of the agent is summarized in the table below. The material was stored at the Hiroshima Supply Depot and the Samukawa Branch of Sagami Arsenal for the Army and Navy respectively.

Table 5.

Yearly Production of Chloracetophenone by Japanese Armed Forces.
Metric Tons.

Source	Prior to 1942	1942	1943	1944	1945	Total
Army	40	7	5	0	0	52
Navy	20	20	40	40	0	120
Total	60	27	45	40	0	172

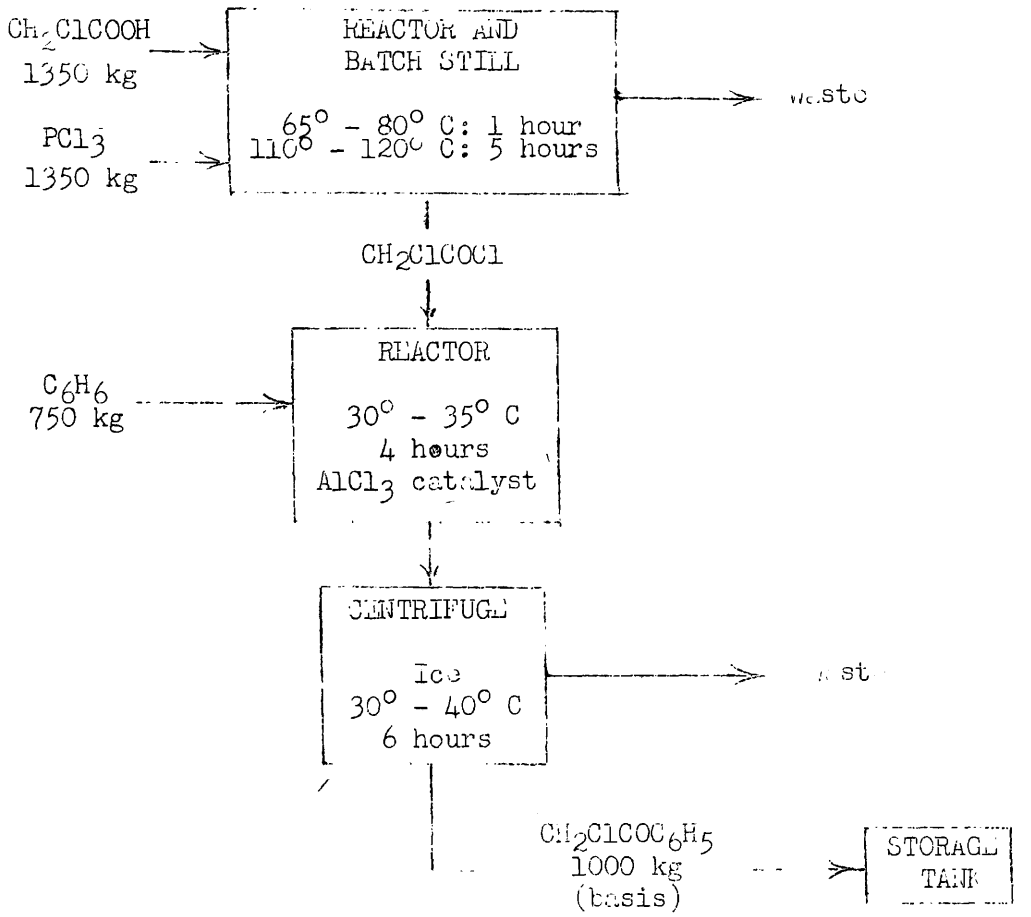


Figure VI.

Flow Diagram for the Production of Chloracetophenone at Tadaneumi Arsenal.

F. Phosgene.

Phosgene was not produced by any Army or Navy arsenals, but was procured from commercial chemical firms. Phosgene is commonly used as a dye intermediate, and the quantity consumed by military applications was not a drain on normal productive facilities.

The process used in the manufacture of phosgene is simple and well-known. The material is produced in banks of catalytic reaction chambers from chlorine and carbon monoxide gases. The yield is then condensed and stored as a liquid.

The amount of this material which was used for military purposes is not definitely known. Some of the material was shipped to the 2d Tokyo Military Arsenal, but the major portion was bought by two dye manufacturers, the Dai Nippon Seiyaku K. K. and the Dai Ichi Seiyaku K. K. The best available production figures are summarized in the following table:

Table 6.

Yearly Production of Phosgene in Japan (For All Applications).
Metric Tons.

Source	Prior to 1942	1942	1943	1944	1945
Miike Dyestuff Co.	Unknown	Unknown	Unknown	6	26
Hodogaya Chemical Co.	Unknown	Unknown	182	197	93
Nippon Soda Co.	85	32	25	38	0

G. Chlorpicrin.

Like phosgene, chlorpicrin was produced solely by commercial firms and almost entirely for use in the dye industry. No record of any shipment of this material to Army or Navy installations has been discovered.

Chlorpicrin was manufactured commercially by the reaction of bleaching powder and picric acid. The product was distilled for purification. Only two firms are believed to have manufactured this compound, the Miike Dyestuff Company and the Nippon Soda Company. Consumers of chlorpicrin from the former were the National Agricultural Economic Association and the Chemical Industries Control Association. The Nippon Soda Company shipped its product to the Whole Country Purchase and Sale Union. Production is summarized in the following table:

Table 7.

Yearly Production of Chlorpicrin in Japan (For All Applications).
Metric Tons.

Source	Prior to 1942	1942	1943	1944	1945
Miike Dyestuffs Co.	Unknown	198	67	120	Unknown
Nippon Soda Co.	500	0	0	0	0

III. MANUFACTURE OF PROTECTIVE EQUIPMENT.

Production of Japanese protective equipment, Army, Navy, and civilian, was carried out in various ways. The Army was largely dependent on two companies for complete production and assembly of all their gas masks. The Navy had many companies producing facepieces, canister casings, and carriers. Final assembly, including the addition of the chemical filler to the canister cases, was carried on at Sagami Arsenal. Civilian gas masks were completely made and assembled by private companies. The greater part of all charcoal used in canisters was manufactured by one company.

Protective clothing, decontaminating materials, detector kits, and collective protectors for the Army were produced by private companies. The Navy, however, insisted on production of these materials in Naval arsenals. The Navy water purification kit was also produced at a Naval arsenal.

The Japanese Navy demanded production under the supervision of Naval personnel, while the Army was content to accept the final product if specifications were met.

A. Production of Gas Masks.

Methods of manufacture and a description of the various masks in use by the Armed Forces and for civilian protection are described in separate sections below. A summary of total production of this equipment is given in the following table:

Table 8.

Yearly Production of Japanese Gas Masks
Thousands of complete masks.

Consumer	1940	1941	1942	1943	1944	1945	Total
Army	678	680	764	890	1,635	334	4,981
Navy	Unknown	59	75	70	501	160	(865)
Civilian	Unknown	213	2,682	5,941	3,125	1,200	(13,161)
Total	(678)	952	3,521	6,901	5,261	1,694	(19,007)

1. Production of Army Gas Masks.

a. Facepiece Production.

