VI. PRODUCTION PROCESSES

A. ALUMINA PRODUCTION

The two processes known to be used currently by the enemy — Modified Pedersen Process and Soda-Lime-Sinter Process—are graphically described in the accompanying flow charts No. 2 and 3.

In each case the primary objective (critical point) has been selected to meet the following requirements:

(a) A point in the process whose destruction or immobilization will stop production in the entire plant.

(b) The point in the process whose equipment will require the longest period to repair or replace.

(c) With due consideration to (a) and (b) above, a point that is readily susceptible to damage or destruction by bombing.

(1) *Modified Pedersen Process:* The most important steps or equipment in the Pedersen process plant, in the order of their importance, are as follows: electric furnaces, rotary kilns, solution tanks, refining troughs and precipitators, and steam plant.

Only one plant, that at Fushun, Manchuria (Target 93:3-32), is known to be equipped for the Pedersen Process. It is possible, however, that subsequent intelligence may disclose that this process is in use in the plants at Antung, Manchuria (Target 93:2-200), and at the new Changtien plant of the North China Light Metals Co., now under construction in Shantung.

The electric furnaces at the Fushun Plant are installed in buildings believed to be reinforced concrete including roofs (Bldgs 30 and 35). If electric furnaces are found at other plants they also will probably be housed in similar substantially constructed buildings. The types of housing the rotary kilns, solution tanks, refining troughs and precipitators, and steam plant are not important to the process and various types may be found. The solution tanks, refining troughs and precipitators require relatively large buildings. The rotary kilns may be partly exposed.

The primary objectives in a Pedersen process plant are the electric furnaces, which, in the Fushun plant, are in batteries of 8 and 12, in single rows in buildings about 240 ft and 385 ft in length respectively. The individual furnaces are necessarily large in order to handle the large bulk of raw materials, which, in this plant, is estimated at 24,000 metric tons per month.

Large furnaces are usually spaced about 15 ft apart. Based on this spacing and the air photography of the Fushun plant the outside dimensions of the furnaces are about 16 by 20 ft. Their height is not known but is probably about 18 ft overall. Such furnaces are built of fire brick on a steel frame and have a lining which must be resistant chemically to the materials with which the furnace is to be charged. The total thickness of the furnace walls is estimated at about 16 in. For the purpose used the furnaces would operate at a temperature of about 2500°F.

Partial damage to or destruction of the furnace buildings would not stop production in the entire plant as it is believed that undamaged furnaces could continue to operate at a proportionately reduced rate. Total destruction of the transformers would stop production in the furnaces and in the entire plant but it is believed that the Japanese could replace the stepdown transformers fairly quickly.

(2) *Soda-Lime-Sinter Process.* The most important steps or equipment in a Lime-Sinter process plant are the rotary kilns and then in their probable order of importance: the hoppers, conveyors, etc., for handling raw materials; the leaching, filtering and clarifying tanks; the precipitators; and the boiler plant.

The rotary kilns are usually housed in a large building with a ventilated, non-combustible roof supported on a light steel frame, but may be partly exposed. Stacks may be present, but are not always visible, at one end of the kilns. The other equipment in a lime-sinter process plant can be housed in almost any type of building. Those housing the leaching and filtering tanks and precipitators are relatively large.

The primary objectives in a lime-sinter process plant are the rotary kilns. These are large, heavy equipment, usually larger than the kilns used in a Bayer process plant. The individual kilns vary from 6 to 11 ft in diameter and from 60 to 500 ft in length—average length about 300 feet. They are constructed of steel boiler plate about 3/4 in thick and are lined with fire brick. They are equipped with 2 to 6 steel tires, the number depending on the length of the kiln. The thickness of the steel at and near the points where the tires are attached is built up to about 2 inches.

B. ALUMINUM REDUCTION

1. Soderberg Process

Only one process is in use for the production of aluminum—electrolytic reduction of alumina with Soderberg electrodes. Electrolytic reduction is the only process that has been developed successfully for commercial use anywhere. The process as used by the Japanese—spoken of as the Soderberg process—differs from the older electrolytic process only in the type of electrodes used. The process is graphically described in accompanying Flow Chart No. 1.

The process consists of dissolving the alumina in a molten bath of synthetic cryolite in the electrolytic pot and electrolyzing it with direct current at 32,000 amperes and about 4.75 volts per pot, the current passing from the Soderberg anode to the carbon lining of the pot which serves as the cathode. The molten aluminum is drawn or syphoned off periodically from the bottom. In the larger Japanese plants the pots are connected in series in "lines" of 132 pots and the direct current is fed to the line at 32,000 amperes, 700 volts. The heat generated by the high amperage current supplied by the mercury-arc rectifiers keeps the electrolyte molten.

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The primary or most essential buildings and equipment in an aluminum reduction plant are the pot rooms, housing the electrolytic pots, the rectifier building, housing the mercury-arc rectifiers and (in Japanese practice) the rectifier transformers, and the open transformer yard, which includes the stepdown transformers, circuit breakers and usually a skeleton steel framework to support the wires, cables and bus bars.

These primary buildings in every aluminum plant will be found in the same arrangement (see accompanying sketch of *Typical Japanese Aluminum Plant Ground Plan*—Illustration No. P1). The rectifier building, which is the primary objective in all aluminum plants, will be found at one end of the long parallel and easily recognized pot rooms, between the pot rooms and the open transformer yard as illustrated in sketch. This should make it possible to locate the primary objective from the air in plants that may not be covered by air photography. In certain of the larger plants this entire installation may be duplicated (see air photography of plants at Fushun, Manchuria, and Niigata, Honshu).

2. Layout

(a) *Pot Rooms.* The pot rooms invariably are large, long, one-story buildings from 70 to 180 ft in width and from 475 to 600 ft long, usually built on a steel frame and with monitor or saw-toothed roofs for the necessary ventilation (see Illustration P2). Usually there are two but there may be 3 or 4 pot rooms in a group (see air photography of the plants at Kambara and Niigata, Honshu. They are always built parallel to each other within the group and from 50 to 60 ft apart.

(b) *Rectifier Buildings.* Rectifier buildings are long and narrow, averaging 65 to 70 ft in width. Their length approximates the total overall width of the pot rooms which they serve, and will probably average about 300 ft (at the plant at Kambara, Honshu, there are 2 rectifier buildings approximately in line serving the 4 parallel pot rooms). All Japanese rectifier buildings will probably prove to be two-story buildings. Those more recently built are probably of reinforced concrete construction including the roof. Rectifier buildings in the older plants do not necessarily have concrete roofs, but even these will probably have a reinforced concrete second floor because of the weight that must be carried thereon. The distance between the rectifier building and the pot rooms ("a" in sketch of typical plant, Illustration P1) is necessarily short. It varies from adjoining to a maximum of about 25 ft. Thus an attack on either part of the installation may be expected to damage the other. One or at most two rectifier buildings will be found at each aluminum plant.

(c) *Transformer Yard.* The distance between the rectifier building and the open transformer yard ("b" in sketch of typical plant, Illustration P1) varies from adjacent to a maximum of about 50-ft. The transformer yard is easily recognizable by the large step-down transformers and circuit breaking equipment, usually be a large skeleton steel structure for supporting wires, cables and bus bars, and by the power line leading thereto.

3. Production Time

The average time required by the enemy to produce aluminum ingot from alumina, including shipment to the fabricating plant is estimated at about one month.

4. Vital Facilities

The vital facilities in any aluminum plant are the mercury-arc rectifiers and the rectifier transformers housed in the rectifier building. Both of these types of equipment are essential to the production of aluminum. Production in any plant would cease immediately if 60 percent or more of the installed units of either type ceased to function. Both types of equipment are easily damaged and both require a long period to replace. This period would increase progressively in the event of a concerted attack as the number of required replacements increased.

The mercury-arc rectifiers are in a single row on the second floor of the two-story rectifier buildings. They are large but delicately adjusted units of industrial electronic equipment whose purpose in the aluminum plant is to convert multi-phase alternating current into a smooth flow of direct current at high amperage. The operating weight of each unit, including water, is from 8 to 15 tons. Mercury-arc rectifiers have no moving parts except the accessory vacuum and water pumps. Their operation is based on the fact that mercury vapor conducts electricity only in one direction between the graphite anodes and the mercury-pool cathode.

A mercury-arc rectifier, of the type known to be in use in the Japanese aluminum industry, consists essentially of a large cylindrical steel tank, from 6 to 8 ft in diameter and from 4 to 6 ft in height, in which are inserted from 12 to 18 graphite anodes and a single mercury pool cathode, and in which is maintained an atmosphere of mercury vapor in a very high vacuum. The side walls of the inner (vacuum) tank are of rolled boiler plate from 0.25 to 0.315 in thick. The side walls of the outer tank (water jacket) are of rolled boiler plate from 0.2 to 0.25 in thick. The openings in the inner (vacuum) tank where the anodes, excitation anodes, starting anode, and cathode are inserted must be insulated, usually with ceramic bushings, and must be sealed perfectly against the vacuum. These are critical points for damage to the rectifier. Rectifiers are insulated from the floor and are either mounted on ceramic insulators which may be lightly bolted to the floor, or on wheels, as in the Siemens-Schuckert type, which may be of phenolic plastic and serve as insulators.

The largest mercury-arc rectifiers known to be in use in the Japanese Aluminum industry (see the photo of installation in Kambara Plane—Target 90:18-1177 in Illustration P2 and the diagram D1, and also Illustration P3) are exact copies of the German Siemens-Schuckert type and are believed to be exact copies of Siemens-Schuckert model VD10010, on which detailed Siemens-Schuckert construction drawings are available.

The following pertinent facts and specifications are for this model:

Capacity	8,000 amperes or 5,600 K.W.
Anodes	18
Overall height	10.4 ft
Outside diameter	8.9 ft
Operating weight, including water for cooling	14.88 short tons
Weight without water	12.12 short tons
Mounted on 10 inch solid wheels (Possibly phenolic plastic for insulation)	
Inner (vacuum) tank	
diameter	8 ft. 3 in.
height	6 ft
capacity	307.6 cu. ft.
side walls, rolled steel plate	0.315 in.
Outer tank (water jacket) side walls, rolled steel plate	0.2 in.

The multi-phase rectifier transformers are in a single row on the ground floor of the two-story rectifier buildings. They are large units with complex windings (see Illustration P4) whose purpose in the aluminum plant is to furnish alternating current to the rectifiers at the proper voltage (in Japanese practice usually 700 volts) and in the proper number of phases (normally 6). In Japanese practice each transformer furnishes the power to a single rectifier.

Specifications of Japanese rectifier transformers are not available but pertinent specifications of a comparable American transformer are as follows:

Output rating—6 phase, 8,000 amperes, 700 volts
For operation from: 13,200 Volts, 3 phase, 60 cycle power
Tanks made from boiler plate, 7/16" thick

Weights per transformer:	
Core and coils	25,000 lbs
Tank and fittings	27,000 lbs
Oil	24,000 lbs
Total Weight	76,000 lbs

C. ALUMINUM ALLOY SHEET ROLLING

The production of rolled sheet from the ingot can be divided into five principal steps:

First, the alloying of the metal and the production of alloy ingots.

Second, the reheating of the ingots in heating furnaces and rolling them into slabs on a slabbing mill.

Third, reheating the slabs in special furnaces and rolling them into plate by several passes on a hot mill.

Fourth, rolling the plate into sheet by a number of passes on cold mills. This involves one or more steps of heat treatment in annealing furnaces depending on the alloy used and the difference in thickness between the plate and the sheet being produced.

Fifth, final heat treatment in special furnaces in which the heat must be controlled within close limits.

This describes the process as it is probably in use in all of the smaller Japanese plants where the rolling is done on simply installed hand-fed rolling mills.

In the four largest mills (those at Nagoya, 90:20-2040; Kiyotaki, 90:13-811; Osaka, 90:25-263A; and Chofu, 90:34-1845), while the process is essentially the same, the third and fourth steps are more complex. Here the third step is probably accomplished by one or more reversing hot plate mills with reversing feed tables on both sides, which feed the plate automatically to the mill in both directions. The fourth step is accomplished by installing the cold mills in tandem so that the metal being processed can be fed to a battery of mills in long strips and is fed from one mill to the next in line automatically thus eliminating the hand-feeding. Tandem mills operate at higher speed and production is greatly increased over that of the same number of mills simply installed for hand-feeding. The installation of tandem mills involves complex electrical wiring, installed in conduits under the concrete floor, and complex electrical equipment to carefully adjust control of the speed of the several mills forming a tandem battery. Also additional essential equipment is involved such as power-driven runout tables and coiling machines (more easily damaged than the rolling mills) and more and larger heat-treating furnaces to handle the greater production. These four plants are therefore more susceptible to air attack than the smaller plants where the rolling mills are installed simply for hand-feeding.

VII. PHYSICAL VULNERABILITY AND WEAPON RECOMMENDATIONS

A. ALUMINA PLANTS

Alumina manufacturing machinery is only moderately vulnerable to HE. Blast is not very effective and damage mostly results from direct hits or from shock and fragments from very near misses. Primary objectives in the two usual processes are all about equally vulnerable and can best be damaged by direct hits of medium-sized HE bombs, which are also efficient in creating damage to mechanical conveyors on which the movement of bulky materials depends.

Buildings are usually of light framed construction of HE vulnerability classification V4 (as defined in memorandum M-8), and serving merely as cover for the equipment. Damage to equipment, which is of medium weight, is therefore the criterion for weapon and fuze selection.

Neither buildings nor equipment are readily combustible and the use of incendiaries is not recommended. For specific HE weapon and fuze recommendations, refer to memorandum M-8 and to individual Target Information and Weapon Recommendation Sheets.

B. ALUMINUM REDUCTION PLANTS

The mercury-arc rectifiers and rectifier transformers are both easily damaged by HE bombs. All other equipment is less vulnerable, besides being fairly easy to replace if damaged.

The rectifiers are large but delicately adjusted industrial electronic units. Any shock damaging one or more of the numerous insulated vacuum seals causes a rectifier to cease to function. Any damage resulting from warping or bending the side wall of the inner (vacuum) tank can probably not be repaired because of the difficulty of restoring the vacuum seal between the main body of the tank and the anode plate.

Contrary to U. S. practice in which rectifier transformers are installed in a row outside the rectifier building, Japanese practice, as exemplified in all known plants, places them on the first floor of a two-story building with the rectifiers on the second floor. The transformer coils operate in a bath of highly refined light oil—a large volume of oil in a typical installation containing a number of transformers—at a temperature high enough to make the oil readily inflammable. A high explosive bomb capable of rupturing the oil radiators and of igniting the released contents is recommended. (For a more detailed discussion of transformers see the General Analysis of Basic Services and Utilities—Electric Power.)

Buildings housing rectifiers and their transformers are usually two-story fire-resistant structures of HE vulnerability classification V1 or occasionally V3. They are usually 65 to 70 feet wide and about 300 feet long. Pot-room buildings are invariably large, long, one-story structures from 70 to 180 feet wide and from 475 to 600 feet long, usually steel-framed, noncombustible, and in HE vulnerability class V4. Other plant buildings are mostly one-story, class V4, noncombustible, with perhaps a sprinkling of class V2 buildings.

Buildings and contents are relatively invulnerable to incendiary attack. For specific recommendations as to weapons and fuzing, refer to memorandum M-8 and to individual Target Information and Weapon Recommendation Sheets.

C. ALUMINUM ROLLING MILLS

Aluminum rolling equipment consists principally of large and heavy machines for the actual rolling operation, and furnaces for heat treatment. Like similar equipment in steel mills it is not very vulnerable either to direct HE effect or to structural debris. Most of the machinery is electrically operated, however, and damage to the motors and to the electrical distribution system effectively stops production, at least temporarily. In modern plants electrical distribution is likely to be effected through very complex wiring in underfloor conduit, which is at least moderately vulnerable to HE bombs fuzed for floor penetration.

Primary buildings are usually large and high (30 to 40 feet to eaves) one-story steel-framed buildings with traveling cranes, and with lightweight noncombustible roofing; HE vulnerability classification is V2. Other buildings are similar or, if without cranes, in class V4. Except for providing craneways the buildings serve merely as cover for the equipment and in themselves are relatively unimportant.

Buildings and contents are of low combustibility and unsuitable for incendiary attack. For specific weapon and fuzing recommendations refer to memorandum M-8 and to individual Target Information and Weapon Recommendation Sheets.

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MAPS & TABLES

BASIC PROCESSING INDUSTRIES

NON-FERROUS METALS

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SHEET NFM-M1
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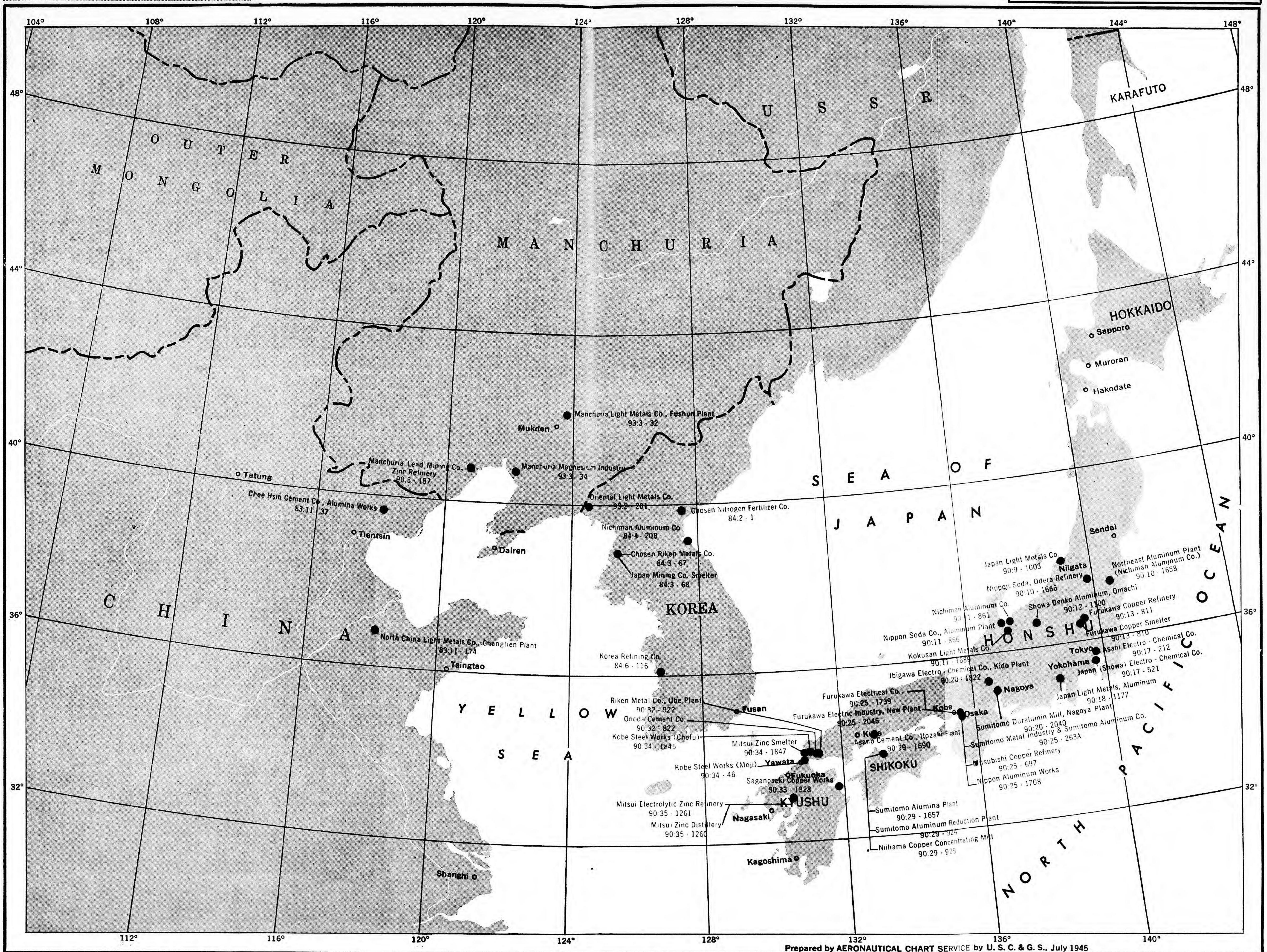

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BASIC PROCESSING INDUSTRIES — NON-FERROUS METALS (ALUMINUM)

TABLE II

Estimated Current Annual Capacity and Production of Japanese Aluminum and Alumina Plants as of June 1945 Arranged According to Aluminum Capacity In Metric Tons

Target No.	Company	Location	Coordinates North	Coordinates East	Aluminum Capacity	Percent of Total	Aluminum Production	Percent of Total	Alumina Capacity	Percent of Total	Alumina Production	Percent of Total
90:18-1177	Japan Light Metals Aluminum Plant	Kambara, Honshu	35°07′	138°37′	40,000	16.3	35,000	19.2				
93:2-201	Oriental Light Metals Co.	Yoshi, Korea	39°59′	124°28′	40,000	16.3	18,000	10.0				
90:9-1003	Japan Light Metals Co.	Niigata, Honshu	37°54′	139°03′	30,000	12.2	18,000	10.0				
90:29-924	Sumitomo Aluminum Reduction Plant	Niihama, Shikoku	33°58′	133°17′	20,000	8.2	15,000	8.3				
93:3-32	Manchuria Light Metals (Aluminum) Mfr. Co.	Fushun, Manchuria	41°50′	123°47′	18,000	7.4	18,000	10.0	48,000	10.9	48,000	11.4
93:2-200	*Manchuria Light Metals Co.	Antung, Manchuria	40°07′	124°23′	18,000	7.4	10,000	5.5	24,000	5.4	24,000	5.7
90:12-1100	*Showa Denko Aluminum, Omachi	Omachi, Honshu	36°29′	137°51′	12,000	4.9	9,000	5.0	8,000[1]	1.8	2,400	.6
84:2-1	Chosen Nitrogen Fertilizer Co.	Konan, Korea	39°50′	127°38′	10,000	4.1	10,000	5.5	24,000	5.4	24,000	5.7
84:3-67	Chosen Riken Metals Co.	Chinnampo, Korea	38°43′	125°23′	10,000	4.1	10,000	5.5	20,000	4.4	20,000	4.8
90:10-1658	Northeast Aluminum Plant (Nichiman Aluminum Co.)	Koriyama, Honshu	37°24′	140°24′	10,000	4.1	4,000	2.2				
90:11-861	*Nichiman Aluminum Co.	Higashi Iwase, Honshu	36°45′	137°14′	8,000	3.3	8,000	4.4	20,000	4.4	20,000	4.8
90:11-866	*Nippon Soda Co., Aluminum Plant	Takaoka, Honshu	36°46′	137°01′	8,000	3.3	8,000	4.4	14,000[1]	3.1	4,200	1.0
90:11-1689	*Kokusan Light Metals Co., Sasazu Plant	Sasazu, Honshu	36°34′	137°13′	6,000	2.4	6,000	3.3				
90:20-1822	*Ibigawa Electro-Chemical Co., Kido Plant	Ogaki, Honshu	35°22′	136°37′	6,000	2.4	4,000	2.2				
90:5-1557	*Nitto Chemical Co.	Hachinohe, Honshu	40°32′	141°31′	4,000	1.6	4,000	2.2	10,000[1]	2.2	3,000	.7
90:25-1726	Osaka Ceramic Industry Cement Co.	Osaka, Honshu	34°38′	135°28′	2,000	.8	2,000	1.1				
90:17-2034	Nasu Aluminum Co.	Tokyo, Honshu	35°42′	139°45′	1,500	.6	1,500	.8				
84:4-208	*Nichiman Aluminum Co.	Genzan, Korea	39°10′	127°26′	1,500	.6	1,500	.8	3,000	.7	3,000	.7
90:32-822	Onodo Cement Co.	Onoda, Honshu	33°58′	131°10′					100,000	22.5	100,000	23.7
90:29-1690	Asano Cement Co.	Itozaki, Honshu	34°23′	133°07′					64,000	14.8	64,000	15.3
	Chi Hsin Cement Co.	Tangshan, China	39°38′	118°11′					50,000	11.2	50,000	11.7
90:29-1659	Sumitomo Alumina Plant	Niihama, Shikoku	33°58′	133°16′					20,000	4.4	20,000	4.8
90:7-1759	*Kokusan Light Metals	Kurosawajiri, Honshu	39°17′	141°07′					20,000	4.4	20,000	4.8
90:17-521	Showa Electro-Chemical Co.	Yokohama, Honshu	35°29′	139°40′					16,000	3.6	16,000	3.8
90:27-1648	Asada Alumina Plants	Shikama, Honshu	34°48′	134°41′					3,000	.7	3,000	.7
					245,000	100.0	182,000	100.0	444,000	100.0	421,600	100.0

*No available photo cover, June 1, 1945.

[1]Plants reported as Bayer-process plants Jan. 1, 1945 but on which ground information is not certain enough to warrant exclusion from current alumina capacity.

BASIC PROCESSING INDUSTRIES — NON-FERROUS METALS (ALUMINUM)

TABLE III

Japanese Aluminum Alloy Sheet Rolling Capacity
Estimated as of 1 June 1945

Target No.	Name	Location	Coordinates	Annual Capacity (lbs)	%
90:13-811	Furukawa Copper Refinery	Kiyotaki, Honshu	36°44′N, 139°33′E	40,000,000	22.8
90:20-2040	Sumitomo Duralumin Mill	Nagoya, Honshu	35°06′N, 136°55′E	40,000,000	22.8
90:34-1845	Kobe Steel Works	Chofu, Honshu	34°00′N, 131°00′E	36,000,000	20.6
90:25-263A	Sumitomo Metal Industry Co., and Sumitomo Aluminum Co.	Osaka, Honshu	34°40′N, 135°26′E	30,000,000	17.1
90:34-46	Kobe Steel Works	Moji, Kyushu	33°55′N, 130°57′E	10,000,000	5.7
90:25-2046	Furukawa Electric Industry, New Plant	Amagasaki, Honshu	34°42′N, 135°24′E	5,000,000	2.9
90:25-1708	Nippon Aluminum Works	Osaka, Honshu	34°44′N, 135°30′E	2,000,000	1.2
	OTHERS			12,000,000	6.9
84-2-1	Chosen Nitrogen Fertilizer Co.	Konan, Korea		?	?
90:25-1739	Furukawa Electrical Co. and others	Amagasaki, Honshu	34°42′N, 135°25′E	?	?
	TOTAL			175,000,000	100.0

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GENERAL LOCATION MAP

BASIC PROCESSING INDUSTRIES

COKE-IRON & STEEL

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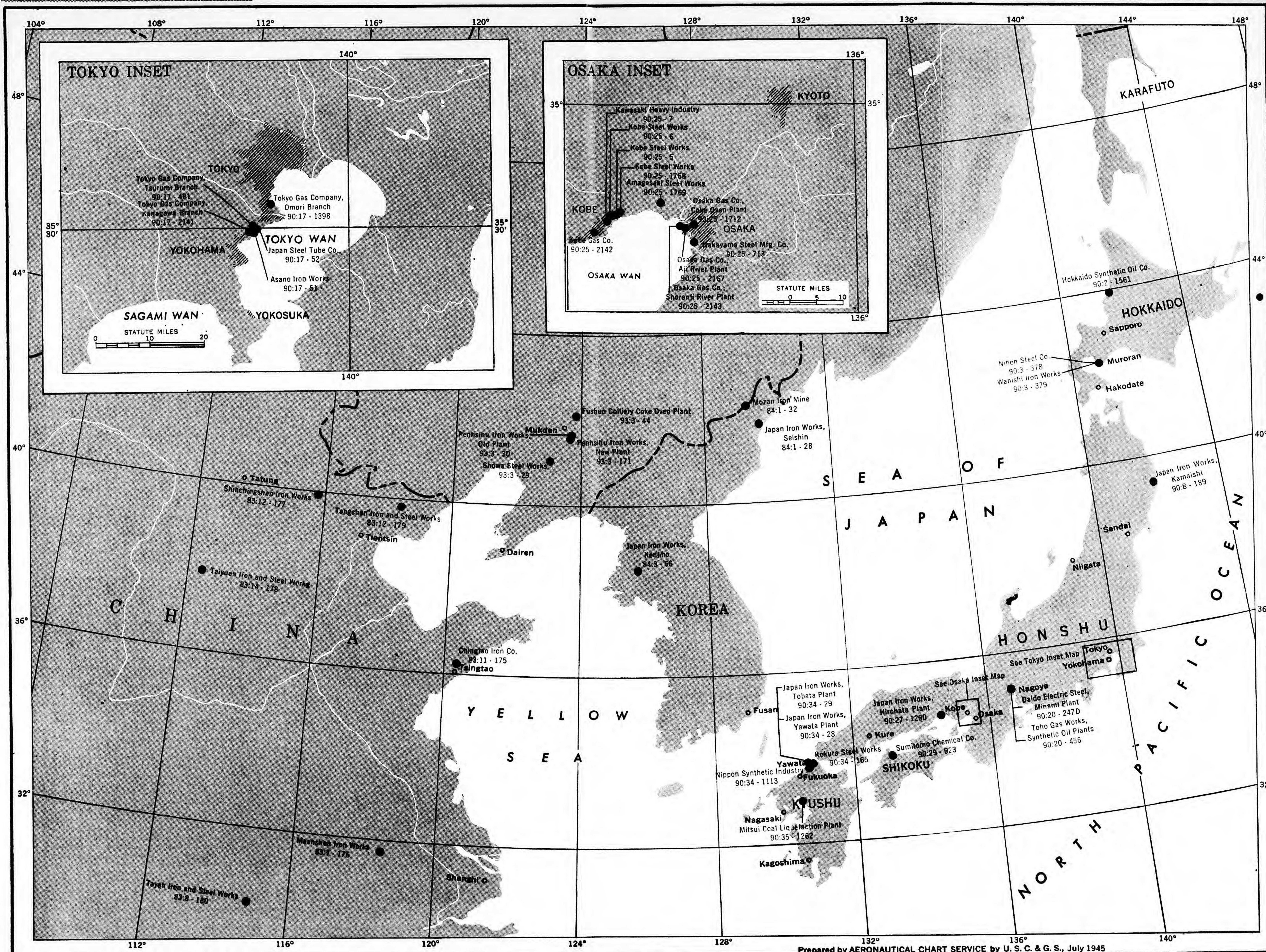

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GENERAL ANALYSIS

C
CHEMICALS
11 June 1945

BASIC PROCESSING INDUSTRIES
CHEMICALS

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BASIC PROCESSING INDUSTRIES—CHEMICALS

INDEX

I. CURRENT STATUS AND DEVELOPMENTS

(1 June 1945)

A. SUPPLY AND REQUIREMENTS

There are no notable changes from the enemy position described in subsequent sections of this study.