The method of manufacture of the rubber facepiece for the Japanese Army gas mask involved the integral molding of the component parts with the "compound" rubber. The rubber, knitted cotton lamina, fastening tapes, and tissot tube are all placed in the mold, together with sulfuric acid, before the application of heat and pressure. The latest model also incorporates a detachable inner mask, which covers only the nose and mouth and directs the expelled air into the outlet valve of the combined inlet-outlet valve housing. The outlet valve itself is seated on hard rubber to prevent failure by freezing in cold weather. All metal parts are stamped to shape, except the combination inlet-outlet valve housing, which is of molded aluminum. The threaded, interchangeable eyepieces are gas-proofed with rubber washers. Eyepieces themselves were made of celluloid-laminated glass or heat-treated glass. The valve housing on the assault mask is threaded to receive the canister directly. Detailed description of these articles will be found elsewhere. ("Captured Japanese Materiel Technical Reports," filed at the Office of Chief CWS, Washington, D. C.) Production figures are summarized in the following table:

Table 9

Yearly Production of Japanese Army Gas Mask Facepieces.
Thousands of units

Source	1940	1941	1942	1943	1944	1945	Total
Nihon Chemical Industries Co.	348	336	304	405	780	206	2,379
Fujikura Industries Co.	300	300	360	400	755	80	2,195
Other Sources	30	44	100	85	100	48	407
Total	678	680	764	890	1,635	334	4,981

b. Canister Production.

The canister casings for the Army mask were made of aluminum or brass sheet, stamped to shape. That portion of the inner surface which is in contact with the chemical filler is coated with a synthetic resin. The smoke filter, made of varying proportions of cotton fiber, asbestos, and paper pulp, is held in a concertina-type frame. The filter is dyed with Congo Red, presumedly to give better results in the filtration of smoke. The chemical filler contains

coconut charcoal, activated by steam or zinc chloride process, and "brown granule", a variable mixture of oxidizing agents. Cheesecloth layers, supported by aluminum or brass ribs, keep the chemical filter in the lower section of the canister. Production is summarized in the following table:

Table 10.

Yearly Production of Japanese Army Gas Mask Canisters.
Thousands of units.

Source	1940	1941	1942	1943	1944	1945	Total
Nihon Chemical Co.	348	350	390	450	1,040	230	2,808
Fujikura Industrial Company	330	330	400	440	830	90	2,420
Total	678	680	790	890	1,870	320	5,228

c. Carrier Production.

For production of carriers for the Army mask, cotton canvas sheet of specified quality was cut to the required size and shape, then sewed together and fitted with pockets, belt, tapes, buttons, buckles, and other accessories. The carriers were waterproofed by dipping in aluminum acetate solution before cutting. These carriers were mostly manufactured in small plants to whom the contract had been sub-let by the Nihon Chemical Company and the Fujikura Industries Company. Production from all sources is combined in the following table:

Table 11.

Yearly Production of Japanese Army Gas Mask Carriers.
Thousands of units.

1940	1941	1942	1943	1944	1945	Total
810	750	840	960	224	410	3,994

2. Production of Navy Gas Masks.

a. Facepiece Production.

The Navy mask used a facepiece fabricated of molded white rubber covered by gray, rubberized fabric. The tissot tube was either molded to the facepiece or was molded separately and attached by rivets Soft glass lenses were fastened to the facepiece with crimped metal rims. The head harness consists of a rubber pad carrying five black, fabric straps. The inlet and outlet valves are housed together in an aluminum alloy housing which is wired and taped to the facepiece. Production of this item is summarized in the following table:

Table 12.

Total Production of Japanese Navy Gas Mask Facepieces.

Source	Approximate Total Units Produced
Mitatuti Rubber Co.	260,000
Nihon Rubber Co.	520,000
Showa Chemical Co.	87,000
Total	867,000

b. Canister Production.

The canister for the Navy mask is larger than that of the Army mask and is constructed of tin or zinc plated sheet metal. The mechanical filter is composed of varying mixtures of kapok* and Moxa fibers, which were filtered, pressed, dried, and cut into elliptical shape. The chemical filler is a mixture of steam-activated, coconut charcoal, and soda lime composed of 67% slaked lime, 21% cement, 9% kieselguhr, and 3% caustic soda. For added protection against HCN, the Navy developed an auxiliary canister which was connected directly to the bottom of the main canister. This sub-canister contained 70% active manganese dioxide and 30% copper oxide. The efficiency of the canister was later increased further by the addition of a drying mixture of silica gel and calcium carbide. By this means, total weight of the canister was reduced 15%. Chemical fillers for the canisters were produced at Sagami Arsenal, and final assembly of the canisters also occurred there. Approximate total production is given in the

*Kapok is called "silk-cotton" in Japanese.

following table;

Table 13

Total Production of Japanese Navy Gas Mask Canister Casings.

Source	Approximate Total Casings Produced
Hirata Industries Co.	520,000
Mitatuti Rubber Co.	347,000
Total	867,000

c. Carrier Production.

Carriers for the Navy mask were fabricated of cotton canvas or silk canvas, cut and sewed to shape. A fiber box with a handle and two fasteners was used in storage and shipment. The box was also used to protect masks being carried at sea. Approximate total production is shown in the following table:

Table 14

Total Production of Japanese Navy Gas Mask Carriers.

Source	Approximate Total Carriers Produced
Nihon Rubber Co.	433,500
Nikka Industry Co.	260,000
Other Sources	173,500
Total	867,000

The total production of Navy gas masks, broken down by types, is summarized in the following table:

Table 15

Yearly Production of Japanese Navy Gas Masks.
Thousands of Masks.

Type	1941	1942	1943	1944	1945	Total
Type 93, M2	57	70	20	0	0	147
Type 93, M3	0	0	40	400	150	590
Type 93, M4	0	0	0	100	10	110
Type 97	2	5	10	1	0	18
Total	59	75	70	501	160	865

3. Civilian Gas Mask Production.

a. Facepiece Production.

Considerable variation in design and methods of manufacture of civilian Japanese masks existed. Some facepieces were molded, others were cut from sheet rubber or from laminated silk and rubber sheets. Eyepieces were made of glass or celluloid, the latter being sewed and taped to the facepiece, while the former were held in place by crimped sheet metal rims. Inlet valves were generally of the celluloid, gravity type. Some masks did not have the conventional outlet valve, but permitted the exhaled air to escape through the canister or by peripheral leakage. Those gas masks whose production was controlled by the government were of the snout-canister type. Other competitive civilian mask manufacturers made their masks with conventional canisters connected to the facepiece by a hose.

b. Canister Production.

Civilian gas mask canisters varied greatly in shape and size. Cylindrical canisters had diameters varying from three to five inches and heights from one to four inches. They were constructed of tin or lacquered cardboard. Other canisters were of conventional shape and made of sheet metal. The chemicals in the canister included charcoal, soda lime, and hopcalite. Mechanical filters were held in place by a wire screen basket. Different canisters were available for various gases on some civilian masks.

c. Carrier Production.

The carrier for some gas masks was made of cotton cloth with a drawstring closure. A cotton cloth carrying strap was attached. Actually, few civilian mask producers made carriers for their masks.

According to the Home Ministry, the following concerns are listed as having produced civilian gas masks:

Nippon Kako Co., Ltd., Itabashi-Ku, Tokyo.
Showa Yako Co., Ltd., Oji-Ku, Tokyo.
Fujikura Kogyo Co., Ltd., Shinagawa-Ku, Tokyo.
Kokka Kogyo Co., Ltd., Kamata-Ku, Tokyo.
Kyowa Koku Kogyo Co., Ltd., Mukojima-Ku, Tokyo.
Nippon Rubber Co., Ltd., Kurume, Fukuoka, Kyushu.

Intelligence investigations have uncovered these additional manufacturers:

Shigematsu Mask Mfg. Co., Kanda-Ku, Tokyo.
Nikka Industry Co., Odawara, Honshu.

Information on these two producers is incomplete. The Shigematsu Mask Mfg. Co. produced 60,000 masks in 1941, but from that time on production was on a very limited scale because of material shortages. The only figure available on the Nikka Industry Co. is that this firm had a monthly capacity of 1,500 masks per month. The period of production is not known. Production of civilian masks may be guaged from figures submitted by the Home Ministry, which controlled procurement and manufacture of this article. These figures appear in the following table:

Table 16

Yearly Production of Japanese Civilian Gas Masks

1942	1943	1944	1945	Total
2,682,756	5,941,607	3,125,025	1,200,000*	12,949,388*

*Records incomplete.

3. Production of Activated Charcoal.

Two types of charcoal were manufactured for use in gas mask canisters. That considered most desirable, was obtained by the activation of charcoal from coconut shells imported from Saipan and other Melanesian islands. The shells were crushed in a roller mill and screened through a 14 mesh sieve. The particles were then fed by gravity through a coal-fired kiln at a temperature of 900° C. Passage time was approximately ten hours. Steam from a small boiler maintained an atmosphere of water vapor in the kiln. Yield was about 60% of raw material. The other type of active charcoal used wood charcoal, locally obtained, as a raw material. This charcoal was crushed to a particle size corresponding to 200-300 mesh. To these particles, tar and pitch, mixed 50-50, were added in the presence of steam. The material was then kneaded in a dough mixer and fed through an extruder to form pellets 1/16 inches in diameter and 1/8 inches long. These pellets were then carbonized at 500° - 600° C. for one hour. Activation followed by contact with steam at a temperature of 800° C. for a period of 30 minutes.

Specifications for activated charcoal were controlled by military authorities and tests were carried out by them. These specifications and descriptions of tests were burned with other military papers on 15 August 1945. However, the following tests are those used by the Nippon Kasseitan K. K., the largest producer of this material:

Hardness	Ro-tap shaker. (Presumedly measured by changes in screen analysis.)
Particle size	Tyler standard screens Army: 8-14 mesh Navy: 8-20 mesh Civilian: 14-20 mesh
Gas adsorption	Chlorpicrin is passed through a specified quantity of activated charcoal in a tube of specified dimensions. A given quantity of the gas must be adsorbed in a set time.
Solvent	The charcoal must adsorb 40% or more of its own weight of alcohol.

Only two large-scale producers of activated charcoal are known. The Nihon Tanso Co. Ltd. manufactured charcoal from 1943 to 1945. All of their produce was shipped to Sagami Arsenal. The Dai Nippon Kasseitan K. K. produced activated charcoal from 1938 to 1945.

Their product was shipped to the following consumers in the quantity shown:

	Metric tons		Metric tons
Sagami Naval Arsenal	137	Nihon Kako K. K.	19
Naval Technical Laboratory	5	Showa Kako K. K.	23
Army Clothing Depot	1,505	Nihon Rubber Co.	34
Army Technical Laboratory	1	Kyowa Leather Co.	4
Fujikura Industries Co.	21	Kyowa Aircraft Co.	14

Yearly production of activated charcoal by the Japanese is summarized in the table below. It is not accurately known what fraction of the total production was used in the manufacture of gas masks.

Table 17.

Yearly Production of Activated Charcoal by the Japanese
Metric tons.

Source:	Nihon Tanso Co.			Dai Nippon Kasseitan K. K.				
	Coconut Shell	Active Charcoal	Wood Charcoal	Coconut Shell	Coal Tar	Pitch	Active Charcoal	Total Active Charcoal
Prior to 1942	0	0	2,770	143	221	205	1,698	1,698
1942	0	0	556	6	36	36	162	162
1943	2.4	1.45	61	0	36	36	84	85.5
1944	35	21	42	0	26	26	136	157
1945	12.5	1.6	163	10	26	26	24	25.5
Total	49.9	24.05	3,592	159	345	329	2,104	2,128

C. Production of Protective Clothing.

Japanese orotective clothing was generally made of laminated rubberized silk, cellophane laminated rubber, thread-reinforced rubber, or sheet rubber, cut to size and vulcanized to the proper shape. The component parts of the better suits of protective clothing included trousers, hooded jackets, three fingered gauntlets, and heelless shoe covers in a cloth carrier. Tie straps at the waist, ankles, wrists, and on the hood were intended to provide vaporproofing. Later capes were made of oilskin or rubberized silk fabric. Production is summarized in the following table:

Table 18

Yearly Production of Protective Clothing by the Japanese
Thousands of units.

Source	1938	1939	1940	1941	1942	1943	1944	1945	Total
Army									
Fujikura Macintosh Co. Protective clothing(pieces)	300	250	228	270	300	360			1,708
Choya Oil Silk Mfg. Co. Mantles						40	186	64	290
Nikka Kogyo Co.Ltd. Horse Mantles	3	6	6	20	11	29	14	6	95
Horse Leggings		6	14	23	28	20	35	2	128
Human Jackets	4	3	5	4	4	1	0	0.1	18
Human Gloves	4	4	5	9	45	59	88	32	246
Human Shoes				5	42	55	87	33	220
Human Trousers	4	3	5	9	45	57	89	307	519
Nokka Kogyo K.K. Protective Suits (less hooded jacket)									2,400
Hooded Jackets									650
Nippon Rubber Co. Horse Leggings	32	54	30	46	26	16	13	7	194
Horse Covers	9	46	14	7	14	72	96	25	283
Navy									
Sagami Naval Arsenal 98 type Protective Clothing				0.5	1	1	0.5	0	3
Light Protective Clothing				0.5	1	1	80	20	102.5
Protective Capes				0	0	0	170	30	200

D. Production of Decontaminating Materials.

The Japanese Navy produced six numbered decontamination agents, of which No. 6 was actually a water purification kit and is discussed under that heading. In the later years of the war a protective ointment known as T-Toyaku was developed for personnel decontamination. The composition of these agents and quantity of active ingredient per package is given in the following table:

Table 19.

Composition of Japanese Navy Decontaminating Agents.

No. 1	150 gm $KMnO_4$)	To be mixed with 30 liters of water and used against adhering sneezing or lachrymatory agents.
No. 2	1000 gm flake NaOH)	
No. 3	High test bleach.	
No. 4	10 gm chlorine, dissolved in CCl_4.	
No. 5	Chloramine-T 16% Bentonite 81% Salt Water Soap 3%	Mixed in a paste with two parts water for use on personnel, with three parts water for clothes.
T-Toyaku	Gum mastic 10% Water glass 90%	To be used as a personnel ointment.

Production of these decontaminating agents for the Japanese Navy is summarized in the following table:

Table 20.

Production of Japanese Navy Decontaminating Agents.
Thousands of packages.

Source	Agent	1941	1942	1943	1944	1945	Total
Yokosuka Arsenal	No. 1	10	10	1	0	0	21
	No. 2	20	20	2	0	0	42
Asahi Denka Company	No. 3	8*	16*	Unknown	1600*	250*	1,876*
Sagami Arsenal	No. 4	5	10	30	34	12	91
	No. 5	0	0	0	150	100	250
1st Naval Medical Depot	T-Toyaku	-----negligible-----			2	80	82

*Metric tons.

Researches on decontaminating agents were conducted over a period of years by the Japanese Army, but the only material which was standardized and supplied in quantity to the field was bleaching powder. This was obtained from the following major producers and twenty other smaller companies;

Asahi Denka K. K., Arakawa-Ku, Tokyo.
Nippon Soda Co., Nihonga Works, Niigata, Niigata-Ken, Honshu.
Towa Gosei K. K., Fushiki Works, Toyama-Ken, Honshu.

The bleach was packaged in rubberized boxes containing 7.7 kg of active ingredient. Production of bleach is summarized in the following table:

Table 21.