B. EFFECTS OF AIR ATTACKS TO DATE

A number of chemical and chemical equipment plants have received various degrees of damage in attacks up to early June 1945 but for the most part they are relatively minor factories.

The Hodogaya Chemical Industries Company plant at Hodogaya (Target 90:10-2025), reportedly an important producer of tetra ethyl lead, received nearly 60% roof damage in a precision attack during April. An unidentified chemical plant of unknown function in the same city received nearly 3/4 roof damage.

One of Japan's largest producers of carbon electrodes—the Nippon Carbon Co. Factory No. 1 at Yokohama (Target 90:17-499)—was 90% destroyed on 31 May. There is insufficient basis for assessing the effects of this attack but it is presumed that some shortage of electrodes for various electrolytic processes will result.

The Japan Dyestuffs Plant at Osaka (Target 90:25-1733) has been reported damaged but details are not yet available. This is the outstanding dyestuffs plant in Japan, accounting for about 45% of total capacity.

Several other plants of lesser importance have received both minor and serious damage. These include several glycerine, dyestuffs, nitrogen, and plastics factories. A number of city gas manufacture and storage plants have received damage.

Although no detailed assessment of these attacks is yet available, there is no reason to believe that the cumulative damage to chemical plants to date will have serious repercussions on Japan's military strength.

C. CURRENT PRINCIPAL TARGETS

The list of targets in Table II represents the most important current targets in the chemical industry except that further details on damage to Target 90:25-1733 may warrant its removal. When additional damage to the industry has occurred, Table I will be issued presenting a revised listing of remaining principal targets.

II. RELATION TO MILITARY STRENGTH

A. TYPES AND USES OF CHEMICALS

1. Main Types

The basic chemicals are heavy acids (sulphuric, nitric, and hydrochloric); alkalies (soda ash and caustic soda); commercial gases (hydrogen and chlorine); coal-tar products such as benzene, toluene, phenol, naphthalene, etc.; ammonia, industrial alcohol and solvents; and nitrogenous fertilizers (ammonium sulphate and calcium cyanamide).

2. Military Uses

The chief military uses of chemicals are for explosives, chemical warfare and armament metallurgy.

a. Explosives—The most commonly used explosives, in order of importance to Japan, are:
Picric acid,
Smokeless powder (nitrocellulose),
T.N.T.,
R.D.X.,
Nitroglycerine

The chemicals from which these explosives are manufactured are the products of several chemical-producing industries, the most important ones being nitrogen fixation and coal carbonization. Nitrogen is a constituent of nearly every explosive and enters into the ones mentioned above in the form of nitric acid. Nitric acid is usually obtained from synthetic ammonia. The coal-tar derivatives, phenol (carbolic acid) and toluene, are important constituents of picric acid (trinitrophenol) and TNT (trinitrotoluol) respectively.

Important chemicals provided by other industries are:

(1) Sulphuric acid, which is combined with phenol before the solution is nitrated to form picric acid;
(2) Caustic soda, which is used to reduce wood pulp to cellulose;
(3) Cellulose, which is nitrated to produce smokeless powder (nitrocellulose);
(4) Formaldehyde, which is used in combination with ammonia and nitric acid to produce R.D.X.;
(5) Glycerine, which is nitrated to produce nitroglycerine.

b. Chemical Warfare — The term chemical warfare includes toxic gases, decontaminating agents, and smoke-producing substances. Chlorine is widely used in this field, serving as an important constituent in many poison gases, in most decontaminating agents used to counteract poison gases, and in some smoke-producing substances. Sulphur is a constituent of mustard gas and of the fuming acid types of smoke. Cyanide gases are products of soda.

c. Ammunition Metallurgy—Steel for rifle barrels, ball bearings, gears and other uses subject to pressure are case hardened to produce a hard carbon-rich surface while the interior remains soft and tough. This may be done by heating the steel while it is packed in carbonaceous material or by nitriding with ammonia gas. Sulphuric acid and soda ash also have many metallurgical uses.

3. Industrial and Agricultural Uses

Fertilizer production is the chief non-military use of fixed nitrogen products and of sulphuric acid.

Large chemical-using industries whose production has been reduced substantially during the war are ceramics, which is a big user of soda ash; textiles and paper, which use caustic soda, sulphuric acid, and chlorine in large amounts. Water purification is an important but fairly small scale use of chlorine.

B. REQUIREMENTS (JUNE 1945)

It is not possible to estimate with precision Japan's minimum requirements for chemicals. It is clear, however, that direct military uses for explosives and chemical warfare goods represent only a small fraction of total Japanese chemical production and an even smaller fraction of available capacity. Non-military and indirect military uses of chemicals which account for the bulk of total requirements are nevertheless important to the conduct of war. This is particularly true of (a) fertilizer production, which is the chief non-military use of fixed nitrogen products and sulphuric acid, and (b) chemicals employed in the treatment of metals for military end-products. Since the uses of chemicals are extremely numerous and vary widely in relative importance, it is evident that highest priority direct military uses are well protected by heavy cushions of lower priority uses. The outlook for 1945 and 1946 is toward increased military requirements for chemicals entering into explosives and increased pressure for more fertilizer to expand food production in the home islands.

C. SUPPLY (JUNE 1945)

Japan's supply of chemicals to date has been ample to fulfill all important military and most non-military requirements. Only in the case of fertilizer is there evidence that supply has been substantially less than needed. The limiting factor on chemicals production has been raw materials rather than processing capacity. On the whole, capacity has been underutilized by a considerable amount.

Japan is confronted by the prospect of a tighter supply position in Chemicals. Increased blockade of mainland traffic and growing disruptions of internal rail and coastwise ship movements is likely to curtail the volume of raw materials for chemicals production, especially coal and salt.

D. MILITARY EFFECT OF ATTACKS ON PRODUCTION

Production of chemicals would have to be reduced to a small fraction of the 1944 level in order to affect critically the important military uses. There would be in any case a considerable time lag between a cut in production and the impact on final uses. Within the military category, explosives and chemical warfare goods would be the first to be affected by a severe cut in chemical supply. Even here the effect on ammunition production would be delayed by production time lags and existence of stocks.

In most other military items the contribution of the chemical industry is buried in some preceding stage, the relationship to front-line strength is not close, and the military effect of loss of chemical production would be long delayed. Similarly, in the civilian economy, chemicals are seldom used in direct consumption; rather they are required at various stages in the production of goods going to direct consumption. An extreme case is nitrogenous fertilizers, lack of which would have little effect on food supply for at least 2 years. The effect on military strength would be even longer delayed.

III. STRUCTURE OF THE CHEMICALS INDUSTRY

A. SUPPLY OF RAW MATERIALS

For basic raw materials the Japanese chemical industry is favorably situated in comparison with other industries. The chief materials include coal, limestone, salt, sulphur and sulphide ores, electric power, water, and air. Total supply of each of these raw materials within the Inner Zone is adequate to meet requirements of the chemical industry, but competing requirements of other industries and transportation difficulties may force the Japanese to make continuing revisions of priority schedules. These raw materials may be considered individually.

1. Coal

The chemical industry does not require important amounts of coal for power purposes but the production of coal-tar derivatives does depend upon coal carbonization. Further, some parts of the chemical industry especially during the dry season use large amounts of steam-generated electric power, which in turn requires coal. Any serious interruption of the coking coal flow from the continent is likely to entail considerable adjustment within the industry, particularly within that part producing coal-tar derivatives. It is believed that substantial adjustment to a loss of coking coal could be made through use of anthracite coal, lower grades of bituminous coal and low temperature carbonization, through the use of electrolysis for nitrogen fixation products, and through the substitution of other chemicals and processes. There is reason to believe that difficulties in coal supply had curtailed Japanese fertilizer production by early 1945.

2. Salt

Japan's large synthetic fiber, paper, glass and other industries required in the order of at least 1,300,000 metric tons of salt annually prior to 1942. In addition at least another 800,000 tons of salt were required for food and food preservative uses. With a capacity of about 600,000 metric tons annually in the main islands, Japan had to import some 1,500,000 metric tons of salt. In pre-war years these imports were chiefly from Kwantung, North China, Manchuria, Southeast Asia, Africa, and Turkey.

The contraction of some of Japan's salt-using industries (synthetic fibers, paper, and glass) has reduced her salt requirements but this has been offset somewhat by increased activity in other industries—such as aluminum and perhaps in chemical warfare items. On balance, it appears that industrial requirements during 1945 are no greater than 1,000,000 metric tons and requirements for food preservatives are no more than some 600,000 metric tons. Thus on the home islands Japan requires about 1,600,000 metric tons of salt for 1945. Production in Japan Proper may be as high as 700,000 metric tons, with the balance of approximately 900,000 metric tons to be imported. It is improbable that home stocks exceed 500,000 metric tons, and they are more likely in the order of 400,000 metric tons. North China and Manchuria, where Japan has drawn programs for expansion of salt production, are the sources of the salt imports.

Salt-producing methods in the Far East do not depend upon advanced technology; rather, sea water, salt beds, and solar or simple artificial evaporation is the ordinary technique, hence vulnerability to attack is extremely low. Since, however, it is unlikely that production in Japan Proper can be increased with great rapidity, reduction of transport and imports will eventually create serious shortages.

3. Electric Power

Though one of the largest industrial power consumers, the chemical industry is estimated to use no more than 15% of total power generated in the Inner Zone. The operations of the chemical industry are varied seasonally to take advantage of more abundant hydropower in the wet season. There is no evidence to date that chemical production has been restricted by power shortages. A sharp cut in total power supply would undoubtedly have an impact on chemical production but nothing short of a virtually complete cut in power would assure a stoppage of highest priority chemical output.

4. Sulphur and Sulphide Ores

Japan has no deficiency in either sulphur or sulphide ores. There are a number of iron pyrites deposits, and North Honshu and Hokkaido have sulphur deposits.

5. Limestone

Japan has an abundance of limestone.

B. CAPACITY AND PRODUCTION

1. Pre-War Growth

The Japanese chemical industry was small in relation to the total Japanese economy until the early 1930's. During the 1930's a series of factors led to a very rapid and large expansion of the industry. Japan's synthetic fiber industry became one of the world's foremost, and chemicals—particularly caustic soda—were required to support the industry. As one of the world's most important exporters of cotton goods Japan required dyes and bleaching materials. Intensive agriculture had always required the extensive use of fertilizers, but during this period Japan shifted more and more to chemical fertilizers, and this led to the development of sulphuric acid production. Chemical fertilizer requirements also were primarily responsible for expansion of nitrogen plants, with nitrogen requirements for industrial explosives, dyes, and drugs an influence of secondary importance. Worldwide technical progress in the chemical industry, such as in the development of coal tar products, was an influential factor since Inner Zone coal resources were available. Growth within the chemical industry was further stimulated by yen depreciation, an export boom, and very high costs for imported chemicals which fostered domestic production. Strategic considerations looking toward a self-sufficient bloc were among the most important factors in the domestic expansion. By 1940 the industry was highly developed and Japan imported very few chemicals from outside the Inner Zone. This expansion has proven to be of great value for waging a war since it has resulted in overcapacity and the provision of a generally large cushion.

2. Utilization of Capacity (June 1945)

The sharp contraction of civilian industrial production and heavy export trade has left Japan with a chemical capacity well in excess of probable war requirements. It is estimated that no more than three-fourths of the plant capacity is required in the case of sulphuric acid; one-third in soda ash; three-fourths in electrolytic chlorine and caustic soda; three-fifths in calcium carbide; and perhaps four-fifths in the case of nitrogen. Nitrogen capacity is not fully utilized because of restricted supplies of raw materials, although nitrogenous fertilizers are believed to be badly needed.

C. CONCENTRATION

Japan's chemical industry is widely dispersed geographically and moderately dispersed by number of plants. Some 384 plants have been located. Of these, 27 of substantial individual importance are listed in Table II. In some chemical products a considerable portion of known capacity is concentrated in a few plants, but in most cases sufficient capacity remains in minor plants to fulfill high priority requirements in an emergency. The large plants typically produce a variety of basic chemicals.

Chemical plants are scattered throughout the home islands and the mainland. Coal-tar derivatives are near coal fields in Japan Proper and on the continent. Plants using quantities of electric energy, such as calcium carbide plants are often located near hydroelectric plants. A few sulphuric acid plants are in Hokkaido near natural sulphur sources; others are near sulphide ore smelters. Much ethyl alcohol capacity is in Hokkaido to take advantage of the raw materials there. Upwards of 100 explosives plants and over 100 sulphuric acid plants are believed to be scattered over Japan Proper. Almost two-score electrolytic chlorine plants are dispersed throughout Japan Proper, although most of them are in Central and Southwest Japan. There is relatively high concentration of capacity for soda ash, nitrogen, and dye intermediates.

D. EXPOSURE TO URBAN AREA ATTACKS

Few of the large basic chemicals plants are located within congested industrial zones of large cities. On the other hand, there are numerous smaller chemical plants, generally specialized, at risk within urban areas. For example, a substantial portion of total capacity associated with pharmaceuticals, electro-plating, and tanning is exposed to urban area attacks. Of those chemical plants within urban area, a large part are relatively combustible.

Listed below are four industrial groupings containing major chemical plants as well as important plants in other industries.

1. Konan, Korea

Here is located one of Japan's largest nitrogen fixation plants (84:2-1) with large nitric and sulphuric acid capacity as well as facilities for production of other chemicals. Chemicals for explosives are shipped to a nearby explosives plant (84:2-2), probably the largest on the continent, and one of Japan's largest. Virtually in the same compound is one of Japan's largest magnesium plants (84:2-1) and a large aluminum plant (84:2-1), as well as some copper and lead refining.

2. Nobeoka, Kyushu

Basic chemicals are supplied by a large plant (90:33-1314) to at least two nearby explosives plants (90:33-1312, 90:33-1310) including one of Japan's largest propellant plants.

3. Omuta, Kyushu

Three adjoining plants, Miike Dyestuffs (90:35-1243), a nitrogen fixation plant of Oriental High Pressure Co. (90:35-1244), and Mitsui Coal Liquefaction plant (90:35-1262), are the nucleus of an important explosives and synthetic oil concentration. Adjoining these plants is one of Japan's most important zinc refining installations (90:35-1260 and 1261), and a machinery works (90:35-1256).

4. Niihama, Shikoku

The Sumitomo Chemical Co. plant (90:29-923) is one of Japan's largest nitrogen fixation and synthetic methanol plants and is believed to supply these products to the Centrol Honshu area. The coke section adjoins a large alumina plant (90:25-1657). Nearby is one of Japan's largest copper refining (90:29-815) installations. Also nearby are an aluminum reduction plant (90:29-924), a copper concentrating mill (90:29-925), and a machinery works (90:29-932). Offshore from Niihama on Mino Island is one of Japan's largest copper smelters (90:29-814), which also produces large quantities of sulphuric acid.

E. RESILIENCE

Japan's chemical industries as a whole have rather high resilience due to the extensive unused capacity, the high degree of substitution between different chemicals and between different types of capacity, and the comparatively simple construction of most equipment. Certain equipment, however, is more complex and would require a long time for replacement. A large proportion of total capacity would have to be destroyed before resilience was sufficiently overcome to assure a lasting curtailment of supply of high priority chemical uses.

IV. STATUS OF PARTICULAR CHEMICALS

A. NITROGEN

1. Uses

The largest use of nitrogen is in fertilizers, which are particularly indispensable to Japan with its high ratio of population per acre of arable land. Strategically, the most important use of nitrogen is in the form of nitric acid which is used to nitrate practically all types of military explosives. In addition, nitrogen is used extensively in the preparation of various chemicals, in case hardening steel, and, in certain instances, as a substitute for caustic soda.

2. Requirements

Estimated requirements for nitrogen exceed probable production. The supply of nitrogen fertilizers is believed to be about 25 percent less than 1938 consumption in spite of the strenuous efforts Japan is making to increase food production. Total production of nitrogen is estimated to be 573,000 metric tons. The probable utilization of this production in 1944 and the possible future utilization of the same amount assuming maximum military demand is indicated by the following patterns:

	Probable 1944 (metric tons)	Possible (metric tons)
Military explosives	111,000	245,000
Essential civilian	4,000	4,000
Fertilizer	458,000	324,000
	573,000	573,000

The probable utilization is based on the estimate that Japanese production of ammunition and explosives in 1944 was only a little in excess of expenditures. The possible future use pattern reflects nitrogen requirements if explosives are produced at the rate of 500,000 metric tons per year, which is probably about the maximum rate at which Japan might produce explosives. Even at the maximum rate of explosives production, military requirements absorb less than 50 percent of estimated nitrogen production.

3. Capacity and Production

The productive capacity of the nitrogen fixation industry is estimated to be 716,000 metric tons of nitrogen, of which synthetic ammonia plants comprise about 598,000 metric tons and calcium cyanamide comprise about 118,000 metric tons. In addition to the capacity of nitrogen fixation plants, there is a productive capacity of about 40,000 metric tons of nitrogen as a by-product from coke-oven plants and 10,000 metric tons as a by-product from oil shale distillation.

Actual production is estimated at 573,000 metric tons of nitrogen of which 450,000 metric tons are supplied by synthetic ammonia plants, 75,000 metric tons by calcium carbide plants, and 48,000 metric tons as by-products from coke-oven plants and oil shale distillation.

In view of the apparent shortage of nitrogen for fertilizer, the gap between estimated production of nitrogen fertilizers and potential capacity for such production requires some comment. The reasons for the disparity are not known. Of the following factors that may be involved, it is likely that the first two are most important.

a. A tightness of the coal supply which might affect the allocation of coal to the nitrogen fixation industry, both as a raw material for calcium cyanamide and as a source of electric power;

b. Seasonal operation at full capacity only when hydro-electric power is available;

c. A rice-fertilizer-electric power price structure not properly adjusted to encourage full use of productive facilities;

d. Utilization of the excess capacity in whole or in part for the production of some other essential product.

4. Concentration

The 31 known nitrogen fixation plants of either the ammonia or cyanamide type are well scattered geographically. The following six synthetic ammonia plants represent over half of the entire nitrogen fixation capacity, but the remainder is widely diffused.

Target area and number	Name	Location
84.2—1	Chosen Nitrogen Fertilizer Co.	Konan
90.17—137	Showa Fertilizer	Kawasaki
90.35—1244	Oriental High Pressure Co., plant A.	Omuta
90.32—818	Ube Nitrogen Fertilizer Co.	Ube
90.29—923	Sumitomo Chemical Co.	Niihama
93.5—19	Manchurian Chemical Industry	Kanseishi

5. Processes

In Japan, as in most other industrial countries, the principal source of nitrogen is synthetic ammonia. This is made by the union of gaseous nitrogen and hydrogen under high pressure at high temperatures in the presence of a catalyst. There are many variations in the processes. The hydrogen and nitrogen gases must be quite pure since impure gases will "poison" the catalyst and seriously reduce production. The hydrogen can be obtained from coke-oven gases, water gas obtained by blowing steam over hot coke, electrolysis of water or salt solutions, or from natural or refinery gases. It is not believed that the Japanese have any plants obtaining hydrogen from natural gas. All other sources of hydrogen are used in Japan. The nitrogen can be obtained from liquefied air or from producer gas, which is made by blowing air over a hot bed of coke.

A second important nitrogen fixation process is the manufacture of calcium cyanamide. In this process lime and coke are fused in an electric furnace to form calcium carbide. The carbide is then heated and nitrogen gas passed over it. The nitrogen is absorbed in the carbide.

A third source, natural sodium nitrate, was formerly important. Chile has virtually a world monopoly on the production of natural sodium nitrate and it is now impossible for Japan to receive substantial amounts.

6. Vital Installations and Recuperability

There is considerable difference in the recuperability of plants making ammonia and those making calcium cyanamide. The typical ammonia plant consists of hydrogen generators (water gas or electrolytic), purifying towers and converters, very heavy compressors and a boiler house which furnishes the necessary steam. Large quantities of water are necessary in cooling and for steam. Ammonia manufacturers in the United States consider the gas generators vulnerable. The oil cooled transformers in electrolytic plants would probably be damaged beyond repair if the case of the transformer were pierced while the power was on. The opinion has been expressed that if Japanese compressors are destroyed, it is doubtful whether they can ever be replaced during the war. It is certain that from 9 months to a year would be required to obtain new compressors even in the United States. Boilers might take several months to restore if destroyed or badly damaged. If the source of water were destroyed, the plant could not operate until water was restored. This probably would not be too difficult. Plants could probably be restored to partial operation relatively soon because gas generators, transformers, and compressors consist of many independently operating units and there is usually more than one boiler. Restoration to full capacity might never be accomplished.

The cyanamide plants are very ruggedly constructed and contain only comparatively simple equipment. Except for the equipment in the air liquefaction section of the plant, all can be rather easily and quickly repaired or rebuilt. It is estimated that there is no part of a cyanamide plant that cannot be rebuilt or repaired within 3 months with the exception of the air liquefaction equipment. The latter is extremely hard to destroy.

7. Raw Materials

The one vital raw material used by the nitrogen fixation industry is coal. Nitrogen in all cases is obtained from the air. Synthetic ammonia plants require hydrogen which is obtained from water by electrolysis or by reaction with coke or other suitable form of carbon to produce water gas. In the case of electrolysis, electric power is essential and, in the case of water-gas formation, coal for steam and power is required in addition to the coke or other carbonaceous fuel used in the reaction with steam. Calcium cyanamide plants require limestone and coal or coke. Limestone is abundant and less than 500,000 metric tons of coal are needed for operation of the calcium cyanamide plants at full capacity.

B. EXPLOSIVES

1. Types of Explosives

The principal military explosives may be classified as:

a. Primary or detonating explosives.
b. Propellants.
c. High explosives.

The function of the primary or detonating explosive is to furnish shock sufficient to detonate the main explosive charge. Captured Japanese ammunition has been found commonly to use mercury fulminate or lead azide, but other detonators, while perhaps not quite as satisfactory, could easily be substituted if necessity should require. The quantities of detonators needed are very small and consequently the requirements and substitutes for this use have been disregarded.

The function of propellants is to expell the shell or bullet from the gun. Propellants burn very rapidly rather than explode, thus giving an even pressure against the projectile. There are two types, single base and double base. Single base propellant consists essentially of nitrated cellulose while double base (usually called Cordite) consist of single base powders mixed with from 20 to 40 percent nitroglycerin.

High explosives constitute the filling of shells, bombs, mines, torpedoes, grenades, etc. The most important types of high explosive are picric acid (a phenol derivative), TNT (trinitrotoluene), PETN (pentaerythritoletranitrate), trintroanisol, RDX, and Amatol (mixtures of TNT and ammonium nitrate). It is believed that picric acid and TNT, in order named, make up by far the greater portion of Japanese high explosives and that the use of RDX is increasing.

2. Requirements

Japanese explosives requirements for 1944 are estimated at 135,000 metric tons of high explosives and 92,000 tons of propellants. This is based on the estimate that 1944 ammunition production only slightly exceeded expenditures. If ammunition production is raised to maximum capacity, the above requirements for explosives would be more than doubled.

3. Capacity and Production

The Japanese are believed to have capacity for producing explosives at the rate of 500,000 metric tons per year, comprising roughly 350,000 metric tons of high explosives and 150,000 metric tons of propellants. Thus, it was possible to fulfill 1944 requirements by producing at only roughly 50% of capacity.

4. Concentration

A total of 119 plants manufacturing explosives of various kinds have been located; of these, 35 are thought to manufacture propellants and 84 are thought to manufacture high explosives and industrial explosives. Geographically, 93 plants are located on the home islands, 23 are located in Manchuria, Korea, and China, and 3 are in Formosa, Thailand, and Java. Productive capacity is not known sufficiently to estimate total capacity nor to indicate the degree of concentration in the larger plants. However, it is believed that the following 3 of the 35 propellant plants have more than enough capacity to have supplied Japan's entire 1944 propellant requirements:

Target area and number	Name	Location
90.33—1312	Raikan Plant of Nippon Nitrogen Explosives Co.	Nobeoka
90.17—205	Army Arsenal and Military Gunpowder Works	Itabashi Ward, Tokyo
90.20—1138	Nippon Explosives Works	Taketoyo

5. Processes

A nitrocellulose propellant plant consists of a large central building, at least three stories high, in which the cellulose is nitrated and dried in centrifugal driers. The nitrated cellulose is then washed in some of the many small "boiling tubs" that surround the main building.

The mixing of high explosives involves simple compounding processes but the danger of explosion is always present so that high explosives are always made in small quantities, usually by mechanical devices operated by remote control.

6. Raw Materials

The principal raw materials used in explosives are nitric acid, toluene, benzene, phenol, contact sulphuric acid, cellulose, glycerin, ethyl alcohol, and acetone. These chemicals are all produced in abundance and the requirements for explosives are believed to be well within the limit of the productive capacity for each one.

An over-all estimate of Japanese requirements for military explosives is of little value in determining the drain upon the chemicals industry since there is no satisfactory method of determining the proportions in which various explosives are being used and production cannot be judged from expenditure. Analysis of captured munitions reveals the explosives that the Japanese have been using and the trend in the use of explosives and this information gives considerable indication of the Japanese explosives position. For instance, almost no captured samples have contained ammonium nitrate. This is a strong indication that so far the Japanese have experienced no shortage of explosives made from coal tar derivatives (picric acid and TNT), because ammonium nitrate can be substituted for TNT up to 50%. This mixture produces amatol, the standard German high explosive and one commonly used by the United States. Captured ammunition and documents indicate that increasing use of RDX (otherwise known as cyclonite, hexogen or T_4) may be the way the Japanese will meet any shortage of coal tar derivatives. This explosive is composed of formaldehyde, ammonia, and nitric acid. There is also evidence that the Japanese are prepared to make explosives by nitrating coal tar fractions that are not commonly used for military explosives.

C. BY-PRODUCTS OF COAL CARBONIZATION

1. Uses

The five essential by-products of coal carbonization in coke-oven plants are benzene, toluene, phenol, cresols, and naphthalene.

(a) Benzene is used as a common solvent, and as a constituent of gasoline to improve the octane rating. It is also the raw material from which are made phenol, styrene, aniline, and various compounds which are used in the production of dyestuffs, pharmaceuticals, disinfectants, explosives, plastics, rubber processing chemicals, poison gases, and other products.

(b) Toluene has its prime use in the making of trinitrotoluene (TNT). It is used in aviation gasoline; as a solvent, particularly in the treatment of Naval cable; and is used in making dyestuffs, medicinals, rubber chemicals, saccharine, and other chemicals.

(c) Phenol (carbolic acid), as such, is a powerful disinfectant. It is also used in the manufacture of explosives (picric acid and picrates), as the basis of bakelite type plastics, in the making of many pharmaceutical chemicals, in the lubricating oil industry as an extracting agent, in the extraction of toluene from gases, and for other purposes.