Production of Bleaching Powder for the Japanese Army.
7.7 kg boxes, thousands

1930-1936	1937-1941	1942	1943	1944	1945	Total
70	400	100	100	100	30	800

E. Production of Detector Kits.

The Japanese Army relied on simple color-change kits for reconnaissance detection of blister gas. These kits were widely distributed to small units in the field. A larger detector, designed to distinguish between various agents, consisted of from three to five tubes through which air was drawn by a hand pump. These were produced in smaller quantities and known as materiel detector kits. The Japanese Navy produced detector kits at Sagami Arsenal similar to the Army materiel kit, using either cylindrical or bulb pumps. The Navy also manufactured a kit using test papers. Production of these various kits is summarized in the following table:

Table 22.

Yearly Production of Gas Detector Kits for the Japanese Armed Forces
Thousands of kits.

Using Branch	Source	Type	Prior to 1942	1942	1943	1944	1945	Total
Army	Nippon Kako Company	Reconnaissance	63	15	20	20	20	138
		Materiel	14.5	2.5	4	4	2	27
	Fujikura Mac-intosh Co.	Reconnaissance	6.5	1.5	2	2	1	13
		Materiel	2.25	0.4	0.5	0.5	0.25	3.9
Navy	Sagami Arsenal	Materiel, cylindrical pump	0.2	0	0	0	0	0.2
		Materiel, bulb pump	0	2	3	5	0	10
		Test paper	0	0	0	0	0.1	0.1

F. Production of Water Purification Kits.

The Japanese Navy developed a kit for the determination and decontamination of arsenic compounds in water. The kit contains mercuric bichloride test paper, detector tubes, a filtering bag and cloth, and ten containers of a decontaminating agent of the following composition:

Reagent 1:	High test bleaching powder	1 gm
	Barium peroxide	8 gm
	Ferric Phosphate	9 gm
Reagent 2:	Calcium Carbonate	8 gm
	Active carbon	4 gm

The three compounds of reagent 1 were in separate compartments of the plastic container but were added together to the water to be purified. After stirring for 10 minutes, reagent 2 was added. No information regarding a water purification kit for the Japanese Army has been uncovered.

Production of the kit for the Navy took place at Sagami Arsenal. Manufacture started in 1944, when 20,000 kits were made. 5,000 additional kits were produced in 1945.

G. Production of Collective Protectors.

The Japanese Army standardized a collective protector in 1934, known as Type 94. Chemical filler and mechanical filters were of the same composition as the Type 95 Army mask. The blower was propelled either manually or electrically. Design capacity was to protect fifteen men for forty hours in an atmosphere of phosgene at a concentration of one hundred mg per cubic meter. Only trial production of this model took place. In 1937, Type 97 collective protector was standardized using the same materials as the Type 99 mask. The protector was equally efficient as Type 94 against phosgene but offered better protection against HCN and other gases. The protectors were manufactured at the rate of 30 per year from 1937 to 1940, inclusive, by the Nippon Kako Co. and the Fujikura Macintosh Co. Field distribution was one unit to each engineering regiment.

The Japanese Navy produced only a small quantity of collective protectors. These items used a number of standard gas-mask canisters connected in series. Each unit was designed to protect from fifty to seventy men for about 30 minutes, and they were installed at four strategically located spots aboard large warships. The protectors were manufactured at Sagami Arsenal in the following quantities:

Table 23.

Yearly Production of Collective Protectors by the Japanese Navy.

1941	1942	1943	1944	1945	Total
40	40	20	20	0	120

IV. MANUFACTURE OF FLAME THROWERS.

The Japanese Army Ordnance Bureau started experimental work on flame throwers in 1918 and completed their main experiments in 1926. Work was concentrated on a portable model and a large stationary model to be emplaced in trenches. The latter was never adopted as standard equipment, but a portable model was standardized as Model M 93 in 1933 and was produced in quantity until 1940. In 1941, when the portable flame thrower was modified to the M 100, production of the M 93 was discontinued and all production concentrated on the new model. Experiments on mechanized flame throwers were conducted in the period of 1930-34. Small-scale production of Model 93, resulting from these experiments, occurred in 1938-1941. Model 96, developed in 1937, was substituted in the production of mechanized flame throwers in 1941, while all production of these terminated in 1943.

According to all sources investigated, the Japanese Army procured all flame throwers from the Tsukamoto Seiki Kabushiki Kaisha, located at No. 343, 5 Chome, Higashi Osaki, Shinagawa-ku, Tokyo. This plant employed an average of fifteen men on the production of flame throwers of all types and never more than thirty men. The estimated maximum production capacity of the plant was 200 portable flame throwers per month and 20 mechanized. Tables giving actual yearly production of the various models (based on figures supplied by the factory and supported by the Japanese Army) are given below:

Table 24.

Yearly Production of Model 93 Portable Flame Thrower.

1935	100
1936	0
1937	50
1938	500
1939	900
1940	1400
1941	400
Total	3350

Table 25.

Yearly Production of Model 100 Portable Flame Thrower.

1941	200
1942	400
1943	600
1944	1200
1945	270
Total	2670

Table 26.

Yearly Production of Model 93 Mechanized Flame Thrower

1938	8
1939	20
1940	12
1941	22
	62

Table 27

Yearly Production of Model 96 Mechanized Flame Thrower

1941	10
1942	9
1943	19
1944	0
1945	0
	38

The above is considered to be a complete report of all flame thrower production for the Japanese Army. The Japanese Navy began development of a portable flame thrower in 1945. By June of that year they had perfected a model utilizing oil, or carbon disulphide and crude rubber, as fuel. This was propelled by hydrogen released from calcium hydride reacting with water. A production schedule calling for 4000 units by the end of August was set, but actually none were manufactured before the termination of the war because of material shortages. The prospective manufacturers were the Showa Hikai Co., Kawasaki City, Kanagawa-ken, and the Daito Koku Co., Adachi-ku, Tokyo. As far as can be ascertained, this was the only flame thrower production contemplated by the Japanese Navy.

V. MANUFACTURE OF JAPANESE SMOKE MUNITIONS.

The only types of smoke munitions which have been revealed as produced in considerable quantity for the Japanese armed forces are the following: smoke pots and candles filled with HC, Berger mixture, or DC; smoke shells and bombs filled with FS, WP or DC; colored smoke shells; frangible glass grenades filled with FM, FM and $SnCl_4$ mixture, or oleum-chlorsulphonic acid; and spray tanks which could be filled with FS or FM. The Japanese Navy also produced a chlorsulphonic acid smoke generator, in which the agent was atomized from a nozzle under pressure, but the Japanese never produced a mechanical smoke generator.

Japanese smoke warfare may be summarized by Table 28, giving the best available figures on total production of agents used in smoke weapons. The figures in the third column represent an estimate based on production figures of filled munitions and are included to provide a rough check on the supply figures.

Table 28.

Production of Agents Used in Japanese Smoke Munitions

Agent	Quantity Produced, metric tons	Estimated Quantity Consumed, metric tons	Using Branch
C_2Cl_6	2,218	1,930	Army
	294	15	Navy
Total	2,512	1,945	
CCl_4	2,314	3,520	Army
Total CCl_4 + C_2Cl_6	4,826	5,465	
Zn powder	1,615	2,500	Army
	7	7	Navy
Total	1,622	2,507	
ZnO	1,329	2,500	Army
	7	7	Navy
Total	1,336	2,507	
DC	1,837	2,800	Army
	120	30	Navy*
Total	1,957	2,830	
Oleum & $ClHSO_3$	1,700	?	Navy
FS	?	45	Army
Special Rubber	10	?	Navy
WP	?	165	Army**

*Used exclusively for toxic effect.
**Used for smoke shells.