(d) The *cresols* are a mixture of ortho-, meta-, and para-cresol. Their primary use is as a powerful disinfectant and as a wood preservative. They are also a useful raw material in dyestuffs and medicinal chemicals. They can be made into explosives (trinitrocresol) and plastics, enter into printing inks, and are used for the deinking of news print, etc.

(e) Naphthalene is probably of the greatest utility to the Japanese in the manufacture of synthetic resins and synthetic coatings. It is also used in the dye industry, and may form the base of high explosives. Use in motor fuels has shown this material is also capable of increasing slightly the octane number of a gasoline.

2. Requirements

The requirements for use in explosives are estimated as follows:

	Metric tons
Toluene	25,000
Benzene and phenol	20,000

In view of the wide range of chemicals which can be used to make explosives these estimates are not particularly reliable. The minimum essential Japanese nonmilitary requirements for these products are estimated to be:

	Metric tons
Benzene	5,000
Phenol	8,000
Toluene	1,000
Cresols	3,000

3. Capacity and Alternative Sources

There are other sources of benzene, toluene, phenol, and cresols besides coke-oven plants as is shown by the following table:

Summary of the Japanese maximum supply position for the principal by-products of coke-oven plants

(Metric tons)

Source	Benzene	Toluene	Phenol	Cresols
Coke ovens	100,200	28,400	6,700	11,700
Gas plants	12,000	3,400	800	1,400
Low temperature carbonization plants	5,800	6,400	200	800
Acetylene	750	290	....	....
Coal hydrogenation	....	....	5,000	20,000
N. E. I. crudes	....	11,700	....	....
Total	118,750	50,190	12,700	33,900
Percent from coke ovens	86	57	53	35

In addition, benzene and toluene could be made from calcium carbide through acetylene by a relatively simple process if calcium carbide were allocated to this use. The conversion of cresols to toluene by dehydrogenation at atmospheric pressure and at moderate temperature offers such good possibilities that it would not be surprising to find that the process is already in use although there is no evidence to this effect.

D. DYE INTERMEDIATES

1. Uses

Dyes have some direct war significance by reason of their use in uniforms, flags, signaling panels, camouflage, etc. Some dyes are essential for civilian purposes as well. However, the greater wartime significance of the dye industry results from the fact that plants making dye intermediates (the chemicals from which dyes are made) can be converted quickly and easily to other uses such as manufacture of explosives and war gases. It may be assumed that a very large percentage of the intermediate plants are so converted but no reliable basis for an estimate of the percentage of conversion has been found. It is believed that a substantial part of Japanese war gases are manufactured in these plants. They can also make chemicals used in the manufacture of pharmaceuticals, photographic supplies, and other fine chemicals and they can be used to manufacture phenol, and other organic chemicals necessary in the production of explosives.

2. Requirements

There is no satisfactory basis for estimating the requirements for dye intermediates. It is believed that rayon production is now down to 30 percent of prewar output, but the manufacture of pigments of various kinds for purposes other than dyes might require some capacity in excess of that needed for dyeing cloth. Almost certainly much of the capacity will be used for purposes other than making colors.

3. Capacity and Production

The latest figures from Japanese sources show that 31,824 metric tons of dye intermediates were produced in 1938. This was an increase of 40 percent over 1937 production and an increase of nearly 300 percent over 1935. If the increase continued after 1938 at anything like the rate in prior years, the capacity to produce dyes, intermediates or other organic chemicals will now be much greater than indicated by 1938 figures. There is no technological reason why the Japanese could not enlarge their capacity since the equipment is not complicated and they had demonstrated before the war their ability to manufacture it.

It is unlikely that any dye intermediates manufacturing capacity is idle. Much of it may be used for making war gases, synthetic drugs, and fine chemicals. If not used for these purposes, it is likely to be used to produce the materials needed in explosives.

4. Concentration

Fifty Japanese plants making dyes and intermediates have been located. Of these the following four in peacetime produced at least 55 percent of the dyes and intermediates:

Target Area and number	Name	Location
90:25-1733	Japan Dyestuff Mfg. (Dye Plant)	Osaka
90:33-1317	Nippon Dye Works	Tsurusaki
90:29-1931	Imperial Dye Works	Fukuyama
90:35-1243	Miike Dyestuffs	Omuta

All four of the plants listed have fractionating equipment for light oil and tar which can be used for producing war materials.

Although reliable estimates of percentages cannot be given, it is believed that destruction of the four plants listed above might seriously curtail present or potential production of war gases, pharmaceuticals, fine chemicals, and the raw chemicals going into explosives.

E. CALCIUM CARBIDE

1. Requirements

Estimated requirements for calcium carbide are 605,000 metric tons made up as follows:

Metric Tons	Product	Uses
240,000	Acetylene	Welding, cutting, illuminating, and carbon black.
90,000	Organic Synthesis	Production of acetic acid, acetone, benzene, etc.
275,000	Fixation of Nitrogen	Calcium cyanamide production.

2. Capacity and Production

The productive capacity of the calcium carbide plants is estimated to be 1,050,000 metric tons. Actual production is estimated to be 605,000 metric tons. Both capacity and production estimates as given are exclusive of the capacity of the plant of the Manshu Denki Kagaku Kogyo KK at Kirin, Manchuria, reported as planned in 1939 with an ultimate capacity of 200,000 metric tons of calcium carbide for the production of synthetic rubber and other organic compounds. It is believed that shortages of coal, coke, and electric power are limiting production at present and that production of calcium carbide might be one of the first products to be cut back by further shortages of coal, coke, or power.

3. Concentration

The calcium carbide industry is characterized by a high concentration of productive capacity in the adjacent prefectures of Niigata and Toyama in Northwestern Honshu.

Although total production capacity is distributed among 40 plants, 6 plants provide 53 percent of estimated production capacity. They are as follows:

Target area and number	Name	Location
90:9-1101	Electro-Chemical Industry, Aomi Plant	Aomi
90:35-1246	Electro-Chemical Industry	Omuta
90:9-1536	Showa Fertilizer, Kanose Plant	Kanose
90:9-1667	Shinetsu Nitrogen Fertilizer Co., Naoetsu Plant	Naoetsu
84:2-3	Motomiya Chemical Plant	Konan
84:3-59	Chosen Chemical Industry	Junsen

4. Military Effect of Attacks on Production

In view of the large excess capacity and the probability that no more than half of production in 1944 went into military use, it is estimated that 65% of capacity would have to be destroyed before military uses would begin to be affected.

5. Vital Installations and Recuperability

It would be difficult to put a carbide factory out of operation for more than a few weeks. Modern plants have fairly complicated grinding, dusting, screening and mixing machinery but in case of urgent necessity, these could be abandoned or simple machinery improvised without seriously decreasing production. The only essential part of the plant is the massive electric furnace, but this could be rebuilt or replaced in three or four weeks' time.

6. Raw Material Supply

Calcium carbide plants consume limestone, coal, and coke. Charcoal or anthracite coal is used instead of coke in some cases. Limestone is plentiful. Consumption of coke and charcoal is estimated at 405,000 metric tons, and consumption of coal at 180,000 metric tons. The industry is a large consumer of electric power, using 1,800,000 kilowatt-hours to turn out the estimated production.

F. SULPHURIC ACID

1. Uses

In normal times upwards of one-half of Japan's sulphuric acid went to the production of fertilizer (ammonium sulphate and superphosphate). The acid for this use is comparatively weak and not suitable to satisfy certain industrial uses requiring a strong acid. This type of sulphuric acid is satisfactory, however, in a wide range of industrial uses where the objective is merely to provide an acid state. Strong sulphuric acid is required for the production of explosives, drugs, dyes, paints and pigments, and in petroleum refining. Weaker acids are generally required for the production of rayon, fertilizer, iron and steel, and in various metallurgical uses.

2. Requirements

In pre-war years Japan used upwards of 2,750,000 metric tons of sulphuric acid for use in fertilizers, and at least 1,500,000 metric tons in other fields, such as explosives manufacture, rayon production, paper manufacture, dyes manufacture, etc. The current war economy requires greatly reduced amounts of acid for rayon, paper, dyes, etc., but acid requirements for explosives production have increased. Acid requirements for fertilizer production have increased somewhat during the war.

3. Capacity and Production

Japanese capacity to produce acid for fertilizer and other uses requiring a weak acid is believed to be in the order of 4,000,000 metric tons. Capacity to produce stronger acids is upwards of 2,000,000 metric tons. It is doubtful if production early in 1945 had to be higher than 75% of capacity in order to meet requirements.

4. Concentration

Japan's chamber acid capacity is scattered in some 85 plants, and the contact acid capacity is in some 45 more plants. The products of these two types of plants are substitutable through dilution or concentration processes. The following 8 largest plants are believed to have no more than 35 percent of total capacity.

Target Area and Number	Name	Location
84:2-1	Chosen Nitrogen Fertilizer Co.	Konan
90:25-1713	Tagi Fertilizer Co.	Behu
90:29-923	Sumitomo Chemical Co.	Niihama
90:17-137	Showa Fertilizer	Kawasaki
93:5-19	Manchurian Chemical Industry	Kanseishi
90:35-1245	Oriental High Pressure Co., Plant B	Omuta
90:20-255	Yahagi Electro-Chemical Plant	Nagoya
90:32-818	Ube Nitrogen Fertilizer Co.	Ube

5. Processes

Sulphuric acid is produced by either the chamber method or the contact method. The chamber method produces a weak acid, which may be stepped up in strength by concentration or admixture with contact acid. The contact method produces a purer and stronger acid. The chamber method consists of mixing sulphur dioxide with air, oxides of nitrogen and water, while the contact method produces acid by dissolving in water the sulphur trioxide formed by passage of sulphur dioxide and air over a catalyst. Sulphuric acid plants may use either or both methods depending upon the strength of acid desired.

6. Raw Materials

Raw materials required are either native sulphur, sulphide ores, or waste sulphur gases from various technical and metallurgical operations. Only small amounts of power are required. Japan is believed to depend heavily upon sulphide ores in the recovery of metals, hence raw materials are believed to consist largely of gases given off in the roasting of sulphide ores. This source alone may be adequate to meet all of Japan's needs, but since Japan also has a number of natural sulphur deposits in Northern Honshu and Hokkaido, the supply of raw materials is believed to be ample for all requirements.

G. SODA ASH

1. Uses

Sodium carbonate, or soda ash as it is known commercially, is used chiefly as the material from which caustic soda is made (see sec. H, following), in the production of glass and ceramics, rayon, paper, for other processes involving chemicals production, for soap manufacture, petroleum refining, and metallurgy.

2. Requirements

It is believed that Japan's war economy requires no more and perhaps considerably less than 200,000 metric tons of soda ash for uses other than those involved in caustic soda production. Demand in wartime for soda ash to produce caustic soda is smaller than in peacetime because more caustic soda is produced as a by-product of chlorine production. It is estimated that Japan's soda ash capacity must operate at no more than one-third of capacity to fulfill wartime requirements.

3. Capacity

Capacity is estimated to be at least 1,000,000 metric tons annually. A small part of this capacity is probably used to produce caustic soda.

4. Concentration

Capacity for the production of soda ash is highly concentrated, with the following three plants having from 70-75 percent, and eight other plants having the remainder:

Target Area and number	Name	Location
90:32-675	Tokuyama Soda Co.	Tokuyama
90:32-1882	Toyo Soda Co.	Tonda
90:34-567	Asahi Glass Co.	Tobata

5. Processes

Most soda ash is produced by the Solvay process wherein a salt solution is treated with ammonia gas, and the resulting solution is then treated with carbon dioxide; the sodium bicarbonate is then filtered, dried, and calcined. The ammonia is recovered and reused. The second and seldom-used process is one of using sulphuric acid on salt to produce sodium sulphate, which is then transformed into carbonate with hydrochloric acid as an important by-product.

6. Raw Materials

Basic raw materials are salt, limestone, and coal. Japan has ample limestone to meet all her needs. About 1½ tons of salt are needed to produce 1 ton of soda ash. Upwards of 300,000 metric tons of salt will be required in 1945 for the production of soda ash (excluding salt requirements for the production of electrolytic chlorine and caustic soda; see below, Electrolytic Chlorine and Caustic Soda). Slightly less than 1 ton of coal is required to produce 1 ton of soda ash but production of soda ash is believed to be so small as to require negligible amounts of Japan's coal production.

H. ELECTROLYTIC CHLORINE AND CAUSTIC SODA

Since in Japan both chlorine and caustic soda are probably made to a very large extent in the same process, they will be discussed together.

1. Uses

a. *Chlorine*—The chief uses of chlorine are for poison gases, smoke screens, decontaminating and disinfecting agents, and for explosives. Some chlorine is also used for the production of other chemicals.

b. *Caustic Soda*—Chief uses of caustic soda are in the production of other chemicals, rayon production, petroleum refining, pulp production, paper, soap production, and as lye. Japan's chief uses currently would probably be in the production of pulp for nitrocellulose, and for other chemicals, with other uses satisfied largely as supply permits:

2. Requirements

a. *Chlorine*—Requirements are probably no more than 175,000 metric tons per year.

b. *Caustic Soda*—Requirements are believed to be in the order of 350,000 metric tons, a great portion of which is used in petroleum refining, remaining rayon production, other chemicals production, and in the production of pulp for nitrocellulose.

3. Capacity and Production

It is believed that Japanese capacity for production of electrolytic chlorine is in the order of at least 225,000-250,000 metric tons annually. Production at capacity would yield in the order of 250,000-280,000 metric tons of caustic soda. If electrolytic chlorine production approximates 175,000 metric tons, about 200,000 metric tons of caustic soda is produced from this source. The balance of caustic soda requirements —in the order of 150,000 metric tons—can easily be met from Solvay process capacity, which may be more heavily drawn upon if electrolytic chlorine production is less than here estimated. Probably no more than three-quarters of total capacity is presently in use.

4. Concentration

Electrolytic chlorine is distributed over at least 38 known plants, only 6 of which are known to produce more than 10,000 metric tons each. The 10 largest plants have no more than 60 percent of capacity. The 6 largest electrolytic chlorine plants are as follows:

Target Area and Number	Name	Location
84:2-3	Motomiya Chemical Plant	Konan
90:20-467	Showa Soda Plant	Nagoya
90:32-1882	Toyo Soda Co.	Tonda
90:12-1642	Nippon Soda KK, Hihongi	Nihongi
90:33-1314	Asahi Bemberg Cuprammonium Plant	Nobeoka
90:17-1396	Tsurumi Soda Co.	Yokohama

5. Processes

Two processes are used for the production of caustic soda. One process, the Solvay, consists of causticizing sodium carbonate with lime. The other method is by electrolysis, where a low voltage electric current is passed through a salt solution in specially constructed but simple cells which produce chlorine and hydrogen as well as caustic soda. In a peace economy the demand for chlorine is smaller than in wartime, hence caustic soda is produced heavily by the lime method. Since the increased demand for chlorine during wartime is met by using the electrolytic process, more caustic soda is produced by electrolysis.

6. Vital Installations and Recuperability

A typical chlorine plant consists of one or more low buildings each housing hundreds if not thousands of small electrolytic cells. The collecting mains for the chlorine and caustic soda are generally fragile. A bomb hit in the cell buildings would almost certainly damage a large number of cells and would disrupt the gathering systems. One chlorine manufacturer in this country has estimated, however, that even if three-fourths of the cells in one building were seriously damaged the unit would be in full operation again in three or four weeks.

All chlorine plants have much electrical equipment, the control board, transformers, rectifiers, etc. With the exception of transformers and rectifiers, it is believed that repairs and improvisions could be easily made. Transformers are beyond repair if they are burned out. The rectifiers are fragile and cannot be repaired. But they are small and can be easily protected.

7. Raw Materials

Chief raw materials for the joint production of electrolytic chlorine and caustic soda are electric energy and salt. Japan's electric power capacity is ample and it is believed that no more than 1½ percent of the annual power production is required to satisfy the energy needs for electrolytic chlorine production. Salt requirements may be as high as 650,000 metric tons and this would represent a burden for Japan since most of this would have to be imported. The use of substitute processes for chlorine production is considered unlikely.

I. OTHER CHEMICALS

1. Industrial Alcohol

Industrial alcohol is an essential material in both war and peace economies. It is used extensively in the manufacture of explosives, chemicals, plastics, pharmaceuticals, and is relied upon as a general solvent. Since Japan lacks adequate petroleum resources, considerable quantities of absolute alcohol (100 percent ethyl alcohol) have been combined with gasoline and used as a motor fuel for several years, and there has been consequent plant expansion. Inner Zone capacity is believed to be in the order of 500,000 metric tons annually and this should be more than ample to meet current essential requirements. Raw materials consist of sugary, starchy, or cellulose materials, such as sugar, grains, sweet potatoes and potatoes, waste liquor from sulphite pulp, molasses, etc. Many of these raw materials may be diverted to satisfy food requirements but it is not believed that deprivation will go so far as to affect seriously the production of enough industrial alcohol to meet essential requirements. Other alcohols (methyl, butyl, propyl) are made by different processes or by synthesis and have specialized but not indispensable uses.

2. Glycerine

Glycerine is a necessary ingredient of certain explosives and is used in the manufacture of paper, rayon, cellophane, certain inks, as a solvent, etc. Japan's current chief use is in the production of explosives. Since glycerin is produced from vegetable and other oils, since pre-war requirements are believed to exceed greatly the current requirements, thereby releasing capacity for war use if required, and since synthetic production is feasible, it is believed that potential capacity far exceeds possible requirements. Plants are numerous and widely dispersed.

3. Ethylene Glycol (Prestone)

While there are several important uses for ethylene glycol (antifreeze, explosives), several substitutes are available and it is not believed to be worthy of special attention.

4. Cellulose

Japan needs cellulose for the production of explosives. Since, however, cellulose was required in large quantities for the pre-war production of synthetic fibers which have now been drastically curtailed, there is ample capacity for all possible cellulose needs. Hokkaido and Karafuto have in the past produced large proportions of Japan's cellulose. Restricted shipping might require movement by rail. Furthermore, cellulose to meet minimum needs is believed available on Honshu and Kyushu.

5. Hydrochloric Acid

Capacity and raw materials are ample to meet Japanese requirements, most of which could be dispensed with or met by substitutes if necessary.

6. Plastics

It is believed that Japan has no critical shortage of plants or materials for the production of either cellulose plastics or synthetic resin plastics, and plant dispersion is extensive.

V. PHYSICAL VULNERABILITY AND WEAPON RECOMMENDATIONS

A. GENERAL

Diversity of products and the wide range of equipment used in this industry preclude generalizations with regard to the physical vulnerability of Japanese chemical plants. Buildings housing the processing equipment, however, are limited to a narrow range of structural types. The majority of structures in a typical Japanese chemical plant are single story, mill type buildings having trussed roofs supported on load bearing walls or columns. Roof covering is usually lgihtweight, noncombustible material. Where roof trusses are supported on columns, side-wall sheathing is also lightweight noncombustible material. Material for framing members may be steel or timbers, the former for the larger buildings with normal to long roof spans and the latter for the smaller buildings with short to normal roof spans. A large percentage of the individual buildings are smaller in plan area than 10,000 square feet and do not contain traveling cranes. Their HE vulnerability classification is V4 (as defined in memorandum M-8). Buildings larger in plan area than 10,000 square feet are usually of the multi-bay type, with interior columns and trussed roofs. HE vulnerability classification is usually V4 except for those which contain overhead traveling cranes, in which case HE vulnerability classification is V2. The presence or absence of traveling cranes is most often inferred from the function of the building. Eave heights for chemical plant buildings vary from low to high depending upon the character of the equipment within the structure. Where traveling cranes are contained within the building eave heights will be greater than normal.

No generalization can be made with regard to the combustibility of chemical plants. The combustible buildings may range from only a small percentage in some plants to a very large percentage in other plants. Fire resistant buildings are seldom found. An individual analysis for each target is required to determine the percentages of combustible and noncombustible buildings.

Although a structural analysis of a chemical plant can be made from adequate photo cover and other intelligence information, the measure of damage to equipment contained in the building is often not directly related to the structural damage that can be obtained. Some chemical processes require high temperatures or high pressures or both to obtain the necessary reactions and the equipment is consequently very strong. Structural debris from collapsed light roofs is unlikely to damage this equipment seriously. This factor is more fully discussed in the following paragraphs.

B. SYNTHETIC AMMONIA PLANTS

Essential equipment is of moderate to high resistance and consists of the following: hydrogen gas generators (water gas or electrolytic), air liquefaction equipment (for nitrogen gas), purifying towers, converters (where the gas synthesis is accomplished) and very heavy compressors. The converters and compressors are usually in the same or adjoining buildings and are the primary objectives. HE vulnerability classification of this building is usually V2 since overhead traveling cranes are generally present. This equipment is strongly constructed and damage by structural debris is normally slight. The electrolysis building (for electrolytic hydrogen) is usually a very large multi-bay structure and often contains traveling cranes; hence HE vulnerability is V2. The electrolytic cells are lightly constructed and are vulnerable to structural debris. However, each cell operates on a unit basis and undamaged cells can be put back into operation with relatively simple repairs to collecting mains. The preferred weapon and fuze is the one best able to create fragment damage to equipment of moderate to high resistance, as indicated in M-8.

C. CALCIUM CARBIDE AND CALCIUM CYANAMIDE

Equipment in these plants is relatively simple. Essential installations are lime kilns, small electric carbide furnaces, crushing, grinding and screening equipment, small nitrification ovens, air liquefaction equipment and electrical equipment. Most vulnerable installations are in the air liquefaction plant and the electrical rectifiers. The remaining equipment is ruggedly constructed, difficult to damage and readily repaired or replaced, if damaged.

D. EXPLOSIVES

The vulnerability of explosives plants is low. The typical plant consists of many small dispersed buildings and the equipment used is relatively simple. Propellant plants are somewhat more vulnerable than HE plants. A typical propellant plant consists of one or more medium-sized high nitrification buildings surrounded by a number of small, low structures. Most critical equipment is the nitrator and this is not too difficult to replace. Structural debris can be expected to damage most of the relatively simple equipment such as the tubs and vats used in washing, boiling and drying. Consequently, weapons should be selected to cause structural damage (M-8).

E. BY-PRODUCTS OF COAL CARBONIZATION

The most vulnerable portion of a coal carbonization plant is the coke oven installation. A full discussion of the vulnerability of coke ovens is contained in the General Analysis of the Coke, Iron and Steel Industry. Equipment used in the by-products plant consists of condensers, separators, scrubbers and purifiers. These are usually steel vessels, some of which are rather tall and in the open. Structures are usually small, single-story and often with greater than normal eave heights.

F. DYE INTERMEDIATES

The typical plant consists of many small buildings spread over a large area. Equipment used is relatively simple and consists of direct-fired and fractionating stills, condensers, mixers, washers, filters, etc. The possibility of substitution and cannibalization, which is typical of the chemical industry as a whole, is pronounced in these plants so that no unit can be called critical. Some of the materials used are dangerous if not confined, others are highly inflammable or explosive. Since equipment is generally light, it can be expected to be damaged by structural debris even from the small and lightly constructed V4 buildings in which it is usually housed. Weapons should be selected for maximum structural damage (M-8).

G. SULPHURIC ACID

Practically all major Japanese chemical plants contain units manufacturing sulphuric acid since it is used extensively as an intermediate plroduct. Essential equipment consists of sulphur burners (by-product sulphur gases may also be used), converters (contact process only), obsorption towers and lead chambers (chamber process only). Critical equipment is the converter in the contact process and the absorption tower (Glover tower) in the chamber process. Vulnerability of the process is low since equipment is generally simple and is readily repaired or replaced.

H. SODA ASH

Necessary equipment consists of lime kilns, carbonating tower, ammonia still, filters and calciners. The carbonating tower is the critical piece of equipment and is difficult to replace. Structural debris will probably damage most equipment and may possibly damage the carbonating tower.

I. ELECTROLYTIC CAUSTIC SODA AND CHLORINE

Essential equipment consists of the electrolytic cells, transformers, rectifiers, chlorine coolers and condensers, and drying towers. All equipment is relatively simple and is readily repaired or replaced except the rectifiers. The complicated electrical control system is easily damaged, but can be repaired. The rectifiers are small and can be protected by blast walls from damage by near misses. Structures are usually small shed-type buildings with low eave heights and short roof spans. Structural debris can be expected to damage most equipment. Weapons should be selected for structural damage (M-8).

J. NITRIC ACID

These are usually associated with ammonia plants. Essential equipment consists of the ammonia burners, absorption towers and the concentrating towers. The buildings housing the equipment may be of almost any type. The plants are not particularly vulnerable to attack since the equipment is not difficult to replace and substitution is easily accomplished.

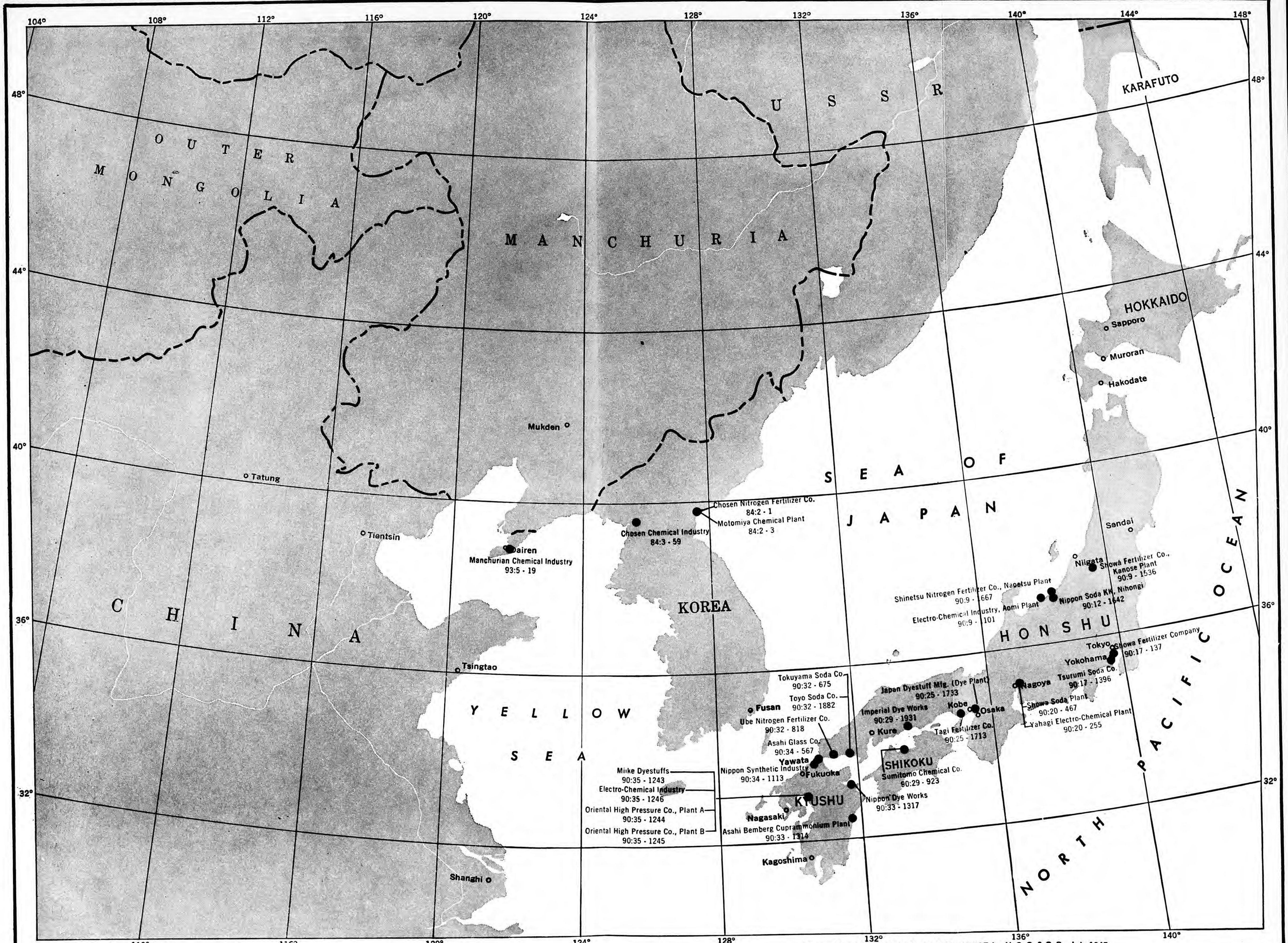
JOINT TARGET GROUP
Washington, D. C.
GENERAL LOCATION MAP

BASIC PROCESSING INDUSTRIES

CHEMICALS

CONFIDENTIAL

SHEET .... C—M1
DATE.................... 15 June 1945



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STATUTE MILES
100 0 100 200 300 400 500

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File No. 31,911

SECRET

JOINT TARGET GROUP, WASHINGTON, D. C.

SUMMARY TABLE

SHEET .... C–ST

DATE.... 11 June 1945

SECRET

TABLE II

Principal Plants—Inner Zone Chemical Industry—1945[1]

Area and target No.	Plant	Location	Major products (estimated capacity in metric tons): Nitrogen	Dyes	Explosives	Chlorine and caustic soda	Soda ash	Sulphuric acid	Calcium carbide	Miscellaneous
90:9-1536	Showa Fertilizer, Kanose Plant	Kanose	10,000-20,000						124,000	Acetone and other carbide derivatives
90:9-1667	Shinetsu Nitrogen Fertilizer Co., Naoetsu Plant	Naoetsu	10,000 calcium cyanamide.						63,000	
90:9-1101	Electro-Chemical Industry, Aomi Plant.	Aomi							137,000; one of largest	
90:12-1642	Nippon Soda KK, Nihongi	Nihongi				Caustic soda one of 3 largest in Japan. Also chlorine.				
90:17-137	Showa Fertilizer	Kawasaki	69,000; 35,000 ammonium sulphate.					Important		
90:17-1396	Tsurumi Soda Co.	Yokohama				10,000 caustic soda; chlorine				
90:20-467	Showa Soda Plant	Nagoya				Second largest chlorine plant				Ammonium chloride; probably hydrochloric acid
90:20-255	Yahagi Electro-Chemical Plant	Nagoya	21,250; 100,000 ammomium sulphate					27,000		Nitric acid
90:25-1713	Tagi Fertilizer Co.	Behu	8,500; 50,000 ammonium sulphate					300,000		27,000 superphosphates
90:25-1733	Japan Dyestuff Mfg. (Dye Plant)	Osaka		Very important; probably converted.						
90:29-923	Sumitomo Chemical Co.	Niihama	50,000; ammonia					350,000		Important methanol; phosphate fertilizer nitric acid
90:29-1931	Imperial Dye Works	Fukuyama		One of 5 largest	Ingredients					
90:32-675	Tokuyama Soda Co.	Tokuyama			Probable	Large	Large			Magnesium carbonate; ammonium chloride; sodium silicate
90:32-1882	Toyo Soda Co.	Tonda			Probable	12,900 chlorine	164,000 pre-war			Tar for synthetic oil; creosol
90:32-818	Ube Nitrogen Fertilizer Co.	Ube	45,000; ammonia		Probably large.			Some		Nitric acid and acetate plastics
90:33-1314	Asahi Bemberg Cuprammonium Plant	Nobeoka	Ammonium sulphate		Very important.	Large		Large		
90:33-1317	Nippon Dye Works	Tsurusaki		Chemical warfare	Probable					
90:34-567	Asahi Glass Co.	Tobata				110,000 caustic soda	350,000			Glass; calcium chloride
90:34-1113	Nippon Synthetic Industry	Kurosaki	17,000; 280,000 ammonium sulphate			10,000 caustic soda; chlorine		Large capacity planned		Synthetic rubber (butadiene); coke ovens magnesium; aluminum
90:35-1246	Electro-Chemical Industry	Omuta	75,000; calcium cyanamide						136,000; one of largest	
90:35-1243	Miike Dyestuffs	Omuta		Probably chemical warfare items	Picric acid and TNT					
90:35-1244	Oriental High Pressure Co., Plant A	Omuta	37,000 ammonium sulphate							Nitric acid
90:25-1245	Oriental High Pressure Co., Plant B	Omuta	Ammonium sulphate					Some		Nitric acid
84:2-1	Chosen Nitrogen Fertilizer Co.	Konan	90,000 ammonium sulphate; 75,000 nitric acid			Large		420,000		Hydrochloric acid; glycerine; nonferrous metals
84:2-3	Motomiya Chemical Plant	Konan	Small calcium cyanamide			Largest			50,000	
84:3-59	Chosen Chemical Industry	Junsen	40,000 ammonium sulphate					Some	Important	Very large nitric acid
93:5-19	Manchurian Chemical Industry	Kanseishi	240,000 ammonium sulphate		Probable			250,000	Important	Nitric acid; coke by-products

[1] Plants have not been ranked in order of importance. Only important plants have been listed and the major products of each plant indicated. Plants producing only high explosives have not been listed because they are so numerous, small, and invulnerable.

SECRET

File No. 31,921

BASIC EQUIPMENT INDUSTRIES

JOINT TARGET GROUP, WASHINGTON, D. C.
GENERAL ANALYSIS

MMT
MACHINE TOOL INDUSTRY
18 JUNE 1945

BASIC EQUIPMENT INDUSTRY

MACHINERY AND MACHINE TOOLS

MACHINE TOOL INDUSTRY

SECRET
By Authority of
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Army Air Forces
18 JUNE 1945 cw FRB
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File No. 35,011

JAPANESE MACHINE TOOL INDUSTRY

II. RELATION TO MILITARY STRENGTH

A. USES

For present purposes, machine tools may be defined as power-driven machines for metal working. Excluded from this definition are light portable power-driven tools, very heavy industrial machines such as forges and cranes, and all woodworking machinery.

Machine tools are instruments of production which are basic to manufacturing processes in all major war industries turning out end products. Some type of cutting, shaping, drilling, boring, grinding and various combinations of such metal-working are required for the finishing of all parts going into modern metal end products. Although there is an almost infinite variety of tools needed for specific uses, many of them are slight variations of general categories doing the same general type of work. Among the most important categories are the following:

	General Use
Planers	Straight line surface machining of large components.
Boring Mills and Machines	Rotary machining of large components.
Millers and Milling Machines	Machining by using rotary cutters.
Drilling Machines	Drilling of round holes in all types of components.
Turrets, Screw Machines, and Chucking Machines	Automatic multiple machine tools for high precision of turned components.
Gear-cutting Machines	Cuttings and shaping all types of gears.
Grinders	Precision finishing of flat or curved surfaces by grinding methods.
Slotters and Shapers	Rough shaping of components by reciprocating ram-driven tools.
Metal Sawing Machines	Cutting stock for machining.

Of these categories, the most basic and most generally used are the drilling machines, lathes, and millers.[1]

The principal important wartime users of machine tools are the aircraft engine, automotive (including combat vehicles), arms and munitions, and shipbuilding industries. Many of the uses to which tools are put by these manufacturers require very close tolerance work which can be performed only by high-precision machines of the best quality. Of the total inventory of tools in Japan, a comparatively small percentage can meet these precision requirements. These high-precision tools are of greatest interest. This group includes both "general" and "special-purpose" tools.

In the United States, the average length of life of a machine tool is around 20 years. However, it is useful for the highest precision work on the average for only 4-7 years. At the end of this time, it is picked up by a dealer and passed on to another user who uses tools with a lower degree of precision. This process may be repeated several times during the life of a machine. There is some reason to believe that in Japan machine tools are maintained in their most precise uses for a somewhat longer period of time than in this country, by means of more expensive and frequent overhaul. This would raise operating costs but would be justified by shortages of tools.

B. REQUIREMENTS

Demands upon Japan's machine tool industry come from three sources: (1) new expansion of industry, (2) replacement of worn or obsolete equipment, and (3) repair and replacement of equipment damaged by air attack.

Machine tool requirements for expansion of the aircraft, armament, and shipbuilding industries were more important from 1940 to 1944 than replacement of old equipment. It is estimated very roughly that Japan added about 100,000 machine tools to her total holdings during this period. This increase, added to a 5% replacement demand, gives a maximum annual requirement for 1943 and 1944 of around 50,000 tools.

By the end of 1944 expansion of Japanese machining industries had ceased for the most part with the exception of aircraft, special armaments, and perhaps electronic equipment. This is believed to have caused a decline in requirements to about 20,000 machine tools per year of which at least half were for replacements. There was probably little or no decline, however, in requirements for specialized high precision tools needed especially by the aircraft industry. Early in 1945 Japan's machine tool industry felt the initial impact of a new requirement which promised soon to overshadow all other demands — the requirement to support the recovery of industries damaged by Allied air attack. This involves a tremendous burden both of repairing damaged equipment and of replacing machine tools damaged beyond repair. The actual requirements of this type at any particular point in the bombing program are virtually incalculable but it is clear that they far exceed any past demands on the industry.

C. SUPPLY

In considering the available supply of machine tools, there must be taken into consideration not only production of new tools but also the entire existing inventory in all manufacturing plants and machine shops. The total inventory cannot be disregarded in calculating the effects of air attack upon either the machine tool

[1] No study has been made of the production of abrasives, cutting tools, jigs and fixtures. Further detailed investigation of these items might be made if intelligence indicates short supply or vulnerability to air attack.

producing industry or upon users of machine tools, because most tools are a relatively flexible production factor. Interchange of tools between uses is a common practice under normal methods of operation. It usually takes the form of movement of tools from higher to lower precision uses, but under emergency conditions the tool requirements of a high priority industry could in some cases be obtained by "borrowing" of equivalent machines from lower ranking industries, rather than out of new production. The burden could thus be made to fall where it would be felt least.

A figure for this total inventory of machines can only be arrived at indirectly through estimates of employment, production, and efficiency factors in the industries concerned. Present indications are that in early 1945 this figure fell between 300,000 and 350,000 machines as compared with the somewhat more than 1.5 million in the United States. There is no basis on which to break this total down according to types or degree of precision work involved. The following table, however, represents an effort to provide a breakdown of the inventory by industry categories, with a comparison between 1939-40 and 1943-44 employment and machine tool holdings in these industries.

TABLE II

Estimates of the Size of the Japanese Machine Tool Establishment

	Establ.	1939-40 No. Shifts	Employment
Total	217,000		1,100,000
Aircraft	7,000	1	60,000
Shipbuilding	35,000	1	200,000
Automotive	20,000	1	75,000
General Metal Fabrication	140,000	1	700,000
Textile Machinery	15,000	1	65,000
	Establ.	**1943-44 No. Shifts**	**Employment**
Total	317,000		2,940,000
Aircraft	60,000	1.8	700,000
Shipbuilding	50,000	1.5	500,000
Automotive	20,000	1	125,000
General Metal Fabrication	185,000	1.3	1,600,000
Textile Machinery	2,000		15,000

On the production side, Japan's machine tool industry has an estimated capacity of 50,000 units per year. Production is believed to have reached a peak of about 50,000 during 1943 and the first half of 1944, declining thereafter to roughly 25,000 by the end of 1944 in response to the falling off of requirements for industrial expansion.

The former belief that the Japanese are incapable of producing certain of the very difficult types of high-precision special-purpose tools has now generally been discarded as having no basis in fact. Although they may not have been able to raise their production figures on certain key machines to the levels they desire, they have been able to reproduce all the latest designs developed in this country and Europe.

Thus, it is believed that by the beginning of 1945 Japan was able to meet fully her requirements for general purpose machine tools without full use of machine tool manufacturing capacity. There is reason to believe, however, that this comfortable position did not extend to specialized and high precision tools for which supply continued to lag somewhat behind requirements, due particularly to the heavy demands of the aero-engine industry.

The outlook, however, was toward a sharp reversal of the machine tool position later in 1945 as Allied air attacks piled up damage in machine tool using industries and in the machine tool industry itself.

D. MILITARY EFFECT OF ATTACKS ON MACHINE TOOL PRODUCTION

Attacks on machine tool manufacturing capacity are of significance only when made in conjunction with attacks on important machine tool using industries, especially aero-engines and armaments. It is estimated that airframe, aero-engine, and propeller plants together contain 47,000 machine tools and primary armament and automotive plants contain about 70,000 tools. Many of the above 117,000 tools are specialized and high precision types. The machine tool industry is a major cornerstone to the resilience of these vital military end product industries. Hence its destruction will greatly retard their recuperation.

It is estimated that destruction of major machine tool plants, especially those producing a large portion of specialized and high precision tools, would retard by at least a few months the recovery of heavily damaged aero-engine and armament plants. The same would be true of shipbuilding plants.

Attacks on urban industrial concentrations which impose extensive damage upon Japan's inventory of machine tools, particularly through damage to the innumerable metal working plants, similarly will reduce the resilience of major military end product industries and increase tremendously the repair burden placed upon the machine tool industry.

Urban industrial concentrations are estimated to contain about 200,000 machine tools. This figure includes 43,000 to 48,000 of the 117,000 tools mentioned above in the aircraft and armaments industries. In all then, about 270,000 of Japan's total inventory of 300,000-350,000 machine tools are exposed to risk in an intensive program of air attacks against urban industrial areas and the aircraft and armaments industries.

III. STRUCTURE OF JAPAN'S MACHINE TOOL INDUSTRY

A. CAPACITY AND PRODUCTION

The salient factor on the production side of the machine tool industry in Japan is the recent development of the industry on a self-sufficient basis. Up until 1937, a majority of Japan's requirements for modern high-precision machine tools had been imported—from the U. S., England, and Germany. Her domestic production for 1937 has been estimated at not over 10,000 units. Ninety (90) percent of these tools were produced in roughly a dozen plants by five concerns generally known in the industry as the original "Big Five."

Tokyo Gas & Electric (Tokyo Gasu Denki)
Niigata Iron Works (Niigata Tekkosho)
Ikegai Iron Works (Ikegai Tekkosho)
Karatsu Iron Works (Karatsu Tekkosho)
Okuma Iron Works (Okuma Tekkosho)

In addition, there were over 1,000 very small plants turning out comparatively simple machines which would meet only very low standards of precision.

In 1938 Japan undertook an ambitious expansion program in the machine tool industry with the stated aim of achieving an annual productive capacity of some 50,000 machines. It is reasonably certain, considering the extent to which the aircraft and other industries have expanded, that this goal was reached during the year of peak machine tool production in 1943-44, although it probably was not by the time set for it in 1942. After the peak period of 1943 and early 1944, production probably declined substantially in response to decreased requirements for industrial expansion. Production at the beginning of 1945 is estimated roughly at 25,000 units, or only 50% of capacity. It is probable, however, that capacity for specialized and high precision tools continued to be utilized fully.

Some reports indicate that a considerable part of the unused portion of Japan's machine tool industry was converted after June 1944 to production of aero-engine parts. If so, this would impose a handicap on the industry in attempting to meet requirements imposed by Allied air attacks.

B. CONCENTRATION BY PLANTS

There are a large number of plants in the Japanese machine tool industry and only a moderate concentration of production in the more important plants. Out of a total of about 400 companies with an estimated 440 plants, some 60—operating 100 plants—are believed to produce about 95% of the total output. Of these, the 27 priority plants listed in Table III probably represent 40-50% of total production. In the absence of any production statistics, these figures are estimated from the data on authorized or paid-in capital, and are therefore to be taken only as indicative of the most probable situation. In terms of precision machines, the degree of concentration in the priority plants is somewhat higher, although by no means all precision tools are manufactured by them. If these plants were neutralized, it would be extremely difficult, if not impossible, to replace their output from the production of other plants, even were their skilled mechanical and supervisory labor shifted to the smaller plants remaining.

In the selection of plants as priority targets in the machine tool industry, primary consideration has been given to the requirements of the aircraft and ordnance industries for the products of the selected plants.

C. GEOGRAPHICAL CONCENTRATION AND EXPOSURE TO URBAN AREA ATTACKS

The machine tool industry has grown up around the industries which it serves. It originally developed in the Tokyo region and much of it is still concentrated there. New development since 1937 has likewise been in the old established industrial regions, although there has been a tendency to build new plants just outside the crowded urban areas. The following table shows the regions in which these concentrations now exist, as well as the extent to which the plants are located within congested industrial areas exposed to urban area attack. For the purposes of this analysis, 143 plants—representing the bulk of the industry—have been selected.

TABLE III

Machine Tool Plants by Principal Industrial Regions

Industrial Region	No. of Plants in Region		No. of Plants in Urban Ind. Concentrations	
	Priority Targets	All Plants	Priority Targets	All Plants
Tokyo	4	47	2	43
Osaka	4	31	1	23
Nagoya	3	13	3	10
Kawasaki	4	8	2	5
Yokohama	2	5	1	2
Niigata	2	3	2	3
Hiroshima	2	2	1	1
Other Regions	6	34	2	16
Totals	27	143	14	103

Thus over 70% of the 143 plants and over one-half of the priority targets are located within urban industrial concentrations. The percentage is somewhat lower for the most important plants because, during the recent expansion, many of the new plants were located outside built-up areas.

D. RESILIENCE

The machine tool industry is largely self-dependent for its resilience, though to some extent it can borrow from other industries. With increased damage to machine tool using industries, unused capacity will disappear quickly in the machine tool industry, thus eliminating this important cushion which existed at the beginning of 1945.

The chief bottleneck to restoration of production following successful attack would be replacement of machine tools doing the work, rather than of the plant buildings themselves. If only one or several machine tool plants were damaged, they would obtain new tools comparatively quickly from other plants in the industry. If, however, a majority of the leading plants were attacked, considerable difficulty would be experienced in replacing machines. Some could be obtained by "borrowing" from end products industries, but only at the expense of loss of production in those industries. Furthermore, comparatively few of the tools which could be made available in this fashion would have the requisite degree of precision, making necessary a further period of delay for overhaul of these borrowed machines in previously reconstructed shop buildings. Probably the greatest difficulty would be experienced with the heaviest models.

In Britain, the greatest loss of production time has occurred from damage to heavy machine shops. It has been estimated that a total of 12 months is necessary for replacement of essential equipment in these shops, entailing an estimated loss of production of about 8 months. The difference is accounted for by a certain amount of subcontracting in the interim period. With damage to light machine shops, on the other hand, 6 months has been required for replacement of productive facilities, whereas only an estimated one-month's loss of production resulted. In Britain, the light machine shop work can be extensively subcontracted, but not sufficient facilities are available elsewhere to perform any great proportion of the heavy work. British statistics for the assembly and packing department are 8 months for replacement and a 2 months' production loss. If considerable stocks of materials are lost, the production time loss will be several months longer.

It is believed that Japanese experience would show a similar time period for restoration of production facilities but that the total time of production loss would be somewhat greater owing to less opportunity for subcontracting. It is doubted that a proportionate machine shop capacity doing precision work would be available in Japan.

IV. PRODUCTION PROCESS

A. MAIN STAGES OF PRODUCTION AND PRINCIPAL EQUIPMENT

Only a comparatively small plant is needed for the manufacture of machine tools. Although part of the production may be organized on an assembly line basis, no mass production is possible in this industry for several reasons. The work must be of extremely high quality in order that the completed machines have the required close tolerances. In addition, the orders for a particular size or type of machine are never large and the pattern of production is constantly changing. Employment in a single plant will generally not run over 1,000 men, most of whom are highly skilled laborers.

Starting with high-grade steels and alloys, the manufacturer produces practically all the parts for the machine himself, including the bed and columns, the main shaft or spindle, gears, cutting tools, jigs (for guiding the work), and fixtures (for holding the work). Bearings and motors are generally obtained from other manufacturers. In this work, a comparatively small number of standard machine tools are required, but they must have a relatively high degree of precision.

The plant required for this work is contained in a compound not over 1500 ft square as a general rule. Within this compound there are 6 to 10 main production units. The larger plants have their own foundries because of the high-quality castings required. Smaller plants may subcontract this work. Practically all plants have forging facilities. There are usually several machine shops in which the normal metal working processes, employing lathes, milling machines, grinders, gear cutters, and so forth, are carried on. A final central assembly shop is needed for building the finished tools. Much final machining is done here because of the close tolerances required of the moving parts. Almost all plants also have a small heat-treating shop, where the work must be of high quality. The administrative section of the plant contains drafting and experimental rooms in which new designs are laid out and new jigs and fixtures are planned for the special requirements of a particular order.

B. PRODUCTION TIME FACTORS

The total time required for the production of machine tools varies greatly according to the type of tool being manufactured. Estimates made by British concerns have varied from three months to over a year. Considerable stocks of raw materials and parts are maintained around the plant at all stages of production. At the start of the production process, castings must be "aged" to prevent deformation during machining. The machining of parts runs consistently ahead of the assembly schedule, in order to have an adequate supply on hand and to provide users of machine tools with spare parts as required. The assembly and final testing require considerable time and cannot be hurried because of the painstaking work involved. Minimum material on hand and machines in process would be the equivalent of three months' production. There is no stocking of completed machines by manufacturers. Shipments are made immediately following testing of those who have ordered them.

C. VITAL FACILITIES

The most critical part of a machine tool plant is the central assembly shop where all parts are brought together for final accurate machining and assembly. This shop contains the indispensable heavy cranes as well as the equipment with the closest tolerances. The various machine shops are also of major importance because of the high-precision machine tools contained in them. Foundries and forge shops are only of secondary importance because their operations are comparatively simple and the work could be subcontracted if necessary.

Damaging the buildings housing the precision processes is considerably less important than destruction of machines and equipment. Loss of tools and material in process is not the major objective but increases the production loss resulting from a successful attack.

V. PHYSICAL VULNERABILITY AND WEAPON RECOMMENDATIONS

The manufacture of machinery and machine tools is carried out mainly in steel framed structures of vulnerability classes V2 and V4 (for definitions see JTG M-8). The proportion of each class in a given target will vary, depending somewhat on the type of product. Normally, the proportion of V2 will lie between 10 and 40 percent of the whole target.

The attack of this type of target is identical to the attack of any machine industry employing similar machinery housed in similar structures. For recommendations regarding choice of weapons and weight of attack for a desired level of damage, reference should be made to JTG M-8 and to JTG Target Information Sheets dealing with specific targets in this category.

BEI—MMT
MAPS & TABLES

JOINT TARGET GROUP
Washington, D. C.
GENERAL LOCATION MAP

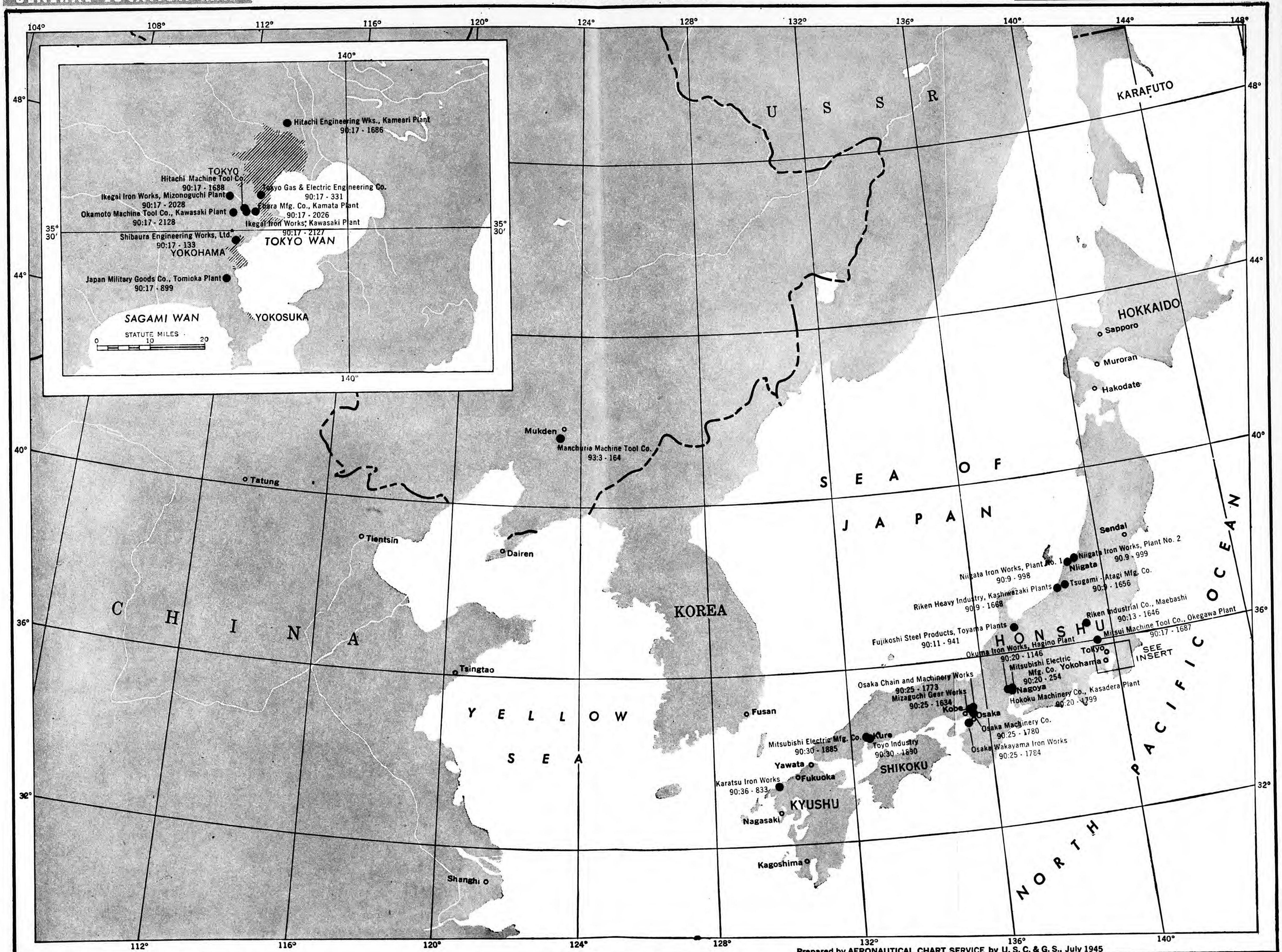
BASIC EQUIPMENT INDUSTRIES

MACHINERY AND MACHINE TOOLS

MACHINE TOOL INDUSTRY

CONFIDENTIAL

SHEET.................... MMT (MT)–M1
DATE...................... 15 June 1945



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STATUTE MILES
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File No. 37,911

JOINT TARGET GROUP, WASHINGTON, D. C.
SUMMARY TABLE

BASIC EQUIPMENT INDUSTRY
MACHINERY AND MACHINE TOOLS
MACHINE TOOL INDUSTRY

SHEET . . . . . MMT (MT)–ST
DATE . . . . . 18 June 1945

MAJOR JAPANESE MACHINE TOOL PLANTS

TABLE IV
Major Japanese Machine Tool Plants

Target	Name of Plant	Location	PRINCIPAL PRODUCTS (REPORTED)													Remarks
			Boring Mills (Vertical)	Broaching Machines and Broaches	Gear Cutting Machines	Grinders	Hones and Lapping Machines	Jig Borers	Gun Turning and Boring Lathes	Millers and Milling Machines	Screw Machines[1]	Slotters	Turret Lathes	Products used in mfr. of: Aircraft Engines	Products used in mfr. of: Ordnance	
90:9 -998 90:9 -999	Niigata Iron Works, Plant No. 1 Niigata Iron Works, Plant No. 2 (Niigata Tekkosho KK)	Niigata	X	X		X	X			X		X		X	X	Old established mfr. of complete line of high-precision machine tools. Also reported to make rolling stock, Diesel engines, oil well machinery.
90:9 -1656	Tsugami-Atagi Mfg. Co. (Tsugami-Atagi Seisakusho)	Nagaoka				X		X						X	X	Thread and screw grinders.
90:9 -1668	Riken Heavy Industry, Kashiwazaki Plants (Riken Jukogyo)	Kashiwazaki			X	X				X				X	X	Piston rings also mfgd. here.
90:11-941	Fujikoshi Steel Products, Toyama Plants (Fujikoshi Kozai Kogyo KK)	Toyama		X										X	X	
90:13-1646	Riken Industrial Co., Maebashi (Riken Kogyo KK)	Shin-Maebashi				X				X				X		Reported production of internal combustion engines, aircraft parts.
90:17-133	Shibaura Engineering Works, Ltd. (Shibaura Seisakusho)	Yokohama	X	X								X		X	X	Heavy duty machine tools.
90:17-331	Tokyo Gas and Electric Engineering Co. (Tokyo Gasu Denki)	Tokyo				X	X			X		X		X	X	A Hitachi concern. Most types of grinders; possibly the most important Japanese producer of milling machines.
90:17-899	Japan Military Goods Co., Tomioka Plant (Dai Nippon Heiki KK)	Yokohama				X				X				X	X	This plant also manufactures ordnance.
90:17-1686	Hitachi Engineering Works, Kameari Plant (Hitachi Seiki KK)	Tokyo				X				X	X		X	X	X	Hand-operated screw machines; reported to specialize in turret lathes.
90:17-1687	Mitsui Machine Tool Co., Okegawa Plant (Mitsui Kosaku Kikai KK)	Okegawa				X								X	X	Recently built with Norton help for production of Norton-type grinders.
90:17-1688	Hitachi Machine Tool Co. (Hitachi Seiki KK)	Kawasaki					X			X				X	X	
90:17-2026	Ebara Mfg. Co., Kamata Plant (Ebara Seisakusho KK)	Tokyo	X												X	Large size boring and turning mills.
90:17-2028	Ikegai Iron Works, Mizonoguchi Plant (Ikegai Tekkosho KK)	Kawasaki			X	X								X		
90:17-2127	Ikegai Iron Works, Kawasaki Plant (Ikegai Tekkosho KK)	Kawasaki			X	X								X	X	Also large size machine tools for special purposes.
90:17-2128	Okamoto Machine Tool Co., Kawasaki Plant (Okamoto Kosaku Kikai KK)	Kawasaki			X									X		Specializes in gear-cutting machines.
90:20-254	Mitsubishi Electric Mfg. Co. (Mitsubishi Denki KK)	Nagoya				X				X			X	X	X	Surface grinders; special milling machines; planned '40 to make Warner & Swazey or Gisholt turret lathe.
90:20-1146	Okuma Iron Works, Hagino Plant (Okuma Tekkosho KK)	Nagoya	X			X				X			X	X	X	
90:20-1799	Hokoku Machinery Co., Kasadera Plant (Hokoku Kikai KK)	Nagoya										X			X	
90:25-1634	Mizaguchi Gear Works (Osaka Seisa Zoki KK)	Osaka			X									X		Gear cutters, Sunderland-type hobbers, Gleason generators, shapers.
90:25-1773	Osaka Chain and Machinery Works (Osaka Seisa Zoki KK)	Ibaragi				X						X		X	X	Cylindrical and internal grinders; heavy-duty slotters
90:25-1780	Osaka Machinery Co., (Osaka Kiko KK)	Itami								X		X		X	X	
90:25-1784	Osaka Wakayama Iron Works (Osaka Wakayama Tekkosho KK)	Fukuizumi				X				X			X	X	X	Now called Japan Machine Tool Co. (Dai Nippon Koki KK) Internal grinders; German Pitler-type turret lathes.
90:30-1885	Mitsubishi Electric Mfg. Co. (Mitsubishi Kosaku Kikai KK)	Hiroshima								X			X	X	X	Formerly Toyo Kikai KK. Van Norman-type millers.
90:30-1890	Toyo Industry (Toyo Kogyo KK)	Hiroshima				X								X	X	Internal and Heald automatic grinders.
90:36-833	Karatsu Iron Works (Karatsu Tekkosho KK)	Karatsu	X		X	X			X	X		X	X	X	X	Gear shapers and hobbers; most types of grinders; gun boring lathes.
93:3 -164	Manchuria Machine Tool Co. (Manshu Kosaku Kikai KK)	Mukden	X		X	X				X					X	Important because adjacent to the Mukden Arsenal (Target 46) which it undoubtedly serves.