A. Army Smoke Production.

Smoke munitions for the Japanese Army were concentrated chiefly in smoke candles and smoke pots. Actually, Japanese nomenclature did not distinguish between candles and pots, but to avoid confusion in the use of tables giving production figures, candles containing larger amounts of mix than five pounds are tabulated as pots. Table 29 lists type numbers of these munitions (all as candles) with smoke agent and approximate weights of filled munition and of filler. The HC and Berger mixtures contained 50% chlorine agent and conformed with standard practice in all respects. The DC was mixed with either powdered pumice or celluloid as binder. The figures in Table 29 refer to weights of pure DC. The list does not include experimental models, or those produced in negligible quantity. The term substitute refers to training models, of lighter construction than standard models of same year. Floating candles were provided with inflating rubber rings for use in screening landing operations. The self-projecting type candles contained sufficient powder to be launched with a range reported at 200 yards.

Table 29.

Composition of Japanese Smoke Candles

Type	Agent	Filled Weight, lb	Filler Weight, lb
94 A	Berger	2 1/4	2
94 B	HC	2	1 1/2
94 Substitute	Berger	1	3/4
99 Self-projecting	HC	2 3/4	1 1/2
94 A Floating	Berger	22	17 1/2
94 B Floating	HC	16 1/2	12
94 A Large	Berger	44	40
94 B Large	HC	35	31
93, 97 Medium, Sneezing	DC	4 1/2	1
98 Medium Sneezing	DC	4 1/2	1
98 Self-projecting, sneezing	DC	1 1/2	3/5
99, 100 Self-projecting, sneezing	DC	2 1/4	2/5
99 Sneezing	DC	1	1/2
98 Large, sneezing	DC	27	9

All smoke munitions for the Japanese Army were procured and manufactured under the jurisdiction of the Second Tokyo Military Arsenal. All of the actual production of these munitions, other than smoke candles, was accomplished at the Tadanoumi or Sone Branches of this Arsenal. Some smoke candle production was let to private companies who obtained all raw materials from the Second Tokyo Military Arsenal, prepared the mix, assembled the units, and returned the completed candles to the Arsenal. The names and addresses of these production agencies appear in Table 30.

Table 30.

Producers of Smoke Munitions for the Japanese Army

Name	Address
Second Tokyo Military Arsenal	
Main Arsenal	6 Chome, Itabashi-ku, Tokyo.
Tadanoumi Branch	Tadanoumi-machi, Toyoda-gun, Hiroshima-ken
Sone Branch	Kokura-shi, Fukuoka-ken.
Kanto Electric Co., Ltd.	No. 2401 Naka-Hagino, Shibui, Oyamura, Iruma District, Saitama-ken.
Showa Gunpowder Mfg. Co.	No. 1731 Ikuta, Kawasaki, Kanagawa-ken.
Chugai Pyrotechnics Mfg. Co.	Nakadai-machi, Shimura, Itabashi-ku, Tokyo.
Dainihon Celluloid Co.	Azukizawa, Shimura, Itabashi-ku, Tokyo.
Asama Koku Mfg. Plant	Shinagawa-ku, Tokyo.

In addition to smoke candles and smoke pots, small production of smoke shells and bombs was reported at Sone Filling Plant (Sone Branch of Second Tokyo Military Arsenal), who were the only producers of this type of munition. The majority of these were filled with FS, although experimental production of undetermined quantities may also have taken place using FM and WP.

A small number of spray tanks were also manufactured for the Japanese Army Air Force which were planned for use with blistering or smoke agents. There was limited production of 28 liter brass spray tanks, chiefly prior to 1940, but these were later melted for use of the brass in shell casings. Later production was of the 80 liter type. These tanks were apparently manufactured only by the Asama Koku Manufacturing Plant.

A list of production figures of all the foregoing munitions appears as Table 31.

Table 31

Yearly Production of Smoke Munitions for Japanese Army

TYPE	PRIOR TO 1940	1940	1941	1942	1943	1944	1945	TOTAL	SOURCE
SMOKE CANDLES HC OR BERGER MIXTURE*									
Type 94 Small	543,800	55,000						598,800	Tadanoumi Arsenal
		50,000	100,000	80,000	80,000	100,000	100,000	510,000	Showa Gunpowder Wks
								200,000	Kanto Electric Wks
								800,000	Dainihon Celluloid
							Total	2,108,800	
Type 94 Substitute	73,500							73,500	Tadanoumi Arsenal
								600,000	Chugai Gunpowder Wks
								700,000	Kanto Electric Wks
								150,000	Dainihon Celluloid
								300,000	Nihon Nitrogen Gunpowder Wks
							Total	1,823,500	
Type 99 Self-Projecting	11,000*	16,600*	98,000*	201,200*	154,600*	145,500*		627,700*	Tadanoumi Arsenal
				40,000*	50,000*	70,000*	70,000*	230,000*	Showa Gunpowder Wks
								700,000*	Chugai Gunpowder Wks
								950,000*	Kanto Electric Wks
								400,000*	Dainihon Celluloid Wks
							Total	2,907,700*	
SMOKE POTS, HC OR BERGER MIXTURE									
Type 94	15,600	14,000	65,800	26,160	26,861		9,000	157,421	Tadanoumi Arsenal
Type 94 Floating	227,500	100*	80,000*	80,000*	65,970*	60,200*		513,770	Tadanoumi Arsenal
IRRITANT SMOKE CANDLES, DC									
Type 93A	547,300							547,300	Tadanoumi Arsenal

*According to one informant only that production marked with asterik utilized C_2Cl_6.

Table 31, Yearly Production of Smoke Munitions for Japanese Army (Continued)

TYPE	PRIOR TO 1940	1940	1941	1942	1943	1944	1945	TOTAL	SOURCE
				IRRITANT SMOKE CANDLES, DC					
Type 98 Melium	6,300	96,000	100,000	10,000				212,300	Tadanoumi Arsenal
Type 98, Self Projecting	144,400	63,900						208,300	Tadanoumi Arsenal
Type 99 & 100, Self Projecting								1,059,910	Tadanoumi Arsenal
Type 99	299,400	174,400	107,000	47,600	150			628,550	Tadanoumi Arsenal
				IRRITANT SMOKE POTS, DC					
Type 98 Large	300	5,000	20,300	30,000	14,000	3,044		72,644	Tadanoumi Arsenal
				SMOKE SHELLS, FS					
Type M-91 100 mm					10,910	1,790		12,700	Sone Mfg Plant
Type M-94 Mortar						5,000		5,000	Sone Mfg Plant
				SMOKE SHELLS, WP					
Type M-14 105 mm	2,460							2,460	Sone Mfg Plant
Type M-13, 150 mm	17,050							17,050	Sone Mfg Plant
Type M-90 75 mm	83,690							83,690	Sone Mfg Plant
Type M-10, Grenade	202,613							202,613	Sone Mfg Plant

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Table 31, Yearly Production of Smoke Munitions for Japanese Army (Continued)

TYPE	PRIOR TO 1940	1940	1941	1942	1943	1944	1945	TOTAL	SOURCE
IRRITANT SMOKE SHELLS, DC									
Type M-95 Mortar	44,000	97,580	360,007	91,993	58,000			641,580	Sone Mfg Plant
Type M-92 75 mm	119,600	112,300	126,360					358,260	Sone Mfg Plant
Type M-91 100 mm	9,500	16,800	32,986	24,014				83,300	Sone Mfg Plant
Type M-92 150 mm			20,622					20,622	Sone Mfg Plant
Type M-93 150 mm		4,500		13,678				18,178	Sone Mfg Plant
SMOKE BOMBS, FS									
Type M-100 50 kg					4,700	2,000		6,700	Sone Mfg Plant
IRRITANT SMOKE BOMBS, DC									
Type M-97 15 kg	1,000	2,080	185	2,000	2,770			8,035	Sone Mfg Plant
SPRAY TANKS, FOR FS OR FM									
80 liter cml tank				10	100	390	258	858	Asama Koku Mfg Plant