[1] Only one plant is listed as making screw machines, and none the multiple automatic variety, but there are undoubtedly others making this important item.

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JOINT TARGET GROUP
Washington, D. C.
GENERAL LOCATION MAP

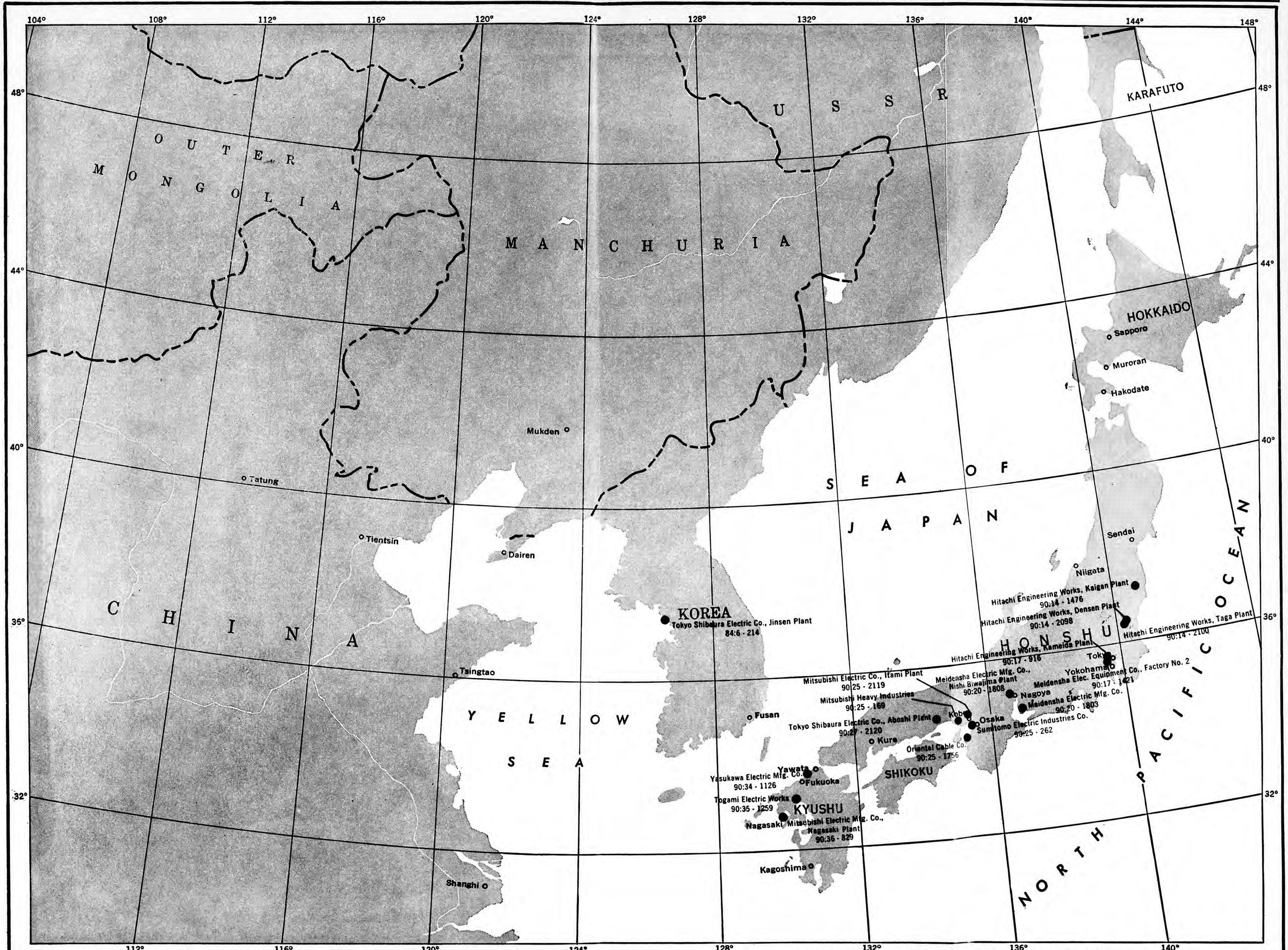
BASIC EQUIPMENT INDUSTRIES

MACHINERY & MACHINE TOOLS

HEAVY ELECTRICAL EQUIPMENT

CONFIDENTIAL

SHEET .... MMT (HE)—M1
DATE .... 15 June 1945



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STATUTE MILES
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CONFIDENTIAL

BEI
TRANSPORTATION
EQUIPMENT

JOINT TARGET GROUP, WASHINGTON, D. C.
GENERAL ANALYSIS

TE
MERCHANT SHIPPING
28 JUNE 1945

BASIC EQUIPMENT INDUSTRIES

TRANSPORTATION EQUIPMENT

MERCHANT SHIPPING

SECRET
By Authority of
The Commanding General
Army Air Forces
28 JUNE 1945 [initials]
(Date) **(Initials)**

Published in Office of AC/AS Intelligence, A. A. F., by Combined Personnel of U. S. and British Services for the use of Allied Forces

I. CURRENT STATUS AND DEVELOPMENTS

A. PRESENT POSITION

1. Requirements

The relative values of shipbuilding and other applications of steel machine tools and manpower to Japan have shifted radically since 1944. In that year Japan was not, until the very end, under direct attack and she was still able to maintain sea traffic with areas south and west of Formosa and had every incentive to do so despite heavy ship losses. Those areas have now been either liberated or cut off from Japan and our forces have moved up to within easy striking distance of the Home Islands. While Japan's appraisal of the situation by her leaders must lead to the conclusion that within a period of months the sea lanes to the mainland will be closed to her regardless of the number of bottoms she then has available. However, as long as sea bases are open and additional imports can be brought in by accepting additional losses there is a large need for new tonnage. Coupled with this is the pressing need to produce more of the ground force armaments which must now be her principal reliance in the fighting that lies ahead. So far as enemy intentions and capabilities will be determined by a choice of the most rational use of the resources available to him, it is to be anticipated that the priority accorded shipbuilding has or soon will be very sharply reduced despite the immediate need for more tonnage.

2. Supply

New estimates of Japan's current output of ships are in the course of formulation. It is certain that the rate is less than 1,200,000 tons of steel ships which may have been the 1944 rate. Occupancy of the major ways is still 60 percent or more but this may represent nothing more than a decision to use up materials on hand. Later in 1945 the building rate will almost certainly be lower due to a drop in the rate of steel production to no more than 2,500,000 tons in Japan Proper and because of bomb damage from urban area attacks. Whether Japan will attempt to maintain the highest possible building rate irrespective of other demands for men and materials is yet to be determined.

B. EFFECTS OF AIR ATTACKS

While detailed study of all the damage to shipbuilding caused by urban area raids is not completed, it is clear that the larger yards have been relatively little affected. Wooden shipbuilding in Osaka received considerable damage, but this represents a minor part of the total in Japan. The most important damage has been to marine engines and marine engine components. Probably more than 25 percent of the capacity for producing smaller marine engines in Osaka was destroyed. The most important plant damaged was the Mitsubishi Heavy Industries Shop (Target 90:25-169). Damage was concentrated in the machine shops producing diesel engines.

C. CURRENT PRINCIPAL TARGETS

In spite of the damage to date the more important yards are those listed in Summary Table 2 (ST1). However, none of these are primary targets at the moment. Attack on wooden shipbuilding facilities has the best possibilities of affecting military strength. Summary Table 2 (ST2), to be issued later, will indicate the current status of each target.

II. RELATION TO MILITARY STRENGTH

A. USES

Japan must build (and repair) merchant ships in order to maintain sufficient shipping to meet her needs for imports, coastal traffic, and military traffic between Japan and the main land. For details as to Japan's minimum requirements for shipping see Basic Services and Utilities; Shipping—General Analysis.

B. REQUIREMENTS

Japanese requirements for new bottoms are practically unlimited. Japan would clearly wish a merchant fleet necessary to carry all the imports needed and available to her. Thus, shipbuilding should be geared to match current sinkings and to "make up" the spread between available tonnage and that required for necessary imports.

With the cutting off of the outer zone Japan's requirements for shipping have decreased. At the same time ship sinkings have fallen to about one-third of their 1944 average. In spite of this, so long as marine movement continues to be possible requirements for new shipping will remain pressing. If the blockade of Japan becomes sufficiently tight as to the use of existing ships new ships would, of course, no longer be required.

C. PRODUCTION

In spite of great efforts production has not met minimum requirements. Even if tonnage produced reached the peak of 1,200,000 tons in 1944, this represents only about ½ of 1944 losses. For the period from 7 Dec 1941 to 31 May 1945 Japan's losses exceed shipbuilding by over five million tons and the size of her merchant fleet decreased from about 6 million tons to around one and three quarters million.

Production will probably decrease in 1945 partly from direct effects of urban area attacks and partly through shortages of war materials. Sinkings during the early months (February-May) of 1945, however, decreased even more sharply and the net loss in Japanese shipping will probably not approach the magnitude experienced in 1944.

D. MILITARY EFFECT OF ATTACKS ON PRODUCTION

The effect of attacking shipbuilding depends on Japan's current shipping position and on the priorities accorded to the shipbuilding industry for procurement of scarce materials, particularly steel. During 1944 attacks of sufficient weight to have cut building by 50 percent for the entire year (possibly as much as 600,000 tons) would have made Japan's position considerably tighter throughout the period. However, in view of contracting requirements attendant upon loss of the Philippines and severance of the southern sea routes, no crucial cut in imports would have been obtained.

In 1945, attacks on shipbuilding reducing output 50 percent over 1944 levels would have only a nominal effect if sinkings in the inner zone continue about on the previous level (see Shipping—General Analysis). Loss of 50,000 tons of new shipping per month (50 percent cut from 1944 rate for steel ships) would not affect the rate of imports within a year. If shipping becomes excess due to blockade there will, of course, be no military effect of attacking shipbuilding.

Shipbuilding has been the principal competitor of armaments for Japanese steel and up to the end of 1944 appeared to have a higher priority. Thus, successful attacks on shipbuilding might result in a shift of scarce steel supplies to the armament industry. Another possible development is a cut in steel output during 1945 which in itself will reduce sharply Japan's rate of shipbuilding.

III. STRUCTURE OF THE SHIPBUILDING INDUSTRY

A. CAPACITY AND PRODUCTION

Production of ships in 1944 was close to Japanese maximum capabilities.

1. Steel

New construction of steel merchant vessels during 1944 may have been at the rate of about 100,000 g. r. t. per month. This rate of building is 240 percent of the maximum prewar rate. It has been attained by giving shipbuilding a priority on men and materials second only to aircraft, by expansion of existing yards, particularly certain of the smaller ones, by building new yards, by adoption of standardized types of vessels and in at least one yard, prefabrication, and by intensive use of existing facilities. The increase of production has been accomplished simultaneously with the maintenance of a high rate of naval building.

The sum of available intelligence indicates the steel shipbuilding industry was working to the limit of capacity at the end of 1944 and that expansion of facilities was still continuing. If major naval construction should cease, a further substantial increase in merchant vessel construction would become possible granted continued allocation of the necessary steel.

2. Wooden

As Japan's merchant marine has dwindled under our constant attack and as it has been made apparent to her that attempts to operate ordinary merchant vessels in areas of active operations will only increase such losses, she has turned to the building of standardized wooden vessels of 70, 100, 150, and 250 g. r. t. The undertaking of this type of construction is in part due to the steel shortage, in part to a policy of dispersion of risk in the face of attack, in part to a hope of achieving a large increase in new construction not only in Japan proper but in conquered areas, without a heavy investment of new plant and skilled manpower.

Despite considerable fanfare in the Japanese press, the participation in the program of such major concerns as Mitsui and NYK[9] and the building of over a score of new yards, little progress was achieved in 1943 and the early part of 1944 in securing new construction of wooden vessels on a large scale. Recent photographs of port areas in Japan and on the mainland and certain prisoner of war reports show, however, that large numbers of standardized wooden craft are operational and that building is extremely active.

B. CONCENTRATION

1. Steel

Japan's steel shipbuilding is heavily concentrated in the Japanese islands which have more than 92 percent of total production. It is believed that in 1944 the mainland was producing at the rate of less than 100,000 g. r. t. at best. While there are important yards at Hongkong and Shanghai, production has been retarded by lack of supplies from Japan, and by air attack. There are only 2 yards known to be on the mainland north of the Yangtze. These 2 yards, one at Dairen and the other at Fusan, are credited with an annual capacity of 25,000 g. r. t. each.

Sixty-two percent of current steel merchant tonnage building capacity is accounted for by 16 major yards. These contain 60 ways constituting 36 percent of the total number of ways available. In addition, these 16 major yards contain 24 ways estimated to be assigned to naval construction. Forty-six minor yards with about 106 building ways (65 percent of ways in Japan) account for 38 percent of steel merchant tonnage capacity.

The distribution of ways between major and minor yards in Japan proper, and the maximum gross tonnage in merchant vessels that can be accommodated simultaneously, set forth below, indicates a somewhat higher concentration of construction facilities for vessels over 2,000 g. r. t., with about 70 percent of the ways appropriate for this type in the 16 major yards.

Tonnage class	16 major yards		46 minor yards		Total, 62 yards		
	Number of ways	G. r. t.	Number of ways	G. r. t.	Number of ways	G. r. t.	Percent of g. r. t.
2,000 g.r.t. and over..	55	251,950	50	116,520	105	368,470	90
1,000 g.r.t./500 g.r.t..	5	4,830	56	37,980	61	43,010	10
Total.........	60	256,780	106	154,500	166	411,480	.....
Percentage distribution	36	62	64	38	100	....	100

The degree of concentration in the major yards is higher than that indicated by the above summary of way capacity since the building rate is likely to be higher in the major yards than in the minor ones, where yard equipment, especially cranage, is less adequate to sustain an accelerated rate. Data on individual yards are given in Summary Table 1 (ST1).

2. Marine Engines and Components

While a large percentage of marine engine capacity for the larger tonnage classes is still concentrated in the major shipyards, production of smaller engines, both Diesel and steam, has been expanded and dispersed.

For the 4-year period just prior to the war (1936-39) when the industry was building on the average 400,000 g. r. t. of merchant vessels per annum, 85 percent of all merchant marine engines (measured in horsepower) and 100 percent of naval engines were built in ten major commercial yards and four naval bases; three commercial yards alone[14] accounting for about 50 percent of merchant vessel engines, and at least 25 percent of naval engines.

[9] Mitsui alone is reported to have had a program for the construction of 200 of the 250 g. r. t. type for 1944.

	Percent
[14] 90.25–171 Kawasaki D/Y (Kobe)........	18
90.36–542 Akanoura Engine Works (Nagasaki)........	17
90.27–1295 Mitsui Tama S/Y (Tama)........	17
	52

An increased demand for engines by a wartime trebling of merchant tonnage construction has been met by stepped up production in the major yards, and by utilization of capacity in the larger diversified engineering plants. This is particularly true of the larger tonnage classes which are powered by steam turbines, a type of engine not readily built in small shops. The concentration of tonnage in the larger merchant vessel classes indicates a corresponding utilization of large plant capacity for engine building. It is estimated that well over 50 percent of marine engines used in merchant vessels of 2,000 g. r. t. and upward is produced by less than 10 major yards and three diversified plants of Hitachi Engineering, Niigata Iron Works, and Shibaura Engineering. The large Shibaura Works in Yokohama is stated by a PW report to be supplying the Tsurumi yard with heavy components, probably turbines, delivered by railroad car.

Engine-building capacity for small tonnage classes using Diesel and steam reciprocating machinery is reported to be dispersed among at least 50 machine shops, 20 of which are said to be producing Diesels for the wooden ship program. While small engine building has been dispersed with respect to plant production, it is heavily concentrated in Kobe-Osaka and Tokyo-Kawasaki. Osaka alone is credited with about 25 percent of all merchant vessel engine components, and the bulk of Diesels (from 75 to 200 horsepower) used in wooden ships.

3. Wooden Shipbuilding

In Japan proper, the numerous independent small yards building wooden craft of all descriptions have been merged to a considerable extent into some 600 organizations, and new groups under the control of major steamship operators such as the Osaka Shosen Kaisha, Nippon Yusen Kaisha, and the Mitsui Co., have been formed. This centralization of control has resulted in the expansion of older yards, and construction of new yards. The wooden shipbuilding program has been given high priorities, and granted heavy subsidies by the government.

Small yards for building and repairing wooden vessels are numbered in hundreds, and are widely dispersed on both coasts, from southern Hokkaido to west Kyushu. While analysis of photo reconnaissance to date has not been complete enough to estimate the number of effective yards operating, or to estimate tonnage production, new yards have been shown which are launching hulls resembling standard types. For instance, in a new yard at Tokushima (east coast of Shikoku), cover of 19 January 1945, there were 8 vessels on the ways, and another 8 afloat alongside. This yard, building two tonnage classes of 115 and 95 footers, as well as craft of 45 feet, has certain features which indicate that it may be 1 of the 20 new yards reported planned by the major wooden ship building concerns.

Standard wooden ship types adopted for a much publicized "mass" production, fall into several tonnage classes ranging from 100 to 300 g. r. t. and including full-powered steam and Diesel, and auxiliary Diesel types. Little is reported of steam propulsion machinery used, but standardized Diesels of 75, 115, and 200 horsepower is reported as adopted for the 100, 150, and 250-ton full-powered classes respectively, giving a cruising speed of 7 knots. The auxiliary types, also engines aft, are gaff-rigged with the gaff serving as cargo boom. While hull building is widely dispersed, engine building is believed to be largely concentrated in the Osaka and Tokyo Bay machine shops; engines, fittings and tackle are reported delivered to the hull building yards.

Another type of composite wooden vessel with a steel frame has been reported. This type, in three size-classes (300, 600, and 1,000 g. r. t.), has been reported under construction in four shipbuilding centers of Japan Proper, while a ship of 2,500 g. r. t., of steel frame and wooden planking, is reported as launched in Tientsin (North China), November 1944.

While some mainland yards for the building of full-powered wooden ships have been reported, especially on the west coast of Korea, the bulk of capacity to produce these types north of Formosa is in Japan Proper. A notable example of junk production, however, is in the extensive yard at Antung, where some 150 "ways" are shown by photo reconnaissance (5 February 1945); 13 ways are occupied by incomplete junks, and some 75 junks are afloat alongside, and at anchor off the yard.

In addition to power-driven wooden vessels, great numbers of wooden junks are being built on the mainland. Cover of Antung in February 1945 shows over a hundred of these ships of a standard type about 115 feet long.

4. Repair and Maintenance

The repair and maintenance side of Japanese shipyards is not so fully occupied. Total drydock capacity in Japan and on the mainland from Hongkong north is somewhat in excess of 600,000 g. r. t. Assuming that the average vessel drydocked occupies about 70 percent of the dock's capacity, some 420,000 g. r. t. of merchant shipping can be simultaneously drydocked. These facilities were built to take care of the needs of a merchant fleet of triple the present tonnage as well as of a much larger naval fleet. While the damage the yards are now called upon to repair is more severe than that occurring in peacetime and while the percentage of ships laid up for repairs is larger, these factors are not sufficient to counterbalance the shrinkage of the fleets and there is substantial unused repair capacity available.

C. EXPOSURE TO URBAN AREA ATTACK

The concentration of shipbuilding capacity in urban areas is shown in Table 3.

TABLE 3

Area	% Steel M/U Bldg. Capacity		% Wooden S/B Capacity	% Marine Engine Capacity	
	Major Yards	Minor Yards		Steel M/U	Wooden
Tokyo (all included)	3.5		3.0	20	10
Kawasaki (included)	8.2				
Yokohama (included)	5.5	4.8	1.0		
Nagoya (included)		5.2			
Osaka (all included)	7.4	32.9	6.5	15	50.0
Niigata		2.0		2	2
Amagasaki		3.5			
Kure				3	
Kobe	15.0[1]	1.0[1]		15[1]	
Sasebo				2	
Nagasaki	22.6[1]		3.0[1]	10	10
Total Inclin U/Cs	24.6	48.4	10.5	47	72
Total For Port	62.2	49.4	13.5	62	72

Building Capacity = Way capacity in gross tonnage of standard M/U types. (All ways counted—no allowance made for ways used for Naval building, or ways not used at all.) Nor is allowance made for a faster hull building rate in the major yards—to adjust for this difference, minor yards should be weighted by no more than two thirds of the major yard building rate.

[1] Not included in Urban Industrial Concentrations.

Wooden shipbuilding while vulnerable to incendiary attack is not located in urban areas. Major Japanese shipyards are at best moderately vulnerable to incendiary attack. Over 60 percent of capacity is located in the major cities, but only 25 percent of it lies in the Urban Industrial Concentrations. Urban Industrial Concentrations include the principle mass of manufacturing structures, while shipbuilding tends to be on the edges of industrial zones. This peripheral position is offset in some measure by congestion and a ramshackle type of shop-housing. With the exception of the Tsurumi Steel and Shipbuilding Co. at Kawasaki (Target 90:17-122), none of the major yards have been modernized in structure or plant layout. This congestion is significant because of the self-container character of the yards which are also engine builders, and fitters.

Marine engines are most vulnerable to urban attack because of the high concentration of such engines in congested industrial zones and the vulnerability of most of the structures to such attack.

D. RESILIENCE

Susceptibility to lasting damage is high in the case of ships even when on the ways or in drydock though the possibility of causing total loss, of course, is considerably less than in the case of ships afloat.

Empty graving docks and ways are difficult to damage severely though if cranes, gates or pump houses are directly hit, repairs may take a matter of months. As to graving docks in low lying ground, it is likely that perforations of the side or bottom would admit large quantities of water and mud.

Floating drydocks have somewhat the same susceptibility to damage as ships though they are more compartmented and less subject to fire damage.

Shops in shipyards have about the same susceptibility to damage as heavy engineering works. Mold loft shops are susceptible to incendiary attack, but the heavy machine shops are relatively poor incendiary targets.

Recovery time following heavy loss of shops in shipyards or marine engine works will largely depend on whether it is possible to substitute other engineering and motoring facilities by transfer from other uses.

IV. PHYSICAL VULNERABILITY AND WEAPON RECOMMENDATIONS

The most important targets falling in this category are (1) steel ship construction, (2) wooden ship construction, (3) marine engine manufacture. The first and last of these are discussed in EPI-A (Armament) while the choice of weapons for attack of merchant ships is given in BSU-S (Shipping).

For attacking wooden ships under construction the preferred weapons are the small IB, M50 or M69. In general, wooden ships will be built in regions where wood is plentiful; consequently most of the structures adjacent to the construction ways, including the ships themselves, will be combustible and vulnerable to IB. It must be expected that fire fighting will be unusually effective due to the proximity to water and the large number of fire fighters available. For this reason, it is recommended that a proportion of incendiaries with X or WP feature be used. When available, anti-disturbance fuzed anti-personnel bombs may usefully be added.

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SUMMARY TABLE

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TABLE 2
Japanese Commercial Shipbuilding and Repair Facilities
MAJOR SHIPYARDS

Target Name	Target Number	Location	Number of Building Ways	Number of Drydocks: Large (Over 300 feet)	Number of Drydocks: Small (Under 300 feet)
Akunoura Engine Works	90:36-542	Nagasaki	—	—	—
Asano Dockyard	90:17-70	Yokohama	2	2	—
Fujinagata Shipbuilding Co.	90:25-273A	Osaka	3	2	—
Fujinagata Shipbuilding Co.	90:25-273B	Osaka	4	—	—
Habu Shipyards	90:29-927A	Innoshima	4	3	—
Hakodate Dockyard	90:4-974	Hakodate	4	2	—
Harima Shipyard	90:27-1296	Oo Bay	5	2	—
Ishikawajima Dockyard	90:17-330	Tokyo	—	—	—
Kawanami Industry Co. Shipyard	90:36-860	Nagasaki (Koyagi Is.)	6	1	1
Kawasaki Heavy Industry Co.	90:25-171	Kobe	6	1	—
Mitsubishi Dockyard	90:36-543	Nagasaki	—	3	—
Mitsubishi Heavy Industries	90:25-169	Kobe	5	3	—
Mitsubishi Shipyard	90:34-1846	Hikoshima	4	2	1
Mitsui Tama Shipyard	90:27-1295	Tama	6	3	—
Muroran Dockyard	90:3-1683	Muroran	?	1(?)	—
Osaka Iron Works, Unit No. 1	90:25-272	Osaka	5	1	—
Shannosho Shipyards	90:29-927B	Innoshima	2	1	1
Susaki Dockyard	90:17-1459	Tokyo	6	2	—
Tategami Shipyard	90:36-544	Nagasaki	6	—	—
Tsurumi Steel & Shipbuilding Co.	90:17-122	Kawasaki	6	—	—
Uraga Dockyard No. 1	90:17-1460	Uraga	2	1	—
Uraga Dockyard No. 2	90:17-1461	Uraga	2	1	—
Yokohama Dockyard	90:17-69	Yokohama	5	3	—
			84	34	3

MINOR SHIPYARDS

Target Name	Target Number	Location	Number of Building Ways	Large (Over 300 feet)	Small (Under 300 feet)
YOKOHAMA					
Kotaki Dock	90:17-N/A	Yokohama	1	—	—
Yokohama Iron Works	90:17-N/A	Yokohama	3	—	—
Yokohama Engineering Works	90:17-N/A	Yokohama	1	—	—
OSAKA					
Amagasaki Shipyard	90:25-N/A	Osaka	1	—	1
Endo Shipyard	90:25-N/A	Osaka	2	—	—
Harada Shipyard	90:25-N/A	Osaka	1	—	2
Horai Shipyard	90:25-N/A	Osaka	1	—	2
Kizugawa Dockyard	90:25-N/A	Osaka	1	—	2
Midsuno Shipyard	90:25-N/A	Osaka	2	—	—
Mihara Shipyard	90:25-N/A	Osaka	2	—	—
Nakada Shipyard (Minami Okajima)	90:25-N/A	Osaka	2	—	—
Nakada Shipyard (Tsumori)	90:25-N/A	Osaka	3	—	—
Namura Shipyard	90:25-N/A	Osaka	2	1	1
Naniwa Dockyard	90:25-N/A	Osaka	3	1	—
Nihon Diseru Shipyard	90:25-N/A	Osaka	2	—	—
Nitta Shipyard	90:25-N/A	Osaka	3	2	1
Ohara Shipyard	90:25-N/A	Osaka	1	—	1
Ono Iron Works Shipyard	90:25-N/A	Osaka	5	—	3
Osaka Iron Works, Unit No. 2	90:25-699	Osaka	—	2	—
Osaka Shipbuilding Works	90:25-1711	Osaka	3	1	—
Sanoyasu Shipyard	90:25-N/A	Osaka	2	1	—
Urabe Shipyard	90:25-N/A	Osaka	4	—	1
Yamamoto Shipyard	90:25-N/A	Osaka	2	—	1
INLAND SEA					
Amagasaki Shipyard	90:25-N/A	Amagasaki	2	—	—
Hashihama Dock	90:29-N/A	Hashihama	2	—	3
Kasado Dock Co.	90:32-668	Kasado Island	2	2	—
Kumagaya Shipyard	90:29-N/A	Saisaki	3	—	2
Mukaijima Dock	90:29-N/A	Mukaijima	2	2	—
Onomichi Dock	90:29-N/A	Onomichi	1	—	1
Ujina Shipbuilding Co.	90:30-1889	Ujina	3	—	—
Urabe Iron Works	90:29-N/A	Innoshima	5	—	2
SHIMONOSEKI STRAIT					
Ishihara Shipyard	90:34-N/A	Shimonoseki	2	—	—
Osaka Iron Works	90:34-43B	Hikoshima	—	1	1
Tanokubi Shipyard	90:34-1673	Hikoshima	2	—	—
Tochigi Company	90:34-558	Wakamatsu	4	1	—
Wakamatsu Shipyard	90:34-1672	Wakamatsu	1	—	—

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MINOR SHIPYARDS—Continued

Target Name	Target Number	Location	Number of Building Ways	Number of Drydocks	
				Large (Over 300 feet)	Small (Under 300 feet)
MISCELLANEOUS					
Ishiguro Shipyard	90:26-N/A	Yonago	2	—	—
Kanezashi Shipyard	90:18-N/A	Shimizu	6	—	1
Kawanami Industry	90:36-N/A	Uranosaki	3	—	—
Matsuura Shipyard	90:28-N/A	Higashino	3	—	—
Miho Shipyard	90:18-N/A	Shimizu	3	—	—
Nagoya Yard of Uraga Dock Co.	90:20-2163	Nagoya	3	1	—
Nihonkai Dock	90:11-N/A	Fushiki	2	—	—
Niigata Iron Works	90:9-998	Niigata	2	—	—
Toba Dockyard	90:24-1216	Toba	—	—	1
Tohoku Dock	90:10-N/A	Shiogama	3	—	1
Yamamoto Shipyard	90:26-N/A	Kochi	3	—	—
MAINLAND					
Chosen Heavy Industry Co.	84:7-N/A	Fusan Korea	3	—	2
Manchuria Dockyard	93:5-10	Dairen, Manchuria	3	3	—
Dockyard	83:12-N/A	Tang-ku/Taku, China	—	—	1
Drydock	83:11-93	Tsingtao, China	2	1	—
International Dock	83:1-119	Shanghai, China	—	1	—
Kiangnan Dock and Engineering Works	83:1-117	Shanghai, China	3	3	—
Kiousin Docks	83:1-122	Shanghai, China	2	—	—
Lunghwa Dock and Engine Works	83:1-N/A	Shanghai, China	—	2	—
Ping An Dock	83:1-123	Shanghai, China	2	—	—
Tungkadoo Dock	83:1-121	Shanghai, China	—	1	—
Yangtzepoo Docks, Nos. 1 and 2	83:1-118	Shanghai, China	—	2	—
		Shanghai, China			

Wooden Shipbuilding Centers

JAPAN PROPER

Location	Target Area	Approximate Coordinates
Aomori	90:5	40-58;140-46
Funakawa	90:6	39-53;139-55
Hachinohe	90:5	40-31;141-32
Hakata	90:35	33-37;130-24
Hakodate	90:4	41-46;140-43
Hirazawa	90:6	39-17;139-58
Ishinomaki	90:10	38-25;141-19
Kobe	90:25	34-40;135-10
Kushimoto	90:24	33-28;135-47
Matsue	90:26	35-28;133-04
Miyako	90:8	39-39;141-58
Nanao	90:11	37-03;136-58
Noshiro	90:6	40-14;140-02
Ofunato	90:8	39-02;141-44

Location	Target Area	Approximate Coordinates
Okazaki	90:27	34-11;134-37
Onomichi	90:29	34-25;133-12
Osaka	90:25	34-40;135-28
Sakaide	90:27	34-20;133-51
Sakata	90:6	38-56;139-49
Shimabara	90:25	32-47;130-22
Tokushima	90:27	34-04;134-34
Tokyo	90:17	35-39;139-46
Tonoura	90:38	31-30;131-23
Tsuruga	90:22	35-40;136-04
Tzuchizaki	90:6	39-45;140-05
Uwajima	90:21	33-13;132-34
Yokohama	90:17	35-27;139-39

MAINLAND

Antung	93:2	40-07;124-22
Chinnamp'o	84:3	38-43;125-24
Dairen	93:5	38-56;121-39
Fusan	84:7	35-07;129-03

Shanghai	83:1	31-18;121-34
Tientsin	83:12	39-06;117-13
Tsingtao	83:11	36-05;120-19
Ying-k'ou (Newchang)	93:3	40-41;122-12

MIC

MIXED INDUSTRIAL CONCENTRATIONS

File No. 39,000

MIC–UA
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MIC
URBAN INDUSTRIAL
CONCENTRATIONS

JOINT TARGET GROUP, WASHINGTON, D. C.
GENERAL ANALYSIS

UIC
25 June 1945

MIXED INDUSTRIAL CONCENTRATIONS

INDUSTRIAL CONCENTRATIONS

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File No. 43,011

I. CURRENT DEVELOPMENTS

SUMMARY

In its attacks on Japanese strategic targets through 15 June 1945, the XXI Bomber Command dropped 61,055 tons of bombs, of which about 75% was delivered in area attacks and 25% in precision attacks. The area attacks were directed primarily against the six leading industrial centers of Tokyo, Kawasaki, Yokohama, Nagoya, Osaka and Kobe. They destroyed about 29% of the area of industrial buildings in these cities, which is estimated to equal 8% of the total area of industrial buildings in Japan Proper. In addition, these attacks destroyed about 50% of the housing in these cities and dehoused approximately 10% of the total population of Japan Proper.

Aircraft engine and airframe plants were the targets of most of the precision attacks. Area attacks accomplished heavy damage to aircraft components plants. The resulting loss is estimated to equal 3 months of Japan's aircraft production. This loss results primarily from damage to the engine plants, where the area of serious damage amounted to 30% of their total building area.

Other losses are estimated to include at least two months' Japanese output of the electrical equipment and machine tool industries and ½ to 1 month's production of the armament and shipbuilding industries. These figures represent losses to be expected during 1945. To the extent that the destroyed equipment cannot be replaced, additional losses will be felt beyond the end of 1945. The rate of destruction of many kinds of equipment has been in excess of the enemy's estimated ability to produce replacements. For example, the destruction of machine tools in four months is estimated to have been equal to about 8 months' prospective output of the Japanese machine tool industry.

Of the 47 Urban Industrial Concentrations that have been recommended for attack, about 20 have been moderately to heavily damaged and their current target value for re-attack by area bombing is considered low, although some contain relatively undamaged precision targets of priority importance. Virtually all of the remaining 27 concentrations retain adequate target value for area attack.

A. PHYSICAL DAMAGE TO INDUSTRIAL AND RESIDENTIAL FACILITIES

Table 1 shows the weight of bombs dropped on strategic targets in Japan Proper by the XXI Bomber Command from November 1944 through 15 June 1945. During that period approximately 75 percent of the tonnage dispatched was delivered to area targets. Prior to March 1945, however, more than half of the tonnage was directed to precision targets. Not included are small tonnages dropped by the XX Bomber Command and carrier-based naval planes.

TABLE 1

Actual Tons of Bombs Dropped on Targets in Japan Proper, November, 1944—15 June 1945 by XXI Bomber Command[1]

Month	Actual Tons Dropped		
	Total all Strategic Targets	On Urban Areas	On Precision Targets
Total through 15 June '45	61,055[2]	46,473[2]	14,582
November, 1944	462	287	175
December, 1944	716	......	716
January, 1945	787	400	387
February, 1945	1,579	1,021	558
March, 1945	12,597	9,575	3,022
April, 1945	10,196[3]	5,301[3]	4,895
May, 1945	20,475	17,785	2,690
June 1-15, 1945	14,243[4]	12,104[4]	2,139[4]

[1]Excludes mining operations, weather missions, attacks on airfields and other tactical targets.
[2]Excludes tonnage dropped in three missions, all relatively small. See footnotes 3 and 4.
[3]Excludes a part of mission 126 on which a combined figure was given for area tonnage and tactical tonnage delivered.
[4]Preliminary data used for period 10-15 June. Excludes missions 196 and 200 for which detailed tonnage and target data are not yet available.

Heavy tonnages delivered to area targets through 15 June 1945 are estimated to have seriously damaged approximately 10 percent of all industrial building area in Japan Proper. Damage in the six major industrial cities of Japan Proper, Tokyo, Kawasaki, Yokohama, Osaka, Nagoya and Kobe against which practically all tonnage was directed amounted to 8.4 percent of the estimated industrial building area in Japan Proper. The proportion of damage to pre-attack building area in each city and in Japan Proper is shown in Table 2.

An analysis of damage by industry discloses wide variations in the proportion of pre-attack building area seriously damaged in the six cities. These variations are due in part to differences in the degree to which each industry is concentrated in these cities, to variations in vulnerability of the industries to IB attack, and to differences in the degree of concentration within sections of cities selected as aiming points for earlier attacks. See Table 3.

In addition to industrial damage achieved through attacks on area targets it is estimated that 1,267,000 dwellings housing 5,748,000 persons were destroyed. Thus, of the civilian population remaining in Japanese cities after evacuation programs had been completed, almost 10 percent of the population of Japan Proper and close to half of that in the six cities subjected to heavy attack were required to seek new housing accommodations. Residential destruction in Japanese cities attacked is complete. While no thorough review has been attempted to determine whether any planned rebuilding of housing areas is occurring, study of photo cover through 1 June of parts of the area devastated in the 10 March attack on Tokyo discloses no development of new housing. Table 4 presents estimates of housing destruction and of persons dehoused through area attacks.

TABLE 2

Estimated Percent of Damage to Industrial Building Area Through Area Attacks on 6 Japanese Cities Through 15 June 1945[1]

City	Percent of total industrial pre-attack building area damaged	
	In Each City	In Japan Proper
Total, 6 cities	29	8.4
Tokyo	29	3.3
Kawasaki	18	0.6
Yokohama	28	0.6
Osaka	28	1.7
Nagoya	31	1.8
Kobe	36	0.4

[1]For Nagoya damage to aircraft plants from precision attacks is included.

TABLE 3

Estimated Percent of Damage to Industrial Building Area Through Area Attacks on 6 Japanese Cities Through 15 June 1945, by Industry[1]

Industry	Percent of Pre-Attack Industrial Bldg. Area in Japan Proper Located in Six Cities[2]	Percent of Industrial Building Area Damaged	
		Of Total Pre-Attack Area in Six Cities[3]	Of Total Pre-Attack Area in Japan Proper[3]
All Industries	30	29	9
Aircraft	40	34	14
Ordnance	37	20	7
Shipbuilding and Repair	44	23	10
Electrical Equipment	75	32	24
Finished Metal Products	73	36	26
Machinery & Machine Tools	48	26	12
Iron and Steel	38	16	6
Non-ferrous Metals	6	30	2
Chemicals	19	23	4
Rubber Products	17	37	6
Textiles	40	38	15

[1]Total pre-attack industrial area for the six cities was based upon measurement of approximately ⅓ of the total area calculated. For Nagoya and Kobe totals were derived almost completely from measured data. For the six cities total estimated building area damaged was based on measurements amounting to 30 percent of the total calculated area of damage. The estimate of total pre-attack industrial building area for Japan Proper included 10 percent measured from annotated mosaics. The estimated total for Japan Proper was derived by extrapolation generally based on proportions shown in Table 3 Section III.
[2]Tokyo, Kawasaki, Yokohama, Osaka, Nagoya, Kobe.
[3]Includes damage to aircraft factories in Nagoya through precision attack.

TABLE 4

Estimated Dwellings Damaged in Area Attacks Through 15 June 1945 and Persons Dehoused

City	Estimated Number of Dwellings Damaged or Destroyed	Estimated Number of Persons Dehoused	Percent of Estimated 1944 population Dehoused[1]	Percent Dehoused of Total Population in Japan Proper
Total, all cities	1,267,000	5,748,000	46[2]	9.2
Tokyo	650,000	2,800,000	46	4.5
Kawasaki	40,000	200,000	53	0.3
Yokohama	132,000	680,000	69	1.1
Nagoya	104,000	401,500	32	0.6
Osaka	223,000	1,095,000	40	1.7
Kobe	96,000	471,500	58	0.8
All other cities[3]	25,000	100,000	..	0.2

[1]Based on preliminary estimates of civilian population adjusted downward for estimated pre-attack evacuation of 10 percent.
[2]Excludes "All other cities."
[3]Related principally to Kagoshima, Hamamatsu, and Amagasaki.

B. EFFECTS OF DAMAGE ON INDUSTRIAL OUTPUT

1. Estimates of Total Losses

Losses of industrial production inflicted upon the Japanese economy by the strategic bombing attacks executed through 15 June 1945, are estimated to include 3 months output of the aircraft industry, at least 2 months output of the electrical equipment and machine tool industries, and ½ to 1 month's output of the ordnance and shipbuilding industries. These figures represent losses in output to be expected during the year 1945; in addition, assuming that heavy attacks continue, the enemy will never be able to replace all the productive equipment that has been destroyed in these earlier attacks, with the result that additional losses from these attacks will continue to be felt beyond the end of 1945. Estimates of production losses in further detail, and for additional industries, are shown in Table 5.

These estimated losses of output result from the destruction of productive equipment amounting to about 8-10 percent of the Japanese totals in the aircraft, electrical equipment, and machine tool industries and about 4 percent in ordnance and shipbuilding. The losses of output will be attributable in part to this destruction of equipment and in part to the disorganization that also occurred and the interruptions of work caused by damage to buildings and to the many additional machines that were not destroyed but required major repair.

Each of these estimates is merely an overall estimate of the damage and production losses suffered by an industry as a whole; while the estimates take account of available detailed intelligence on the effects of attacks at particular plants, most of them are based primarily on the application of average relationships to data of a general nature, and therefore must be regarded as no better than rough indications of the size of the enemy's losses to date. Also, assuming that the average figure shown for a given industry is correct, it is likely that some segments of the industry will have been damaged much more seriously, and others less seriously. Where intelligence permits, more specific incidences of loss are summarized below and details will be incorporated in the individual industrial system folders.

Where the estimates have been based on the total areas of serious damage to the building of an industry, there have been taken into consideration such factors as differences in the vulnerability of equipment and stocks in different industries and differences in the ability of the different industries to utilize excess capacity of requisitioned equipment to assist in post-attack recuperation. The effects of the damage to buildings themselves have also been taken into consideration, although in most industries the replacement of buildings can be accomplished more readily than the replacement of equipment, so that it is primarily the damage to equipment that determines the effect on output.

Of the figures under "Equipment—percentage destroyed or seriously damaged" in Table 5, it is estimated that about two-thirds represent equipment destroyed and one-third represents equipment requiring major repairs or rebuilding. Since repairs to machinery of the latter category, even though requiring 4-8 months for completion, involve a much smaller drain on the machinery industry than would be required to produce new machinery, it is assumed that substantially all such equipment will be repaired over such a period.

TABLE 5

Effects of Strategic Bombing on Selected Industries—Attacks Through 15 June 1945

Industry	Percentage of building (roof) area seriously damaged[1]	Equipment		Estimated Losses of Output, in Weeks' Production for Japan Proper					
		Vulnerability Factor[3] (Percent)	Percentage destroyed or seriously damaged[1]	Loss of production, March-June 1945, due to physical damage and industrial disorganization	Loss of production due to absenteeism	Destruction of work-in process and finished stocks	Total loss, March-June 1945	Loss of production, July-Dec. 1945	Total loss, March-Dec. 1945
Aircraft..............	18[2]	80	14	6.0	.3	2.7	9.0	3.0	12.0[4]
Ordnance..............	7	80	6	1.1	.3	.6	2.0	.2	2.2
Shipbuilding............	10	50	5	1.6	.4	.3	2.3	1.2	3.5
Electrical Equipment......	24	60	14	3.8	.6	1.3	5.7	3.4	9.1
Finished Metal Products...	26	80	21	4.5	.6	1.7	6.8	5 2	12.0
Machinery & Machine Tools	12	90	11	1.9	.4	2.2	4.5	2.6	7.1
Iron and Steel..........	6	20	1	.5	.3	.1	.9	.2	1.1
Non-ferrous Metals......	2	50	1	.3	..	..	.3	.2	.5
Chemicals.............	4	90	4	.8	.2	.2	1.2	1.0	2.2
Rubber Products........	6	80	5	1.0	.1	.3	1.4	1.2	2.6
Textiles...............	15	80	12	2.4	.3	.8	3.5	.5	4.0

[1]Percentages of building area and of equipment damaged or destroyed are percentages of the industry's total in Japan Proper.

[2]Includes approximately 14% damaged in 6 cities (including damage both by area and by precision attacks) and 4% damaged by precision attacks elsewhere in Japan Proper.

[3]The "vulnerability factor" as used here represents the estimated ratio of (a) the percentage of equipment destroyed or seriously damaged to (b) the percentage of building area seriously damaged. It thus represents the vulnerability of the equipment as related to the vulnerability of the factory buildings, and is used to estimate the damage to equipment when the damge to buildings is known. Further explanation appears in Sec. 4 on Page 3.

[4]A substantial part of this loss resulted from precision attacks, especially those on engine factories, as noted in text.

These calculated figures are based on damage in the six cities covered by Table 2 (Tokyo, Kawasaki, Yokohama, Nagoya, Osaka, Kobe) plus damage by precision attacks on aircraft (and aero-engine) factories elsewhere in Japan. This damage constituted substantially all of the damage to industrial installations during the period to 15 June; there was also some damage in other urban areas and to some precision targets outside of the aircraft industry, but (with the possible exception of petroleum) not sufficient to affect significantly the overall totals. All of the figures relate to industry in Japan Proper only; damage in Formosa and Manchuria is omitted, and industrial capacity in those areas has been excluded from the totals used as a basis for calculating percentages.

It may be noted that the figures here are not intended to represent the total loss of production to be expected from all causes, but only the loss attributable to the effects of the strategic bombing attacks—*i.e.* the difference between the output that the enemy would have been expected to achieve (following these attacks but in the absence of further bombing after 15 June) and the output that he would have achieved in the absence of all strategic bombing. The effects of raw material shortages (including those caused by sea mining) would be added to these losses; on the other hand, where expansion programs were underway prior to the bombing, the effects of such programs will tend to offset the losses.

2. Notes on Losses in Specific Industries

The production losses shown for manufacturers of front-line military items (aircraft, ordnance, radar, etc.) indicate the extent of the reductions in the supplies that will be available to the enemy's armed forces. Losses shown for producers of general industrial equipment (such as machinery and machine tools, electrical equipment, etc.) indicate reductions in supplies available to all equipment users, including producers of miliary end products. Damage to manufacturers of industrial equipment must be assessed in terms of additional demands resulting from repair and replacement requirements in other industries.

a. *Aircraft:* Detailed study has emphasized the importance of attacks upon aero-engine factories. The percentage of building area thus far seriously damaged approximates 30%—virtually all resulting from precision attacks. It has been estimated that the total effects of damage to the aircraft industry, resulting largely from this damage to engine factories, will amount to a loss of around 7000 aircraft—equal to 3 months output at pre-attack production rates. Most of this loss will have taken effect before the middle of 1945. Because of the high priority which this industry has in obtaining repairs and replacement, attacks prior to 15 June are likely by themselves to have relatively little effect on aircraft production after July or August.

Damage to aircraft assembly and to components production, the latter particularly high as a result of area attacks, has probably not accomplished a substantial additive loss because of the estimated shorter position of aero-engines. The relatively heavy damage to the output of components accomplished by area attacks in such cities as Tokyo and Nagoya may have created individual bottlenecks of short duration but have probably not further reduced current aircraft output, although they may serve to hamper future dispersal or expansion. An important exception exists in the case of losses imposed on the propeller industry, largely by area attack and partly after 15 June. Damage to three of the Sumitomo Company's propeller plants (in Amagasaki, Shizuoka, and Osaka) and to the Nippon Gakki plant at Hamamatsu has resulted in a substantial additive aircraft loss, particularly in naval types least affected by precision aero-engine attacks.

b. *Ordnance:* Damage to ordnance production has been relatively light, having affected primary producers only in Nagoya, Tokyo, Hiro, and Kure. In view of assumed under-utilization of capacity in this industry, this damage has probably resulted in comparatively little overall production loss, although output of individual items may have suffered significant short-term delay. The high level of loss sustained by producers of communications equipment, precision fire control apparatus, etc., may reduce the frontline effectiveness of some ordnance items. Losses in combat vehicles and trucks have been more substantial although it is believed that increased production in undamaged plants can wipe out the loss in a short time.

c. *Machine Tools and General Machinery:* Area attacks have had a major impact on the machine tool industry. In view of the increased demand caused by damage to equipment in other industries, the substantial losses in machine tool and machinery output have not only wiped out any possible pre-attack capacity cushion but have probably already pushed machine tool output below current requirements. As indicated below losses sustained through 15 June are estimated as equivalent to 6-8 months production. If continued or increased, these losses may critically retard general industrial recuperability and also hamper dispersal or expansion programs.

d. *Electrical Equipment:* Damage has been particularly significant to the electrical equipment industry. A large number of plants producing light electrical items, including a substantial percentage of aircraft and ordnance electrical equipment, have been severely damaged. This, together with moderate damage to producers of heavy equipment, will also operate to retard the recuperation of other industries.

It is estimated that electronic tube production has probably suffered an overall loss of approximately 1 month's output as a result of light to moderate damage to the key producers in Kawasaki and Kobe. Production losses are estimated to amount to about 15% for 2-3 months. Stock losses are also believed to have been substantial. In the absence of known excess capacity, this will not only result in an immediate effect on front-line equipment, but may result in a continuing loss, especially following more damage to the industry.

Also noteworthy are losses in the production of wire and cable. A number of wire and cable plants which are estimated to have accounted for roughly 25% of pre-attack output have been at least moderately damaged, several completely destroyed. It is believed that this will have at least a short run retarding effect on most types of communications equipment industries and may also have some immediate effect on front-line equipment. Much of the remaining capacity is accounted for by two plants, 1 in Osaka and 1 in Yokohama.

e. *Shipbuilding:* The most significant damage to the shipbuilding industry fell largely on the marine engine producers, in Kobe and Osaka, and the resulting production loss will be reflected in delay in completing both large and small ship types not only at these shipbuilding centers, but also at some Inland Sea yards which they supply. The loss of small marine engine building capacity has been particularly heavy in Osaka, largest center for this type of production.

f. *Miscellaneous Industries:* While not considered of priority importance, losses in other industries will—in a few cases—have the effect of retarding general industrial recuperation, maintenance and dispersal. For example, 2 of 3 Kobe plants of the Hanto Rubber Belting Co. have been severely damaged. These plants accounted for a substantial percentage of pre-attack output of industrial belting, being especially important producers of heavy conveyor belting. Loss of their current output is known to have resulted in production and expansion delays in plants and mines as far away as Mozan, Korea. This loss can probably be made up by increased utilization of remaining capacity, but it is typical of the wide ramifications of production loss which may follow damage to relatively obscure industries supplying general equipment now in critical demand for repair and replacement.

3. Causes of Production Losses, and Incidence in Time

Of the total losses of output that are to be expected during the year 1945, it will be observed that more than half of the loss in each industry is attributed in Table V to the months of March-June, with less than half attributed to the remaining six months of the year. This concentration in the period during and immediately following the attacks represents the large short-term losses of production during clearance of debris, first-aid repairs, and reorganization of the production flow, along with the effects of workers' absenteeism (in undamaged as well as damaged factories) and the destruction of stocks on hand. Thereafter, some recovery is to be expected, as reorganization is accomplished; the losses of output that are expected during the remainder of the year result primarily from the reduction in productive capacity pending the repair or replacement of equipment that was seriously damaged or destroyed.

In addition to these losses, however, it should be emphasized that there will also be longer-term losses, not included in Table 5 because of the impossibility of forecasting their amount at the present time, consisting of losses resulting from the enemy's inability to replace all the productive equipment that was destroyed during this series of attacks.

Following are general comments on the various categories of losses outlined above:

1. The loss of production during the first two months after an attack will include substantial losses of output from equipment that is undamaged or only slightly damaged—pending the clearance of debris, the completion of first-aid repairs, and the reorganization of production flow in preparation for attempting to carry on efficient production despite the destruction of some part of the equipment. The loss in this period includes losses during minor repairs to slightly damaged machinery, and losses during relocation of machinery where damage to buildings makes this necessary; it also includes losses due to forced inactivity of undamaged machinery whose operation has been dependent upon equipment that has been destroyed or upon public utility services that have been interrupted, etc. Where the proportion of a factory that has suffered serious physical damage is small, the amount of equipment that is temporarily immobilized in this way may be several times the amount that is actually destroyed or seriously damaged; at the other extreme, where a factory suffers total destruction, the amount of equipment that is immobilized without being seriously damaged is of course nil—except to the extent that equipment in other factories is immobilized because of dependence on the factory that is destroyed.

For most industries, it may be estimated very roughly that there will be an average period of about 2 months after the occurrence of the damage in which there will be substantial losses of output due to the immobilization of undamaged or slightly damaged equipment, and that the percentage of production lost during this period (due partly to serious damage or destruction of some equipment and partly to such immobilization of equipment not seriously damaged) will be equal to about twice the percentage of building (roof) area seriously damaged.

2. In estimating the longer-term loss of production pending major repairs or replacement of equipment, a first consideration is the existence (or absence) of excess capacity; if the pre-raid output of an industry was limited by the supply of labor or of materials or by limited demand for the product, then the effects of the damage upon production may be much less than if the limiting factor had been the supply of equipment. For most industries, it may be estimated very roughly that the production loss, while awaiting the repair of heavily damaged equipment or the replacement of such destroyed equipment as can be replaced, will extend over a period of about 6-9 months (*i.e.* about 4-7 months beyond the 2-month period already counted under debris clearance, first-aid repairs, etc.) and that the percentage of production lost during this period will be about equal to the percentage of equipment destroyed or seriously damaged. These figures assume the absence of any substantial excess capacity; where excess capacity is large, the percentage of production lost during this period will be less. In some particular factories, of course, production losses will be greater than these figures would suggest, because of dislocations impairing the usefulness of undamaged equipment, but such cases are likely to be offset by others in which the equipment damaged is not vital and the enemy is able to compensate for the damage by working undamaged machinery more intensively or by converting excess capacity from other uses.

3. If heavy and continuous attack is maintained, the enemy will not be able to replace all the equipment destroyed, and hence some of the production losses will be permanent. The extent to which replacement can be made in any given industry will depend on the original capacity of the equipment producing industries, minus allowances for the effects of damage to those industries; it will also depend on the priority status of the industry. It is estimated that the machine tools destroyed in Japan in the four months ending 15 June 1945 were equivalent to 6 months' output of the Japanese machine tool industry at its maximum pre-attack rate, or about 8 months' output if allowance is made for the effects of damage to the machine tool factories themselves. Thus, if this scale of attack were continued, not over half of these machine tools could be replaced from new production.

4. The amounts of finished goods and of work in process destroyed in factories may be estimated, in terms of weeks' production of the factories, by applying vulnerability factors to the amount of building damage, in the same manner as was done to estimate the amount of equipment destroyed. These losses are in general additive to the losses of production in determining the total effect of the damage upon the output of products.

5. In addition to the losses of production caused by damage to factories, there will be losses caused by the absenteeism of workers whose homes are destroyed or who are otherwise prevented from attending their work. Using data on the absenteeism of British workers after German raids, and extrapolating to the scale of damage that has been inflicted in area attacks to date on Japanese cities, absences equal to about 15 days for the entire working populations of these cities would be estimated. Such absences would not affect industrial production, however, except for those workers whose factories continued to work and to need their services; since it is known that most Japanese workers lived in the vicinity of their factories, and hence lost their homes and their working places simultaneously, it may be estimated that not more than 40% of the absenteeism affected industrial production—*i.e.* an additional loss equivalent to approximately 6 days' production of all the factories (damaged as well as undamaged) in these cities.