B. Navy Smoke Production.

The chief smoke munition used by the Japanese Navy was the Type 91 smoke generator which was mounted in the stern of all new cruisers, destroyers, torpedo boats, mine sweepers, etc., commissioned since 1931 and in older ships as they underwent major repairs. Each generator contained four smoke tanks and four storage tanks. Smoke agent was a mixture of oleum and chlorosulfonic acid. Compressed air from storage bottles at about 150 kg/cm^2 was reduced to less than 10 kg/cm^2 to provide pressure for ejection of agent, and to atomize the agent in a rotating type spray nozzle attached to each smoke tank. The total weight of the complete generator (less air bottles) was about 2,000 kg including 1,000 kg of smoke agent. No accurate figures on the number of these generators actually produced is available, but it is believed that the number was less than 500. The supply of smoke agent procured for this purpose by the Navy was approximately 1700 metric tons, of which 1500 were procured prior to 1940.

A similar type of generator, known as the 40 kg smoke box, was used as a floating smoke pot. This device contains 25 kg of oleum-chlorsulphic acid in a steel tank with a central container of 200 cc of methyl formate. To generate smoke a blasting cap at the top of the box is struck by hand. This ruptures the central container and permits the methyl formate to react with SO_3, resulting in the generation of CO gas. This provides sufficient pressure to atomize the agent.

A smoke shell utilizing metallic sodium was produced in small quantities, chiefly for training purposes. Five to eight kilograms of metallic sodium were contained in the shells, depending on the calibre (12.7 cm and 14 cm, respectively). The sodium was released above the surface of the ocean ahead of the ship and reacted with water to provide screening smoke for the ship. Only several thousand shells were produced in all.

For naval landing forces a frangible smoke grenade consisting of a spherical glass flask containing about 200 cc of FM or of oleum-chlorsulphonic acid was produced. Approximately equal numbers of these grenades were manufactured using each agent. For landing forces an 80 mm trench mortar smoke shell was also produced which utilized a smoke agent containing C_2Cl_6 and Zn mixed with Thiokol. Colored smoke shells were also produced in quantity. The composition of these smokes is given in Table 32.

Table 32.

Composition of Colored Smoke Shell Filler.

Raw Material	% Total Composition White	Yellow	Red	Blue
Potassium chlorate			23	31
Saltpeter		24		
Realgar		55		
Zinc Oxide	20			
Black Powder		3		
Milk Sugar			7	17
Sulfur		16		
Pine charcoal		1		
Zinc powder	25			
Methylene blue				30
Indigo				22
Rodhamine red			40	
Para red			30	
Carbon tetrachloride	50			
Kieselguhr	5			

Limited production of smoke candles similar in every respect to Army candles and a 30 kg smoke pot also took place. A small number of airplane spray tanks were also produced. All other weapons, including bombs and DC or other irritant smoke agents, were produced only on an experimental basis. Table 33 gives the names and addresses of the principal supply sources of the above munitions. Table 34 lists production figures of the same.

Table 33.

Producers of Smoke Munitions for the Japanese Navy.

Name	Address
Hodogaya Kagaku Kogyo Co., Ltd. Tsurumi Factory	Yokohama, Kanagawa-ken.
Sumitomo Kagaku Kogyo Co., Ltd. Osaka Factory	Kasugadecho, Konohana-ku, Osaka.
Kokohin Goshi Co.	Kawaguchi City, Saitama-ken.
Nippon Kako KK Totsuka Factory	Yokohama, Kanagawa-ken.
1st Naval Air Technical Arsenal	Yokohama, Kanagawa-ken.
Sagami Naval Arsenal	Hiratsuka, Kanagawa-ken.

Table 34.

Production of Japanese Navy Smoke Munitions

Munition	Unit	Prior to 1941	1941	1942	1943	1944 - 1945	Total	Source
Oleum & $ClHSO_3$	Metric Ton	1,500	0	0	0	160	45	1,705) (Fodoga,a KK
40 kg Smoke box	Piece	0	0	0	2,500	3,000	500	6,000) (Sumitomo KK
30 kg Smoke pot	Piece	0	1,000	2,000	2,000	0	0	5,000 Kakohin Goshi
1 kg Smoke candle	Piece	0	2,000	5,000	2,000	5,000	25,000	39,000 Kakohin Gosni
1 kg Smoke candle (self-projecting)	Piece						30,000	Kakohin Goshi
80 mm mortar shell	Piece						11,000	Kakohin Goshi
Smoke bottle	Piece	0	0	0	0	8,000	10,000	18,000 Sagami Arsenal
Colored smoke shell	Piece	0	0	5,040	2,196	11,700	9,720	28,656 Nippon Kako

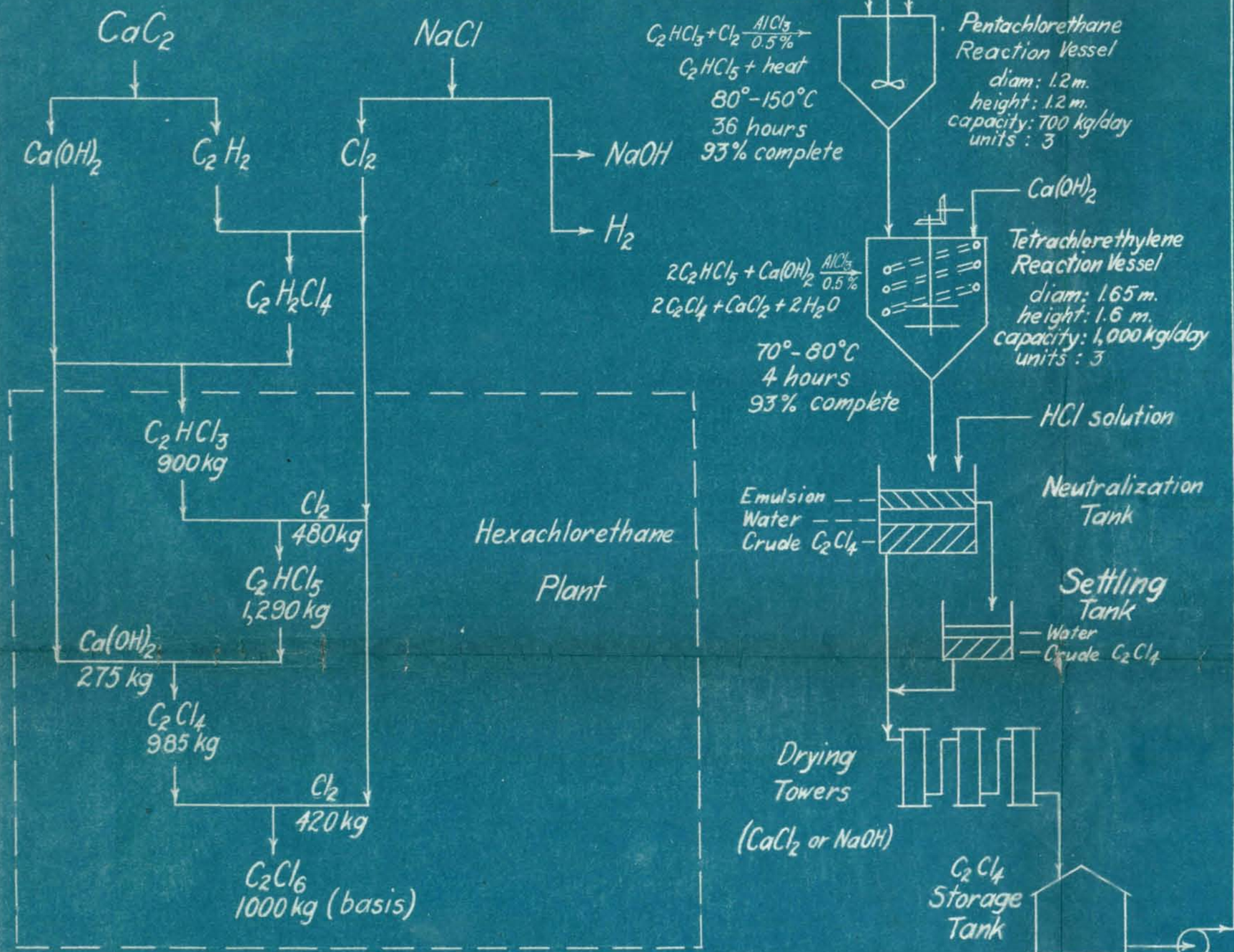
C. Manufacturing Methods.