4. Procedure Used in Estimating the Percentage of Equipment Destroyed and Seriously Damaged—Application of a "Vulnerability Factor" to the Percentage of Buildings (Roof Area) Destroyed

Where damage to buildings consists of structural damage by fire, it might be assumed as a first approximation that all the equipment in the damaged areas has been destroyed or seriously damaged. Then, if it could be assumed that the areas of damage in factory complexes are distributed at random among buildings containing productive equipment and buildings housing other functions, the percentage of equipment seriously damaged would tend (for any large number of factories) to equal the percentage of total building (roof) area seriously damaged. Such a relationship might be expressed as a "vulnerability factor" of 100%—*i.e.*, the percentage of equipment seriously damaged is equal to 100% times the percentage of building (roof) area seriously damaged.

In fact, these "vulnerability factors" will be reduced to less than 100% because of the following points: (1) the workshops containing the principal productive equipment will ordinarily be less vulnerable to incendiary attack than the other buildings, because, comparing the workshops with the other buildings of a factory (stores, offices, etc.), the contents of the workshops are ordinarily of lower combustibility, and the workshops are more likely to be housed in non-combustible or fire-resistive buildings; (2) in some industries with very heavy equipment, much equipment may be readily repairable despite the burning of the building housing it; and (3) the areas of visible damage will include not only areas of structural damage by fire but also areas of superficial damage and areas of damage by HE.

These points will be partly counterbalanced by the fact that there will be some damage to equipment in areas where the building itself is not seriously damaged (or where the damage to the building is not visible from the air).

Some data are available on the relation between damage to equipment and damage to buildings in British factories that were damaged by German attacks, and the "vulnerability factors" that have been estimated for the principal Japanese industries which appear in Table 2 are based primarily on the British data, with modifications for the types of damage inflicted in Japan and for known differences in the characteristics of Japanese industries.

C. FUTURE TARGET VALUE OF URBAN INDUSTRIAL CONCENTRATIONS

Preliminary assessments of the original 33 selected Urban Industrial Concentrations indicate that the bulk have been at least moderately damaged by area attacks through 15 June 1945. The estimated current target value of these and 14 other concentrations is shown in ST2 (Summary Table). Because post-attack cover has not been examined in detail for a number of cases, and is lacking for a few, these estimates of current target value must be regarded as tentative and subject to modification. Target value is indicated as "high" if the target area is currently considered worth area attack; it is shown as "low" if the target area is not currently considered worth re-attack by area bombing. It is emphasized that several Urban Industrial Concentrations shown as having a low target value for area attack contain relatively undamaged priority targets which may warrant precision attack. Several of these may also warrant future consideration for "clean-up" area attacks.

Of the total 47 Urban Industrial Concentrations, approximately 20 are judged not to warrant re-attack by area bombing at the present time. Virtually all of the remaining 27 retain sufficiently high target value for this type of attack, although a few are doubtful. Those concentrations indicated as having a high target value constitute the currently recommended target areas for area attack. A few other suitable industrial concentrations are being studied and will be added to the recommended list.

II. RELATION TO MILITARY STRENGTH

A. CHARACTERISTICS OF "AREA" ATTACKS

"Area" attacks can be broadly distinguished from "Precision" attacks in that they are directed against cities, sections of cities or groups of factories and not at specific plants. The target area may consist of diversified industry, combinations of industrial and military facilities, mixed concentrations of industrial, commercial and residential structures and housing.

Japan's industrial economy is highly concentrated in relatively few cities and a program of area attacks against these cities can effectively reduce her war potential. Further, it is possible to deliniate within these cities smaller areas of heavy concentration of industrial plant, the size and configuration of which will vary widely. For Japan proper 46 such target areas (Urban Industrial Concentrations) have been selected to date. Typically these consist of plants with diversified industrial products, but in isolated distances, e.g. 90:20-3638, Kagamigahara UIC/1, industrial activity may be restricted to a single industry.

The principal characteristics, principal advantages and disadvantages of area attacks are:

1. They impose a relatively large amount of physical damage and production loss. Estimates for Japan based on precision attacks through 31 May 1945 and on area attacks through approximately mid-April 1945 disclose the following attacks by the XXI Bomber Command.

Type of attack	Damage per ton[1] (Sq. ft. of roof area)	
	Airborne	Released over target
Precision (A/C Plants)..........	550	852
Area (all industrial plants)......	3200	3500

[1] Figures represent approximate areas of serious damage. The figures for precision attacks include "structural damage, damage resulting in clearance or removal of plants and, where estimated, internal fire damage." Those for area attacks include "total roof area damaged, including superficial," but the amount of superficial damage from incendiary attacks is relatively small, and most of it would be classified as serious because of the accompanying fire damage to contents of structures.

The table discloses that as in Germany, damage per ton of bombs through area attack is heavy relative to that which occurs through precision attack[2]. Attacks by Navy carrier-based planes on aircraft plants showed a higher ratio of damage per ton of bombs released over the target than for area attacks which, for operational reasons, is to be expected.

[2] Figures for attacks on German cities disclose a ratio of industrial loss per ton of bombs of 2:1 in favor of area attacks. This understates the ratio, which may approach 3:1 if losses in materials and component flows and losses caused by general administrative disorganization were included.

2. Physical damage and production loss while more extensive usually affects a number of industries. Thus the industrial loss imposed is widely diffused and the effect on any single target system may not reach the desired proportions.[2]

[2] The objective of precision attacks is to concentrate damage within industries considered most important to the enemy war machine. However, strong forces, good visibility and accurate bombing is required. In the absence of these conditions recuperation between attacks on various key plants within an industry will prevent decisive concentration of loss against a particular system.

3. Area attacks constitute the most efficient means of imposing production loss on industries with small units spread throughout congested, vulnerable areas. For example, in Japan, machine tool production and light electrical equipment facilities can probably be most seriously affected through area attack.

4. For area attacks accurate assessment of physical damage and particularly production loss is difficult since identification of products and functions of numerous, very small plants is impossible. As a result remaining target value after a series of attacks and the planning of future attacks is difficult.

B. DUPLICATION IN AREA AND PRECISION ATTACKS

Area and precision attacks are duplicating in part (a) when area attacks dehouse workers disemployed by destruction of their place of employment by precision attack and (b) when they destroy plants supplying components or raw materials to factories which themselves have, within a short interval, been destroyed (assuming equal rates of recuperability for the different productive facilities involved).

However, even under the circumstances described above, there would be some additive damage: (a) In some cases, the resultant shortage of components, etc., may preclude the use of stand-by capacity which otherwise could have been brought into operation after the destruction of final assembly capacity; (b) the burden of repairing damaged component plants and damaged housing is additive and might retard the recovery of the final assembly plant. However, where high priority items are involved, such retardation should not be substantial until a high level of damage is achieved, with the resultant saturation of repair and replacement industries.

As a general rule, attacks which inflict duplicating losses on both plants within a target system and their suppliers do not involve the most efficient use of available forces. Such forces could more profitably be used in attacks against additional plants in the target system under attack or against another target system. Only with proper timing and planning, can area attacks be mounted in such a way as to minimize duplicating effects and to complement precision attacks.

Area attacks effectively supplement precision attacks by increasing the burden of repair and replacement and by damaging the industries and facilities on which that burden falls. Successful attack on precision systems may result in dispersion to existing buildings (e.g., former textile mills) or construction of new buildings; and requisitioning of tools and machinery from lower priority uses or allocation of new output to the facilities involved. Area attacks will probably destroy building space which would otherwise be available for dispersal. They will inflict widespread damage to housing, thereby imposing additional burdens on the construction industries confronted, or about to be confronted, with the need to reconstruct damaged precision facilities. The destruction of machinery and tools in small factories will impose further demands on the machine tool industry, and the destruction of some of the machine tool factories themselves will render the replacement problem more difficult. These consequences, coupled with the widespread disorganization accompanying area attacks in force, should gravely complicate the problems involved in the recovery of pre-attack output by precision targets.

C. POSSIBLE OBJECTIVES IN ATTACKS ON JAPANESE AREAS

It is possible to have different objectives in devoting effort to area attack. The more important possibilities are:

1. The loss of production in industries manufacturing end products for the Japanese military machine, or materials and components suppliers.

2. Reduction in the capacity available for repair and replacement of equipment and structures damaged in attacks on other industries.

3. Overall decrease in output over a wide variety of industries without particular regard to the direct impact on war product industries, or those essential to a rehabilitation and repair program.

4. To undermine the will to continue the war through attacks on housing, food stores, and other essential civilian necessities or comforts, with consequent decreased standards of living, casualties, etc.

It is clear of course that achievement of some of these objectives will incidentally partially achieve others. Due to this distribution of industry among residential areas, to the intimate connection of backyard industry, heavy in some cities, with residential structures and to operational factors, attacks directed at civilian morale will destroy some productive capacity. If the primary objective is to decrease the output of military end products, to reduce the productive capacity of industry closely related to military products, and to reduce industrial resilience then attacks will be directed to industrial concentrations and not to cities in general.

D. EFFECTS OF AREA ATTACKS ON MILITARY STRENGTH

Area attacks damage or destroy a wide variety of industrial plant, equipment stocks, and commercial structures, destroy workers homes and disrupt urban life in general. Military potential is affected in various ways:

1. Production loss to industrial establishments producing military end products or to components facilities. This occurs through direct damage to factories, their structure and equipment or to absenteeism resulting from damage to workers' homes, and to transport and utilities systems.

2. Reducing recuperative capacity of the economy to replace losses sustained by plants producing military end products. This would occur in destruction of factory areas and equipment which otherwise could be transferred to factories producing implements of war, or in destruction of facilities directly used for rebuilding or replacing damaged priority equipment in war implement plants.

3. Reducing overall production and efficiency of the enemy economy. This would occur through widescale losses of capacity in many manufacturing industries as well as disruption of normal inventory—production ratios and to interruptions in transport and communications services. It would also be due to lowered efficiency caused by disruption of family life, dependence on workers for fire-fighting activity with resulting fatigue and absenteeism, war weariness, etc.

E. RESULTS OF ATTACKS AGAINST INDUSTRIAL CONCENTRATIONS ON MILITARY STRENGTH

Effects on military strength will depend on the characteristics of industrial concentrations in Japan's cities and the weight of effort employed against them. These concentrations are reviewed in detail in Section III. Concentration of industry is high and it is fairly vulnerable to attack. An analysis of selected Japanese industrial concentrations indicates that about 55 to 60 percent of the area of industrial structures is combustible and that an effective density of 225 tons per square mile will damage seriously up to 80% of the combustible industrial structures. On a small number of concentrations (e.g., Amagasaki UIC/1 and Kawasaki UIC/2) a substantial load of HE would be required to produce significant damage.

The expected percent of physical damage to the industries' entire capacity by attacks of this weight of attack on 46 concentrations is shown in Table 1.

In addition to the loss of industrial plants, there will be extensive loss of housing, possibly dehousing as many as 7-8 million persons.

The fraction of industry suffering production losses will be greater than the fraction physically damaged for a number of reasons:

a. A great deal more floorspace is immobilized than that damaged. On the average, twice as much production will be lost in the immediate period after damage than indicated by the percent of damage.

b. There is a considerable immobilization of plants completely undamaged both in and out of the area under attack because workers do not work due to loss of homes, injury, etc., or, probably more important because the flow of components from damaged plants is interrupted.

c. General industrial disorder which reduces labor efficiency is widespread.

d. The recuperation time in plants attacked by precision methods is increased because facilities for restoring production have been eliminated.

Economic loss due to physical damage can be partially offset by the following factors:

a. Production in undamaged plants can be stepped up by additional shifts, fully utilizing partially idle capacity, etc. The presence in Japan of excess capacity and plants operating only on one shift in industries as important as armament makes some adjustment of this type feasible if the organizational problems could be solved. As a wide-scale solution it has the weakness of requiring such large-scale shifts of workers and great industrial reorganization that Japan probably cannot carry it out extensively.

TABLE I

Expected Physical Damage to Japanese Capacity in Priority Industries

Assuming Attacks Against 46 Urban Industrial Concentrations with Effective Density of 225 Tons Per Square Mile

Industry	Expected Per cent damage to building area
Combat Aircraft	
Final assembly	18.9
Engine manufacturing and assembly	18.5
All parts	44.5
Armament	
General Ordnance	30.0
Autos-Trucks	23.2
Marine Engines	22.4
Shipbuilding	11.2
Ship repair	8.9
Machine Tools	31.2
Anti-friction bearings	14.9
Heavy electrical equipment	20.7
Light electrical equipment	39.9
Electronic tubes	31.5
Pig iron	15.4
Steel	20.0
Intermediate Steel	20.4
General Metal Working	40.6
Synthetic Petroleum refining	9.5
Crude oil refining	7.8
Rubber tires	34.5
Other rubber products	32.0

b. Damage can be repaired and new dispersed plants built or existing plants converted. This solution is quite possible when the scale of damage is small. When it is large, however, as it will be if 46 industrial concentrations were attacked, this solution will probably be feasible only for a small segment of the economy.

A rough balancing of these factors leads to the conclusion that if the 46 UIC's were attacked effectively within a six month period the results would be as follows:

a. The immediate overall loss of capacity will be 25%. A great part of this will be permanently lost. However, loss of capacity in some of the priority industries may be restored in part.

b. Production loss immediately after attack would probably be about twice as great as the percent of physical damage imposed. Recovery would require as much as six months.

c. The average production loss for all manufacturing for a 12 month period after the beginning of the attack would be about 30% with the greatest loss in the fifth and sixth month of approximately 40%.

d. Only a part of the priority industry seriously damaged by the precision program would be able to recover. This does not necessarily mean that the level of production after recovery would be less than the pre-attack level, since excess capacity would, where available, be used to replace, in part, production lost in plants not repaired.

e. There would be a direct loss of military supplies in a number of important categories, and a great volume of miscellaneous military stores in an area under attack would be destroyed.

f. A part of the program against other target systems would be accomplished. A number of arsenals, aircraft installations, etc., would be partially destroyed, thus reducing the size of the program of precision attack.

g. Destruction of much of the aircraft component industry would hamper reactivation of aircraft production.

III. CHARACTERISTICS OF PRINCIPAL JAPANESE URBAN AREAS

The rapid expansion of Japan's industrial economy which occurred between 1925 and 1938 centered largely about the four principal industrial districts of Tokyo-Yokohama, Nagoya, Osaka-Kobe and Yawata-Kokura. Although a number of new industrial districts were developed during this period (such as Niigata, Toyama, Omuta, etc.), the availability of industrial labor, developed transport facilities and established supporting industries at the old industrial centers attracted to them the bulk of new plants.

A. CONCENTRATION OF INDUSTRIAL LABOR FORCE

After 1938, and especially following the outbreak of the war, a desire to disperse vital war production and the approaching saturation of industrial facilities in the old centers led to a policy of decentralization. Despite an increase in the number of incorporated municipalities from 109 in 1931 to 208 in 1943, this policy was only mildly effective and the relative degree of concentration in the primary centers was little affected. It is estimated that about 34 percent of the total industrial labor force in Japan Proper is in the 6 cities of Tokyo, Kawasaki, Yokohama, Nagoya, Osaka and Kobe. Whereas the 15 German cities[1] which have been the leading targets for RAF attacks were estimated to account for about 12.3 percent of the total labor force of greater Germany, the 14 principal Japanese urban areas currently listed as suitable area objectives probably account for about 42.5 percent of industrial labor force.

B. CONCENTRATION OF POPULATION

Population concentration follows generally the same pattern. An estimate based on 1940 statistics indicates that about 22.6 percent of Japan's total population is found in cities of over 800,000, while such cities account for less than 12 percent of Germany's population. Of the total increase of 4,000,000 during 1935-40, about 50 percent occurred in the 4 principal Japanese industrial regions, centering around Tokyo, Osaka, Nagoya and Yawata. Most of this increase was the result of the migration of industrial workers. Whereas Tokyo's annual increase averaged 180,000 between 1930 and 1935, Berlin's average yearly increase was only 17,000 between 1928 and 1938. Table 2 indicates the estimated concentration of population and industrial labor force in the 14 principal urban areas.

TABLE 2

Estimated Distribution of Industrial Employment in 14 Principal Urban Areas

[In thousands]

City or area	Civilian population	Number and proportion of population gainfully employed	Total industrial employment	Percent of gainfully employed population in industrial employment	Percent of industrial employment in Japan Proper
Tokyo.......	6,779(1944)	3,541(52%)	1,375	39	14.8
Kawasaki....	426(1944)	222(52%)	176	79	1.9
Yokohama....	1,102(1944)	556(50%)	297	53	3.2
Osaka.......	3,061(1944)	1,650(54%)	751	46	8.1
Kobe........	906(1944)	481(53%)	223	46	2.5
Nagoya.....	1,401(1944)	728(52%)	380	52	4.1
Nagasaki....	253(1940)	131(52%)	89	68	1.0
Kure........	276(1940)	144(52%)	*94	*65	*1.0
Yawata, Tobata, Wakamatsu, Kokura....	613(1940)	319(52%)	*239	*75	*2.6
Sasebo......	206(1940)	107(52%)	*70	*65	*.8
Amagasaki...	181(1940)	94(52%)	*70	*75	*.8
Hiroshima....	344(1940)	179(52%)	*90	*50	*1.0
Hamamatsu...	166(1940)	86(52%)	*43	*50	*.5
Omuta.......	177(1940)	92(52%)	*60	*65	*.6
Total....	15,891	8,320	*3,957	*47.6 (average)	*42.5

*Preliminary estimates made in advance of completion of study.

C. PATTERN OF WAR-TIME INDUSTRIAL EXPANSION

Because the present Japanese economy represents an attempted war-time rationalization of an unbalanced peacetime economy, it exhibits divergent tendencies with respect to concentration. War plant expansion has proceeded along three lines: (1) Some new plants have been built within the established industrial centers, (2) many have been located along the immediate outskirts of these centers or in satellite industrial communities within the general metropolitan areas, and (3) numerous plants, including some of the largest, have been established in previously non-industrial districts or in isolated localities. Of these, the first two undoubtedly account for the bulk of newer war industry, indicating a continued dependence on the primary centers.

Moreover, it is believed that the much-publicized policy of dispersing war production from Japan to Manchuria and Korea has not appreciably reduced Japan Proper's overwhelming share of the Empire's total manufacturing capacity. The great bulk of industrial expansion on the Mainland has been in basic raw materials processing capacity, an inevitable result of Japan's dependence on Mainland sources of coal, shale and iron ore. The recent trend toward evacuation of some military end-product manufacturing capacity to the Mainland is not likely to result in a significant short-run change in this balance, in view of the loss of current war production involved in such a program. In any event, such a policy would seem to have a few, if any advantages, over widespread dispersal within Japan Proper, unless the Japanese intend to carry on the war on the Mainland.

D. PATTERN OF URBAN INDUSTRIAL CONCENTRATIONS

Like most industrial towns, the principal Japanese urban areas contain districts of high industrial occupancy, discussed herein as Urban Industrial Concentrations. While these industrial districts are generally located along the waterfront or in other peripheral sites, a considerable number are more centrally located,

[1] Berlin, Cologne, Hamburg, Munich, Leipzig, Essen, Stuttgart, Dortmund, Duesseldorf, Frankfurt, Duisburg, Nuremburg, Magdeburg, Dresden, Hannover.

comprising highly built-up, mixed industrial/residential districts. These concentrations are particularly noteworthy in the cities of Tokyo, Kawasaki, Kobe, Osaka, and Nagoya, where they offer target areas of high vulnerability to area attacks. Table 4 lists 47 Urban Industrial Concentrations, including one in Mukden, Manchuria. A few other suitable concentrations are being studied and will be added to this list.

The following considerations have governed the selection of the indicated concentrations and their general priority rating:

a. Density of industrial occupancy — Generally speaking, the prime consideration in delineating Urban Industrial Concentrations has been the density of industrial/military installations, since this is the principal factor determining their vulnerability to area attack.

b. Contribution of Concentration to Japan's Military End-product Production—Principal weight was given to the incorporation of large plants producing aircraft, ground armament and munitions, etc. Next in importance has been the inclusion of a maximum number of industrial facilities directly supporting military end-product output, such as machine tools, electrical equipment, ordnance and aircraft components, etc.

It will be noted that the indicated concentrations do not include all of the industry within urban metropolitan areas. Relatively isolated factories, such as the Nakajima and other aircraft producing facilities in the Musashino-Tama districts of west Tokyo, have been excluded because they constitute individual objectives for precision attack. A few industrial/military facilities sparsely scattered throughout the large urban areas have also been omitted, as have the predominantly commercial or residential districts, such as the built-up section of Tokyo directly W and N of the Imperial Palace. It is felt that because of their general peripheral location, attacks directed against the urban industrial concentrations would spill over into most of the built-up districts and, as a by-product, result in the destruction of the bulk of housing and commercial facilities. The accompanying maps illustrate the relative disposition of the UIC's within the cities.

E. SIGNIFICANCE OF HOUSEHOLD INDUSTRY

Another important feature of Japanese industrial cities which makes them suitable area targets is the relatively large amount of industrial production carried on in very small factories and household shops. During the immediate pre-war years, the total number of plants employing 5 or more persons was reported to about 15,000 in Tokyo, 15,000 in Osaka and 5,000 in Nagoya. Of these the great bulk were small establishments employing 30 or less. In 1937, the distribution of factories and workers in Japan Proper for plants employing 5 or more was as follows:[2]

Size of factory (number of workers)	Percent of total factories	Percent of industrial workers
5–30	86.3	27.7
30–500	13.0	38.4
Over 500	.7	33.9
Total	100	100

[2] Compiled from *Rodo Tokei Yoran*, 1939, Office of Strategic Services.

Adequate statistics are not available for household shops employing less than 5 persons, but it is known that they accounted for a large proportion of total gainfully employed. If included with the above, they would increase substantially the relative percentages for plants employing less than 30. It should be noted that, with the possible exception of machine tools and general machining, both the quantity and quality of the output of these plants are of less significance, relatively, than is suggested by the employment data. Moreover, war-time conversion has undoubtedly resulted in a decrease in the number of these small shops, but the efficient peacetime system of sub-contracting in which these plants participated has probably been largely retained. As producers of simple components and small sub-assemblies for the large war plants, and in view of their relatively high vulnerability to fire, these small shops assume special significance for area attacks.

F. INTERDEPENDENCE OF INDUSTRIAL CENTERS

The foregoing has indicated the general impact on priority war production which may result from successful area attacks. Such losses may have important ramifications beyond the industrial complexes in which they occur. Japan's great dependence on a comparatively few large industrial centers has made them the main suppliers of industrial materials for satellite and isolated plants. There is a complex inter-dependency resulting from extensive sub-contracting and the consequent flow of components and sub-assemblies.

It should be noted, however, that there also exists a significant degree of regional industrial "self-efficiency," especially with respect to armament and heavy industry. Under regional administrative control and supplied by nearby satellite manufacturers, such regional complexes are intended to reduce the interdependency of the principal centers. On the other hand, as has been noted above, these regional complexes entail a special vulnerability of their own, since most are organized around the producing and transport facilities of the leading industrial centers and would be affected directly by major damage to the centralized facilities.

G. CONCENTRATION OF PRIORITY INDUSTRIES IN SELECTED URBAN AREAS

Table 3 indicates the estimated concentration of selected industries in the 46 urban industrial concentrations currently listed as suitable for area attack (excluding Mukden UIC/1, in Manchuria). It should be noted that the selected industries do not include all significant production which is concentrated in these areas, since it has not been possible at this time to compile estimates in this form for chemicals (other than nitrogen), general machinery or heavy industrial equipment, precision instruments, etc., all of which are known to have a substantial concentration in these areas. In general, these areas also contain an equal (and greater) relative amount of Japan's total non-priority industry, such as textiles, consumer durables, food processing, building materials, etc. While relatively unimportant individually, the non-priority industries assume significance in the aggregate as a secondary source of recuperative facilities for damaged priority industries.

Of the indicated industries, the most significant as to priority and degree of concentration are the aircraft (particularly components), armament, electronic tubes, marine engines, machine tools and electrical equipment. General metal working capacity, an important source of miscellaneous parts and components, is also highly concentrated.

1. *Aircraft:* Prior to attack, aircraft production displayed a fairly high degree of concentration, with 42% of engine production, 41% of aircraft assembly and about 77% of parts and components in the selected urban areas. Of this, all engine and assembly capacity and about 63% of parts and components was included within the Urban Industrial Concentrations. Nagoya had by far the heaviest concentration of engines (25%) and assembly (40%). Aircraft engine production near Tokyo (approx. 40%) is located well outside the limits of the UIC's and is, therefore, susceptible to loss of production from area attacks on Tokyo only through absenteeism and interference with the flow of sub-contracted components. On the other hand, Tokyo had Japan's largest percentage of components production, estimated at about 22%, of which approximately 18% was at risk within the UIC's.

   With the dispersal of engine and assembly facilities following recent attacks, the remaining concentration of component production may be one of the more vulnerable aspects of the aircraft industry.

2. *Armament:* Ordnance production also displays an important degree of concentration. It is estimated that about 55% of general arms-munitions capacity and about 58% of trucks and combat vehicles is included within the UIC's. The most notable concentrations of ground ordnance are in Tokyo, 10% ordnance, Osaka, 10% ordnance, Nagoya, 7% ordnance and 5% combat vehicles, and Yawata-Kokura, 7% ordnance and 5% trucks. Yokohama accounts for about 35% of trucks. The under-utilization of capacity in the armament industry (due primarily to the shortage of steel) and the existence of a few isolated, secondary armament plants tend to reduce vulnerability to area attack.

   Naval ordnance production, of considerably lower current priority because of substantial excess capacity, is somewhat less concentrated. Because naval ordnance capacity is potentially at least partly convertible to ground ordnance production, it is shown in Table 3 in terms of Japan's total ordnance (both ground and naval) capacity. Kure, Nagasaki, Yokosuka, and Sasebo have the largest naval ordnance capacity, but there are a number of other isolated naval ordnance plants.

   While not shown in Table 3, the production of heavy AA guns is believed to be very highly concentrated, principally in the ordnance works at Osaka, Kure, Tokyo, Yawata-Kukura and Nagoya, which are included with the indicated concentrations.

3. *Electronic Tubes:* The production of electronic tubes centers largely in the Kawasaki UIC's (70%), with 10% in Tokyo and 10% in Kobe. Radar gear production and assembly,not shown in Table 3, is known to be correspondingly concentrated. With electronic tubes believed to be in short supply, this industry is estimated to be operated at maximum capacity.

4. *Machine Tools:* The machine tool industry represents a major objective for area attack. There are roughly 27 priority plants and approximately 200 additional identified plants, rendering the industry too dispersed for consideration as a precision bombing target system. However, approximately 26% of total capacity is in Tokyo city (20% within UIC's), 14% in Osaka (12% in UIC's), and 7% in Nagoya (6% in UIC's).

   The relatively small size of most of these plants and their general location in compactly built-up districts make them suitable area targets. The correlation of high machine tool capacity and equally high aircraft and ordnance capacity in the key cities of Tokyo, Osaka, and Nagoya is of special significance in view of the critical importance of machine tools for repair and replacement of damaged equipment in these priority industries. Area attacks which resulted in some damage to these three systems, particularly following substantial damage to the aircraft engine industry by precision attack, would extend substantially the recuperative time of the damaged industries, while at the same time hindering the expansion or dispersal of remaining capacity.

5. *Electrical Equipment:* The production of light electrical equipment centers largely in the cities of Tokyo, 34% with 25% in UIC's, Kawasaki 8% with 6% in UIC's, Osaka 8% with 6% in UIC, Nagayo 5% with 4% in UIC's, and Yokohama 4% with 3% in UIC's. The production of heavy electrical equipment is also well concentrated, with approximately 20% in Hiratsuka UIC/1, 14% in Tokyo (12% in UIC's), 12% in Kawasaki (10% in UIC's), 8% in Kobe (2% in UIC's), 5% in Osaka (5% in UIC's) and 4% in Nagasaki (4% in UIC's). The electrical equipment industry is of major significance, both as a supplier of components for priority war industry and as a source of repair and replacement capacity for damaged factories.

6. *Shipbuilding and Repair:* The location of most shipyards, normally in peripheral waterfront areas, lower their vulnerability to area attack, since relatively few are included within the limits of the Urban Industrial Concentrations. Thus, while approximately 60% of total shipbuilding capacity and 45% of total ship repair capacity are accounted for by the selected urban areas only about 32% of shipbuilding and 25% of

ship repair are actually located within the indicated UIC's. Osaka, Yokohama, Kure, and Kawasaki contain the bulk of shipbuilding and repair capacity at risk in UIC's.