The manufacture of the foregoing munitions conforms to ordinary practice. Most of the chemicals are common to the chemical industry, but because of the particular interest of CWS in hexachlorethane, its production and the method of mixing and filling HC is discussed below.

Commercial production of C_2Cl_6 was begun in the early 1930's at the instigation of the 6 Military Laboratory who had been conducting research on hexachlorethane with imported material obtained from the I. G. Farben Gsft. The Nihongi Plant of the Nippon Soda Co. produced a trial run of one month's production of about one ton, but the product did not meet military specifications and the production cost was ¥ 2.50/kg as compared with ¥ 1.20/kg for the German product. Production in Japan was thus on an extremely small scale until 1938, when the Japanese Army contracted to purchase the total annual production (estimated) of 240 tons from the Hokkai Soda Co., to whom Nippon Soda had transferred this problem. (The Hokkai Soda Co., was controlled by Mitsui interests which had financial connections with the Nippon Soda Co.) From April 1938 until August 1945 the Hokkai Soda Co. (now the Towa Gosei Kagaku Kogyo K. K.) produced C_2Cl_6 at an average annual rate of about 500 metric tons. This was the only appreciable Japanese source of this compound. The plant is located at No. 90 Shin-Shima, Fushiki, Takaoka-shi, Toyama-ken. Information on production was obtained from the following personnel located at the company's main office at 2-8 Tamuracho, Shiba-ku, Tokyo: Production Manager Yoshihara Miwa and Engineer Hideo Nakagawa. Almost all the production was shipped to the 2d Tokyo Military Arsenal at Tokyo (for smoke candle production by private companies) or to its Branch Arsenal at Tadanoumi.

The process used by the Hokkai Soda Co. to produce hexachlorethane is summarized on the attached flow diagram (Figure VII) which also describes the equipment. This equipment is of standard design and no special construction materials appear to have been used. Figures on the concentration and quantities of HCl and NaOH used in the neutralization of tetrachlorethylene and hexachlorethane were unavailable. Originally litmus paper was used to control the end points, but when war shortages made this no longer available the experience of the operators was relied on. According to Mr. Nakagawa they were guided by "taste, smell, and color". The finished product decomposed readily with the evolution of Cl_2. At first it was packaged in 20 kg cans, but when these were unavailable the product was packaged in cardboard boxes lined with tarred (waxed?) Kraft paper.

Flow of Materials



Process Diagram

Note: All reactions at atmospheric pressure.

Figure VII

Flow Diagram for the Production of Hexachlorethane by the Hokkai Soda Co.

Under the difficulties of wartime production considerable laxity was observed in meeting specifications of hexachlorethane. Apparently only one batch was ever rejected by the Army (for excess moisture) and this before the war. Some difficulty was met with spontaneous ignition during mixing operations at Tadanoumi Arsenal. The 6th Military Laboratory investigated this and concluded that the cause was excessive moisture in the product and recommended that a strict control of 1% moisture be instituted. Three sets of specifications were obtained, from Hokkai Soda Co., from the 2d Tokyo Arsenal, and from the 6th Military Laboratory (established for Tadanoumi Arsenal). These figures are reproduced in Table 35 and are the figures actually met in practice. Original specifications are given in parentheses, but these were relaxed because of war-time difficulties. The results of control tests on the last 10 month's production by Hokkai Soda indicate that standards remained high, however, although some individual batches did not meet the more stringent specifications.

Table 35.

Specifications of Hexachlorethane.

Specification	Hokkai Soda	2d Tokyo Arsenal	6 Military Lab. (Tadanoumi Factory)	Averaged Figures for Last 10 Months Production
% C_2Cl_6, more than:	98%(99.5%)		85% (92%)	
% available chlorine:	87%	87%		
% moisture, less than:	1%(0.1%)	0.2%	1% (0.1%)	0.015%
% ash	0.5%(0.2%)			0.10%
% free HCl, less than:	Trace	Trace	2%	0.011%
% free Cl_2, less than:			0.5%	
% $FeCl_3$, less than:		Trace		
Ignition point, lower than:	- 4° C			
Melting point, higher than:		175° C		177.3° C
Appearance:	White to light yellow crystals.			

The test for moisture established by the 6th Military Laboratory consisted of the addition of CaC_2. The volume of H_2 gas evolved was measured by bubbling into a calibrated tube at room temperature and pressure. The 2d Tokyo Arsenal seems to have relied chiefly on a test wherein C_2Cl_6 was mixed with dry Zn powder in the ratio of 2 : 1.5 at room temperature. It was specified that the temperature should not rise more than 4° C. Average temperature rise for the last 10 months production by this test was 0.64° C. Other testing procedures are not known.

The product was stored in ordinary warehouses (not air-conditioned). No evidence of special handling or surveillance was revealed. (In fact, the officer at the 2d Tokyo Arsenal who was charged with the storage of this material claimed that it was given less attention than was Portland cement.)

The procedure used in mixing the hexachlorethane with Zn and ZnO involved no elaborate technique. Both at government and private plants the material was screened through an iron sieve of about 6-8 mesh. The powder was blended either in a small ribbon blender or by hand, using paddles in a wooden trough. The HC was then rescreened and reblended. It was then filled into a candle which was placed in a mold to prevent rupture during packing (a brass tube was placed in the self-projecting types to provide space for a black powder charge). The candle was then placed in a hand press, similar to a cider press. HC was packed into the candle by this means until it conformed by weight to specification. Pressure was not accurately controlled, the operator usually just giving the hand-wheel a spin and allowing its momentum to apply the pressure to the candle. The remaining parts were then assembled, crimped, and pressed in similar equipment.

VI. PRODUCTION OF TOXIC MUNITIONS.

A. Army Bombs and Shells.

Standardized bomb and shell cases for toxic agents were made at the Osaka Arsenal, Osaka-Ken, and shipped to Sone Factory, Yoshida, Kokura City, Fujuoka Ken for filling. The following is a summary of the filling operations at this factory.

Table 36.

Production of Japanese Army Chemical Bombs and Shells.
1931 to 1945, inclusive.

Type	Filling	Munition	Quantity
95	DC	Mortar Shell	635,580
92	DC	Artillery Shell 75 mm.	393,260
95	Blister	Mortar Shell	87,566
93	DC	Artillery Shell 100 mm.	83,300
92	Blister	Artillery Shell 100 mm.	149,800
93	DC	Artillery Shell 150 mm.	18,178
92	DC	Artillery Shell 150 mm.	20,622
92	Blister	Artillery Shell 150 mm.	67,000
97	DC	Bomb 15 Kg.	9,164
97	Blister	Bomb 50 Kg.	1,574
100	Blister	Bomb 50 Kg.	5,135
Unknown	CN	Shells	33,740

Filled bombs and shells were shipped to Tadanoumi Branch, Hiroshima Army Supply Depot, Tadanoumi, Hiroshima Ken.

B. Navy Munitions.

The Navy received bomb cases for toxic bombs from the Second Air Naval Arsenal, Yokosuka. Metal gas containers for shells were made at Sakura Kokan Kogyo, Sakura, Chiba-Ken; Nihon Kokan Kogyo, Tokyo; and Daito Koku Kogyo, Tokyo. These containers were filled and stored to prevent tie-up of large numbers of shell cases. The following is a summary of Navy filling at Samukawa Branch of Sagami Arsenal:

Table 37.

Production of Japanese Navy Chemical Munitions.

Filling	Munition	1941	1942	1943	1944	1945	Total
Blister	Gas can for 12 cm. shell	7,000	3,000	0	0	0	10,000
Blister	Gas can for 12.7 cm.shell	5,000	4,000	0	0	0	9,000
Blister	Gas can for 14 cm. shell	4,000	3,000	0	0	0	7,000
Blister	Gas can for 15 cm. shell	3,000	4,000	0	0	0	7,000
DC	# 1 M 2 Bomb 60 Kg.	0	2,000	0	0	0	2,000
Blister	Bomb 60 Kg	0	0	0	35,000	600	35,600

VII. PRODUCTION OF JAPANESE INCENDIARY MUNITIONS.

Production of incendiary munitions was carried on in very small scale during the war. They were considered less important than HE munitions, which had highest priority throughout the war although requirements were rarely met. It has been possible to obtain a relatively complete report on Japanese Navy production of incendiary bombs (the only incendiary munition produced by this branch). Japanese Army production figures are only approximate, since actual records were destroyed and those officers who were responsible for requisition and production appear to be ill-informed regarding these munitions. Investigation of these munitions was the responsibility of Air Technical Intelligence Group, FEAF, and will be reported by that organization.

A. Japanese Army Production.

The Japanese Air Force received incendiary munitions from the Sone Filling Plant of the 2d Tokyo Military Arsenal. Responsible officers of both the Air Force and Army Ordnance Departments have stated that all incendiary munitions used by either branch were produced at this plant. Production figures on these munitions were obtained by the Air Technical Intelligence Group, Advanced Echelon, FEAF, and appear in their report No. 175, dated 29 November 1945. (Copies of this report are available from Air Documents Division, T-2, Wright Field, Dayton, Ohio.) The following table is reproduced from that report:

Table 38.

Production of Incendiary Munitions, Sone Factory

Type	1938	1939	1940	1941	1942	1943	1944	1945	Total
1. M-94 Mortar shell*	8,000								8,00
2. 75 mm shell*			16,900	227		500			17,66
3. Hand grenade *			20,000	56,000		3,726			79,72
4. M-100, 50 Kg. bomb*	500		13,396	30,000	16,000	10,000	1,790	1,796	73,48

*Incendiary mixtures were either (1) Oil and rubber pellets (2) phosphorus and Carbon disulfide or (3) phosphorus, Carbon disulfide, and rubber pellets.

B. Japanese Navy Production.

The Japanese Navy produced incendiary bombs at two plants only, the 1st Naval (Air) Technical Arsenal (Target No. CW5008) and the Tagajo Naval Arsenal (Target No. CW5003). These arsenals produced five types of incendiary bombs. Production figures and description of the bombs are included in the following tables:

Table 39.

Production of Japanese Navy Incendiary Bombs

Type	1941	1942	1943	1944	1945	Total
Type 99, No. 3, Mk 3						
1st Naval Technical Arsenal			1,510	15,700	700	17,910
Tagajo Naval Arsenal				8,100	14,530	22,630
						40,540
Type 1, No. 7, Mk 6						
1st Naval Technical Arsenal		200	21,120	8,240		29,560
Tagajo Naval Arsenal				15,800	6,525	22,325
						51,885
Type 2, No. 25, Mk 3						
1st Naval Technical Arsenal			1,150	2,610		3,760
Tagajo Naval Arsenal			1,450	6,500	2,940	10,890
						14,650
Type 3, No. 6, Mk 3						
1st Naval Technical Arsenal				7,100	24,850	31,950
Type 3, No. 6, Mk 27						
1st Naval Technical Arsenal				130	3,850	3,980

Table 40.

Description of Japanese Navy Incendiary Bombs

Type	Filling	Wt of Bomb, kg	Wt of filler, kg(approximate)	Number of pellets	For attack of:
Type 99, No. 3, Mk 3	WP	33.72 ± 1.5	4	144	Aircraft
Type 1, No. 7, Mk 6	Rubber-Thermit	17.1 ± 3.0	5	180	Houses, Forests, etc.
Type 2, No. 25, Mk 3					
I-A	WP	246.0 ± 5.0	50	780	Airfields
2		251.8 ± 3	56	1086	Airfields & Aircraft formations
Type 3, No. 6, Mk 3	WP	56.6	14	144	Aircraft
Type 3, No. 6, Mk 27 (Rocket bomb)	WP	60	4	135	Aircraft

VIII. DISCUSSION.

In view of the fact that the Japanese had no centralized chemical warfare agency in either branch of service, it was necessary to collate information from various sources in the preparation of this report. These sources included members of Japanese Army, Navy, and Air Ordnance Bureaus who were responsible for the production of items of interest to CW; productive facilities, military and civilian; and military research organizations, whose personnel were frequently found to be well-informed on matters of production.

Throughout the investigation much information of conflicting or inconsistent nature was collected. It is believed that this was generally the result of the poor records kept by the Japanese and the fact that many records were destroyed, either by bombing or by order of the Japanese War Ministry (dated 15 August 1945). Actually it was only in rare instances that original records were supplied to the investigators and it was necessary to rely in large part on the memory (and integrity) of interrogated individuals. It was possible roughly to ascertain the reliability of the data by cross-checking information from various sources. No discrepancies of disturbing magnitude were discovered by this method, but in many instances it was necessary for the investigators to exercise careful judgment. No deliberate attempt to give false information was discovered in any of the sources investigated, but it is felt that some officers interrogated preferred to guess at answers than to admit ignorance of facts and other information within the scope of their responsibilities during the war.

Whereever possible, such inconsistencies as arose during the course of the investigation were clarified by demanding more complete information from the sources involved. Frequently, however, where lack of adequate records made this impossible, as indicated above, it was necessary to rely on the judgment of the investigator to select the most reliable data. In consideration of these facts, the figures in the foregoing text are believed to represent only the correct order of magnitude in all cases, but beyond that their accuracy cannot be vouched for.

In view of the small scale and technological inferiority of Japanese production of chemical warfare materiel, it was not considered that the time required for more thorough investigation would be fruitfully spent, or that any further information of value would accrue. Experts sent to this Theater from chemical arsenals in the United States corroborated in this opinion, following their visit to the major Japanese arsenals.

IX. CONCLUSIONS.

1. The production of chemical warfare materiel by the Japanese was inadequate for waging offensive gas warfare on a modern scale.

2. The production of defensive materiel by the Japanese was not of sufficient size to have sustained continued, large-scale gas warfare.

3. The production methods in general use by the Japanese for the manufacture of chemical warfare materiel are not so far advanced as those in the United States.

4. No further investigation of facilities for the manufacture of chemical warfare materiel is necessary.

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