The production of marine engines, on the other hand, is both more concentrated and more at risk in UIC's. Furthermore, marine engines have been considered somewhat of a bottleneck in Japan's shipbuilding program, particularly for small, wooden vessels. Osaka, with 22% of total capacity (20% in UIC's), Nagasaki, 13% with 13% in UIC's, Kawasaki, 9.5% with 8% in UIC's, Tokyo, 8% with 6% in UIC's and Kobe, 13% with only 3% in UIC's are the principal marine engine building centers.

7. *Other Industries:* Other industries which display substantial concentration at risk to area attack are general metal working and iron and steel. General metal working capacity centers largely in Tokyo, 22% with 18% in UIC's, Osaka 20% with 15% in UIC's and Nagoya 10% with 9% in UIC's.

The production of iron and steel, including intermediate products shows a marked concentration in Yawata-Kokura, which accounts for 35% of Japan proper's pig capacity (25% in UIC's), 26% of steel (20% in UIC's) and 25% of intermediate products (15% in UIC's). Other important iron and steel centers are Kawasaki, Osaka, Tokyo and Kobe.

While considerably less at risk to area attack than the above-mentioned industries, the production of anti-friction bearings, synthetic and crude petroleum, nitrogen and rubber products also display a significant degree of concentration in the listed UIC's.

In considering the impact of area attacks on priority target systems and on the Japanese war economy the industries discussed above assume primary importance because of the probability that they will suffer a relatively high degree of direct damage. However, a significant amount of additive production loss in these industries will result from the widespread disorganization and confusion following concentrated attacks against the principal urban areas. This, together with damage done to non-priority industries, must be taken into account in assessing the impact area attacks.

It is recognized that the full impact of this type of attack against the Japanese economy can be assessed accurately only by consideration of the aggregate and cumulative industrial loss in each entire urban area and within the urban area target system as a whole.

TABLE 3

Concentration of Selected Industries in Urban Areas Suitable for Area Attack

Concentrations and in Built-Up Sections of Urban Areas

Estimated Percent of Total for Japan Proper Located Within Selected Urban Industrial

	Combat Aircraft			Armament		Shipbuilding & Repair					Electrical Equipment			Iron and Steel				Petroleum Refining			Rubber Products	
Urban Area	Final Assembly	Engine Mfg. and Assembly	All Parts	General Ordnance	Trucks and Combat Vehicles	Marine Engines	Ship Bldg.	Ship Bldg. Repair	Machine Tools	Anti-Friction Bearings	Light	H'vy	Electronic Tubes	Pig Iron	Steel	Intermediate Products	General Metal Working	Synthetic	Crude	Nitrogen Fixation	Tires	Misc.
TOKYO	—	—	22	10	—	8	4	3	26	20	34	14	10	3	6	7	22	—	3	—	—	15
(Within 5 UIC's)	—	—	18	10	—	6	2	3	20	15	25	12	10	3	5	6	18	—	3	—	—	12
KAWASAKI	—	—	7	0.5	8	9.5	6	—	3	9	8	12	70	9	14	12	3	1.5	14	13	20	2.5
(Within 3 UIC's)	—	—	6	0.5	8	8	6	—	2	9	6	10	70	9	12	10	3	1.5	14	13	20	2
YOKOHAMA	—	—	1	1	35	1.5	6	4	—	—	4	3	—	1	—	—	1	—	7	2	—	2
(Within 2 UIC's)	—	—	1	1	35	1	4	3	—	—	3	3	—	1	—	—	1	—	7	2	—	2
NAGOYA	25	40	15	7	5	—	1	0.5	7	—	5	2	—	—	1.5	2	10	7.5	—	4	—	5
(Within 8 UIC's)	25	40	13	7	5	—	1	0.5	6	—	4	2	—	—	1.5	2	9	7.5	—	3	—	5
OSAKA	—	—	12	10	—	22	12	10	14	10	8	5	—	2	8	8	20	—	1	—	—	12
(Within 7 UIC's)	—	—	8	9	—	20	11	10	12	4	6	5	—	2	7	7	15	—	1	—	—	10
AMAGASAKI	5	1	3	0.5	—	.5	—	—	—	1	1	1	—	—	3	5	2	10	3.5	—	—	1
(Within 3 UIC's)	5	1	2	0.5	—	0.5	—	—	—	1	—	1	—	—	3	4	2	10	3.5	—	—	1
KOBE	—	—	4	1.5	5	13	10	6	—	—	2	8	10	4	8	8	3	—	—	—	32	8
(Within 2 UIC's)	—	—	4	1.5	5	3	—	—	—	—	2	2	10	4	8	7	3	—	—	—	32	8
YAWATA-TOBATA-WAKAMATSU-KOKURA	—	—	1	7	5	—	1	1	1	—	1	—	—	35	26	25	2	2.5	—	3	—	1
(Within 3 UIC's)	—	—	—	7	5	—	—	—	1	—	1	—	—	25	20	15	1	2.5	—	3	—	1
KURE	—	—	—	5	—	3	4	6	—	—	—	—	—	—	0.5	—	—	—	—	—	—	—
(Within 1 UIC)	—	—	—	5	—	3	4	6	—	—	—	—	—	—	0.5	—	—	—	—	—	—	—
HIROSHIMA	—	—	0.5	—	—	—	0.5	—	2	—	—	—	—	—	—	—	—	—	—	—	—	1
(Within 1 UIC)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
NAGASAKI	—	—	0.5	4	—	13	10	8	—	—	—	4	—	—	—	—	—	—	—	—	—	—
(Within 1 UIC)	—	—	0.5	4	—	13	—	—	—	—	—	4	—	—	—	—	—	—	—	—	—	—
SASEBO	—	—	—	3	—	1.5	2	4	—	—	—	—	—	—	—	—	—	—	—	—	—	—
(Within 1 UIC)	—	—	—	3	—	1.5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
OMUTA	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	10	—	15	—	1
(Within 1 UIC)	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	10	—	15	—	1
HAMAMATSU	—	—	3	—	—	—	—	—	1	—	—	—	—	—	—	—	1	—	—	—	—	—
Within 8 other UIC's (Sakai, Niigata, Kyoto, Yokosuka, Kagamigahara, Hitachi, Hiratsuka, Himeji) (Mukden *not* included)	12	—	8	6	—	8	4	3	5	4	10	20	—	—	—	—	5	—	2.5	15	1	5
Total Within General Urban Areas	42	41	77	55.5	58	80	60.5	45.5	60	44	73	69	90	54	67	67	69	31.5	31	37	53	53.5
Total Within UIC	42	41	63.5	54.5	58	64	32	25.5	48	33	57	59	90	44	57	51	58	31.5	31	36	53	47

TABLE NOTES

1. For combat aircraft, ordnance, and electronic tubes, estimated production is the basis of computations.
2. Estimated capacity is the basis of computation for other industries.
3. Kawasaki includes the contiguous portion of Tsurumi Ku of Yokohama which lies generally north of the Tsurumi River.
4. "Combat aircraft" excludes trainers and gliders. "All parts" include propellers, instruments, sub-assemblies and other components not produced in engine or assembly plants.
5. "Machine tools" are nonportable electrically operated equipment used to remove metal in chips or shavings. Excludes machine shops on contract work, general industrial equipment and abrasives.
6. "Arms and Munitions" includes tanks, guns, small arms, shells, torpedoes. Excludes propellants.
7. "Intermediate" steel products are composed of primary and secondary prefabricated shapes and forms.
8. "Heavy" electrical equipment includes turbo-generators, converters, rectifiers, large motors, etc.
9. "Light" electrical equipment includes small motors, wire and cable, meters, instruments, magnetos, sparkplugs, etc.

IV. PHYSICAL VULNERABILITY AND WEAPON RECOMMENDATIONS

A. INTRODUCTION

This is one of a series of technical papers on the attack of target categories, each of which is issued as an Annex to the General Analysis of the category. It is written for personnel in Army or Navy Air Forces engaged in selecting weapons, estimating force requirements, and formulating operational orders for attacks on targets in the system.

This Annex attempts to answer the following questions in connection with attacks on urban areas:

1. What are the physical characteristics of Japanese cities as targets for air attack?
2. What parts of cities should be selected for attack?
3. Which incendiary bombs should be used?
4. To what extent is the success of incendiary attacks influenced by weather?
5. In what circumstances should HE be used in conjunction with or in place of incendiaries?
6. What weight (or density) of attack is required?

Appendix A attached explains the preparation and use of Target Information Sheets and Weapon Recommendation Sheets issued by the Joint Target Group on individual Urban Industrial Concentrations recommended for attack.

B. SUMMARY

1. Most zones of major Japanese cities are vulnerable to incendiaries. Industrial zones are somewhat less vulnerable than the most congested residential zones, but sufficiently vulnerable to justify their selection as the target for predominantly incendiary attacks.

2. For a combination of economic reasons (explained in Part III) and vulnerability considerations, it is recommended that attacks be directed against MPI's in or near selected Urban Industrial Concentrations (predominantly manufacturing) rather than against congested (predominantly residential) areas.

3. Clustered M69, M74, or M50 bombs are preferred, with the M47 as an alternate choice. The use of WP or X features, where available, is strongly recommended. The M74 and M69 will be more effective than the M50 against residential areas.

4. By far the most important weather factor influencing the effect of an area incendiary attack is wind; with a strong wind the fire is much more likely to spread beyond the bomb pattern and the damage may be increased several fold.

5. No HE should be used in support of urban area incendiary attacks where IB's with X and/or WP features are available; where not available, the amount of HE or fragmentation bombs used in *support* of IB should never exceed 10-20% of the total load. In attacking concentrations consisting predominantly of petroleum, steel, heavy industries, or fire-resistant buildings, a high density of HE is required in addition to the incendiaries, and the most suitable HE should be chosen for causing damage (not for "supporting" the incendiaries).

6. The density of suitable incendiary bombs required to burn out the bulk of the combustible portion of an industrial zone is 8 to 12 tons per million square feet (225 to 350 tons per square mile). The combustible portion is, on the average, about 50% of the total industrial floor space. The density required on congested residential zones is less: it is tentatively estimated from the first series of attacks that 4 tons per million square feet (120 tons per square mile) is effective against the most vulnerable zone (R_1—more than 40% built-up) when weather conditions are favorable (low humidity, average wind velocity). Operations should be planned to reduce overhitting or underhitting (in terms of the above densities) to a minimum.

7. Lack of adequate information regarding bombfall has seriously handicapped the analysis of the first series of area incendiary attacks; for this reason the conclusions of this Annex are incomplete and must be regarded as tentative. If weapon selection and operational techniques are to be improved, it is essential that suitable means be developed and necessary steps taken to determine the mean point of impact and distribution of incendiary bombs.

C. PHYSICAL PATTERN OF CITIES—ZONES

Because of climatic and geographic considerations the major Japanese cities have developed along the coastal areas of Kyushu and southern Honshu. In pattern they are generally similar to occidental cities. In most cities a residential area of graduated density surrounds a central core (usually located on or adjacent to the water front) of industrial, commercial and administrative units. Additional industrial and commercial units may be found scattered throughout the city or in the outskirts along lines of transportation. For purposes of analysis Japanese cities have been divided into the following zones, which are outlined on the UA/PZ mosaics to be issued for each important city:

Zone R —Residential.
Zone R_1—Fully built-up (more than 40 percent of zone area covered by buildings).
Zone R_2—Moderately built-up (from 20 to 40 percent of zone area covered by buildings).
Zone R_3—Sparsely built-up (5 to 20 percent of zone area covered by buildings).
Zone M—Manufacturing.
Zone X —Mixed Residential-Industrial.
Zone S —Storage.
Zone T —Transportation.

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Table 1 summarizes the chief characteristics of the different zones—building density, occupancy, construction, and vulnerability to incendiary attack. The descriptions given are generalizations which ignore differences between cities and exceptional cases.

TABLE 1

Characteristics of Zones

% of total roof area of city	Average Building Density	Occupancy	Construction	Susceptibility to Incendiary Attack
Zone R—Residential R1 25% to 35% R2 30% to 40% R3 5% to 15%	More than 40% 20% to 40% 5% to 20%	*Residential Type* (85% to 90%) used for homes, small shops, and household industries.	Wood framed, walls of mud plaster, floors of wood covered with continuous heavy, compressed straw matting, roofs of tile or sheet iron over wood rafters and light boarding. A detailed study of residential building sizes in Nagasaki and Yawata indicates that the average size of residence (mean) is approximately 1,000 sq. ft. The most common type (mode) is smaller—about 700 sq. ft.	Excellent to poor, depending primarily on building density, secondarily on construction. Where houses are widely spaced, as in R3, they are a poor IB target because of the small size of fire divisions, each of which must be separately ignited. Roofs are readily penetrable by M69 type bombs; penetration by M50 from high altitudes is excessive.
		Other Types (10% to 15%) used for commercial, industrial and municipal purposes.	Generally of reinforced concrete or steel frame construction.	Fire resistant buildings are generally not penetrable by small IB's; they are subject to contents damage from exposure to intense fires in nearby buildings and from spreading fires.
Zone M—Manufacturing 15% to 25%	20% to 50%	Manufacturing and administration buildings; warehouse facilities which are part of factory complexes.	Manufacturing bldgs. are predominantly one-story structures framed either in steel or wood with roofs of light weight sheet materials. Administration bldgs. and a small proportion of manufacturing bldgs. are of reinforced concrete construction, though, if small, the former are frequently of wood frame construction. Plant warehouses are likewise of wood frame.	Good to poor, depending primarily upon combustibility of construction and contents. Many of the more important industrial complexes are isolated from adjacent residential areas by streets or canals or by specially constructed firebreaks. Roofs of all except reinforced concrete buildings readily penetrable by small incendiary bombs.
Zone X—Mixed Small	30% to 50%	Mixed residential and manufacturing for Zone R and M described above.	Mixed types of construction as for Zone R and M described above.	Usually good, but depends on building density. Owing to their location in the midst of residential areas, manufacturing plants in this zone are vulnerable to damage by spreading fires.
Zone S—Storage Small	20% to 35%	Warehouse and storage facilities (outside factory complexes). Most are associated with docks.	Predominant are gable roof bldgs. of steel or wood frame, covered with corrugated asbestos or iron. There are a few multi-story bldgs. of reinforced concrete.	Usually good, but varies with type of construction, combustibility of stored materials, and extent to which isolated from congested areas by streets, canals, etc.
Zone T—Transportation Very small	Always sparse	Ferry and rail terminals, classification yards, and rail administration and repair facilities.	Structures are of widely varied construction, but generally non-combustible or fire-resistant.	Usually poor.

D. CHOICE OF AREAS FOR ATTACK

The selection of areas for attack within cities requires consideration of the vulnerability of the area (construction and building density) and of its economic importance.

For reasons fully explained in Annex II of the Urban Areas General Analysis, the destruction of industrial capacity is considered of far greater importance as an objective than the destruction of residences. The losses inflicted will be greater in magnitude and of much longer duration.

The first series of incendiary attacks have revealed that the industrial and mixed industrial-residential areas are vulnerable to IB provided a sufficiently high density is achieved. Large factories of high priority are usually protected from firespread by firebreaks, wide streets, or waterways; but in most cases have a high percent (30% or more) of combustible buildings and/or contents vulnerable to direct hits. Small factories are in most cases vulnerable both to fire spread from adjoining residences and to direct hits.

A rough quantitative measure of the relative vulnerability of the different zones to incendiary attack has been derived from an analysis of damage from XXI Bomber Command Missions 41, 42, and 43. (Mission 40 was excluded because most of the damage resulted from a spreading conflagration; Mission 44 because the attack fell on an area already heavily damaged.) The fraction of damage to Zone R_1 within the area attacked was measured and called 100. The fraction of damage in other zones in the same area was then measured and expressed as a percent of the fraction of damage in Zone R_1. This percent was defined as the relative vulnerability of the zone. Finally a weighted average was calculated of the relative vulnerabilities found in the different attacks. Results are given in Table 2.

TABLE 2

Relative Vulnerability to IB of Zones

Zone	Relative Vulnerability (Missions 41-43)
R1	100
R2	36
R3	10
M	46
X	89

These figures must be regarded as tentative because of the small size of the sample. It is believed, however, that the general order of magnitude of the figures is reliable. The relative vulnerability of Zone M was high (at least 33) in each of the attacks.

It is therefore recommended that the next series of incendiary attacks be directed at MPI's in or near the Urban Industrial Concentrations listed and described in Part III. These concentrations are irregularly shaped areas which have been so drawn as to include:

1. All major factory and storage areas (Zones M and S) of high priority.
2. Mixed or predominantly residential areas (Zones X and R) containing large numbers of small factories important in the aggregate.

They also, of necessity, include segments of all other zones as well as some open spaces.

The Urban Industrial Concentrations, as drawn, are not usually of the right size or shape for selection, without adjustment, as target areas for any particular type of operation. MPI's for the type of operation planned should be so selected that the bomb patterns in an attack or series of attacks will include all or most of the area of the concentration.

E. CHOICE OF IB

Against the industrial portions of the concentrations the small clustered bombs—M50, M69, and M74—are usually the preferred weapon. Insufficient evidence is available to determine which of the three is the most effective per ton.

Where the average industrial fire division is medium or large, the M47 will be about equally effective. Where there are numerous small fire divisions, it will be less effective on a tonnage basis.

The M69 or M74 will probably be more effective than the M50 against the residential portion of the concentrations when bombing is from high altitudes, because of excessive penetration by the M50. It is not yet possible to assess the relative effectiveness of the large incendiaries (M47 and M76) against residential areas.

It is believed that the WP cup or X feature on small incendiaries will substantially increase their effectiveness.

F. EFFECT OF WEATHER ON INCENDIARY ATTACKS: FIRE SPREAD

Weather (except in extreme cases) has no measurable effect on incendiary attacks on industrial complexes. The initiation of fires within buildings depends to a very minor extent on weather, and industrial buildings are usually too widely spaced for fire spread to be an important factor even in very favorable circumstances.

In attacks on congested Japanese residential areas, on the other hand, fire spread can make a major contribution to the damage. Appliance fires (i.e., fires which survive immediate attack by civilian fire fighters) started by direct action of incendiary bombs are known as *primary* fires; the aim should be to start enough of these within the bomb pattern to cause them to spread to adjacent buildings (*secondary* fires) and merge. If they spread outside the bomb pattern (*tertiary* fires) a true conflagration has been achieved.

By far the most important factor influencing spread is wind velocity and direction. Wind aids internal spread (secondary fires), and is essential for external spread (tertiary fires). Where wind and other conditions are favorable, the damage from spread (secondary and tertiary fires) may be many times that from primary fires. The high damage per ton in the Tokyo attack of 9/10 March (XXI Bomber Command Mission 40)—about three times the average on other urban incendiary attacks — is believed to have been due mainly to wind.

The major effect of the extensive firebreaks cut by the Japanese is to hinder the external spread of fire downwind. A preliminary analysis of the perimeters of fire damage in the early attacks reveals that on the up-wind side and flanks fires usually stopped at narrow streets or even between streets; but that on the downwind side they frequently burned until they reached wide streets or artificial firebreaks. Where a network of firebreaks has been created, as in Tokyo UIC/3, little bonus can be expected from tertiary fires in the absence of high winds. Firebreaks are of minor significance in hindering spread when bombs fall on both sides of the break.

Humidity and precipitation are of much less importance than wind. A full discussion of the effects of weather factors on urban incendiary attacks is attached as Appendix B.

It is recommended that every effort should be made to obtain reliable predictions of weather conditions at the target, so that attacks can be timed to take advantage of high ground winds.

G. USE OF HE IN SUPPORT OF INCENDIARIES IN URBAN AREA ATTACKS

HE weapons may be carried with incendiaries for three purposes:

a. To interfere with firefighters
b. To secure levels of damage higher than is possible with pure IB (discussed in Section H below)
c. To mark the fall of the incendiaries (discussed in Section J below)

In order to interfere with firefighting one or more of the following effects must be achieved:

a. Killing firefighters or at least reducing their effectiveness by keeping them under cover.
b. Hindering access of firefighting personnel and equipment to the scene of fires by craters and debris.
c. Destroying underground utilities such as communications and water supply systems.

Killing and discouraging firefighters is best done by large numbers of small anti-personnel bombs in the immediate neighborhood of the fire. If incendiaries such as the M69X or the M69 with WP cup are available, it will not be efficient to carry any additional anti-personnel bombs. If these incendiaries are not available it may be desirable to carry some anti-personnel bombs, but this has not been definitely proved. In no case should more than 10% to 20% of the total load be composed of anti-personnel bombs. The butterfly bomb (M83) in the 500 lb cluster (M29) is most suitable provided the attack is from medium altitudes. If altitudes over 8000 feet are used it will be necessary to use the 100 lb cluster (M28) with spoiler ring and drag plate; this will probably be unsatisfactory due to the excessive trail and the smaller number of bombs per unit weight of cluster. The butterfly bomb has a decisive advantage because large numbers can be carried and delay and anti-disturbance fuzes are fitted which will cause a continuing threat to firefighters. The 20 lb frag (M41) is a very poor alternative and is not recommended; there will be far fewer bombs, and since it has an instantaneous fuze it will be effective only if dropped in the same area as the incendiaries and 2-20 minutes later. Larger frag bombs, GP bombs, and LC bombs will be too few in number to have any significant effect on firefighting.

It will not be profitable to carry any bombs intended to hinder access to fires or to destroy underground utilities. The density of appropriate GP bombs or LC bombs which could be laid down would be so small as to be almost completely ineffective.

It should be particularly emphasized that it will never be profitable to carry more than 10% to 20% of the total load in HE weapons to assist the incendiaries in causing *fire* damage. The results beyond this percentage will always be such that the displaced incendiary load would have produced a greater damage return.

H. USE OF HE AS A MAJOR WEAPON

Since the objective of attacks on Urban Industrial Concentrations is maximum overall destruction of industrial capacity, rather than a very high level of damage in particular establishments, the attacks should be predominantly incendiary. Incendiaries destroy *combustible* buildings or contents far more economically than HE, and a high production of Japanese urban industry (an estimated 50% of total floor space) is combustible.

In the typical Urban Industrial Concentration the proportion of combustible industrial buildings and/or contents (alpha value*) will be between 40% and 70%. Against such concentrations no HE is recommended for the initial attacks.

A few concentrations, however, consist predominantly of industrial plants with low alpha values (petroleum, steel, heavy industries, light industries in fire-resistant buildings). Examples are Amagasaki UIC/1, Kawasaki UIC/2, and Yawata UIC/1. Where the average alpha value for the concentration is low (industrial plants only) a *mixed load* of HE and IB should be used, in which the HE is not supporting the IB, but each weapon is contributing direct damage to the target. Alternatively, the HE may be dropped in a subsequent attack; this would permit better briefing regarding MPI's for the HE, but any supporting effect of the HE's on the IB's would be lost.

The HE bomb and fuzing should be selected to cause maximum damage to the non-combustible portion of the target. The methods of selecting the most effective HE for any target type or combination of types are described in JTG M-8, (filed in Air Target Index, Japanese War). Some of the concentrations are suitable targets for large blast bombs (e.g., the 4000 LC), which are probably better than GP's against light industrials, and would also be very effective against residential-type buildings.

I. REQUIRED DENSITIES

The density of suitable incendiary bombs required to burn out about 80% of the combustible portion of an industrial target varies with a number of circumstances, but is generally of the order of 8 tons per million square feet (225 tons per square mile). This estimate is based primarily on experience in the ETO; and has been confirmed by an analysis of the attack on Hankow dock area by XX Bomber Command. Confirmation from the first series of incendiary attacks on Japanese cities has not been possible because of the uncertainties regarding the fall of bombs.

* JTG M-8 for definition and methods of computing.

In attacks on Urban Industrial Concentration it is recommended that an attempt be made to achieve densities of 8 to 12 tons per million square feet (225-350 tons per square mile) of incendiary bombs.

Considerably lower densities will probably be effective, under favorable weather conditions, against Zone R_1. Analysis of XXI Bomber Command Mission 42 against Osaka (low humidity—wind 7-10 m.p.h.) indicates that 80% destruction was achieved in those parts of Zone R_1 in which the density was about 4 tons per million square feet (120 tons per square mile). Higher densities (probably of the same order as against industrial) will be required against Zone R_2 and the less densely built-up portions of Zone X.

Where a mixed attack (HE and IB) is required on a Concentration with a small proportion of combustible buildings and/or contents, the IB density should be 8 tons per million square feet (225 tons per square mile). The additional density of HE required to cause any desired level of damage can be calculated by methods explained in JTG M-8 (filed in Air Target Index—Japanese War).

Operations should be planned to reduce overhitting or underhitting to a minimum. Overhitting and underhitting results when the densities of incendiary bombs are markedly higher or lower than those stated above.* Where densities are very low, the bombs will be well within the capacity of fire fighters, and the number of primary fires per ton of bombs will be low. Moreover, the partial damage resulting from scattered fires will make the destruction of the area in a subsequent attack more difficult. Where densities are much higher than those recommended, bombs will be wasted on buildings already fired.

Attacks in which aiming is by individual planes on a single aiming point (or closely spaced aiming points) have the disadvantage that the distribution of bombs about the MPI tends to be "normal." If appropriate densities are achieved in a middle range, there will be overhitting near the MPI and underhitting over a wide area on the periphery. It may be possible to overcome this disadvantage to some extent in heavy attacks by selecting widely spaced aiming points, or by other methods.

Light, scattered attacks are relatively ineffective and spoil the target.

* This suggestion applies to average densities over sizeable areas; it does not imply that a high local density within the bomb pattern from one aircraft is undesirable.

To overwhelm civilian firefighters and create areas of uncontrollable fires before professional forces can be brought in from adjacent areas, attacks should be delivered in the shortest possible period of time.

J. BOMB-FALL

The conclusions and recommendations of this paper are tentative and incomplete because little reliable data are available on the fall of bombs in the initial area incendiary **attacks.**

Analysis of weapon effectiveness and of the influence of weather and operational factors can be made with reasonable accuracy provided the MPI and distribution of the bombs are known. In the absence of this knowledge, it is never possible to determine with certainty whether divergent results on two attacks are due to known differences in tactics, type of bomb, or weather or merely to a difference in the proportion of gross aiming errors.

If weapon selection and the timing and tactics of attacks are to be improved by systematic analysis, better information on the fall of incendiaries is essential. Since incendiaries leave no crater, the only presently recognized possibilities of determining their MPI and distribution are:

1. Strike photographs (day or night). It was possible to plot the general pattern of incendiaries from strike photographs taken on Missions 17 and 26 (formation bombing in daylight). In night attacks with bomb release by individual planes the analysis of strike photographs presents much greater difficulties, so far not overcome.
2. The use of HE as a marker for the incendiaries. This was tried unsuccessfully in Mission 38, in which one marker bomb (500 GP, fuzed 0.025) was carried in each plane. Craters were not visible in the burned out areas, presumably because ash from the fires settled in and obscured them. This difficulty might be overcome by using a long delay fuze (6-12 hours). It is believed that an explosion after the fire would cause a crater which could be readily identified on post-attack reconnaisance cover. One bomb (500 or 1000 GP, fuzed long delay) should be carried in the bomb station of each plane.

PART V

Explanation of Weapon Recommendations for Use Against INDUSTRIAL CONCENTRATIONS

A. INTRODUCTION

The methods of analyzing the efficiencies of various weapons against individual industrial targets and the presentation of the results of this analysis as Weapon Recommendation sheets have been described in JTG M-3 (nontechnical) and JTG M-8 (technical). In applying these methods to Urban Industrial Concentrations certain modifications have become necessary, and these are described below. Changes have also been made in the form of the Weapon Recommendation Sheet (WR1). A sample of this revised sheet is attached, and full explanations for its use are given below. No WR2 Sheets (Low Altitude Attack by carrier based aircraft, fighter-bombers, etc.) will be issued for these concentrations.

B. VULNERABILITY ANALYSIS

1. Objectives of the Attack

The Urban Industrial Concentrations are a number of areas in Japanese cities each of which includes a group of important industrial plants as well as some domestic housing (which is considered to be of secondary importance). These concentrations have areas of the order of several square miles and are designated as suitable targets for area rather than precision attack.

The chief consideration in choosing weapons for such an attack is the expected damage to the industrial plants in the concentration. Damage to domestic housing is not taken into account in the calculations. The recommended weapons, however, are such as to cause widespread damage to domestic structures.

2. Target Information Sheet—Construction and Vulnerability Section

The first step in the analysis is the estimation of the vulnerability of the individual industrial plants in the concentration to HE and IB respectively on the basis described in JTG M-3/1 and JTG M8. Because of the large number of individual plants involved, detailed structural analyses have not been prepared in most cases, and consequently the estimates (especially those concerning fire vulnerability) are rough and preliminary in these cases. The percent of "combustible", "non-combustible", and "fire-resistant" buildings in each plant is estimated, as is the percent of the floor area covered by combustible contents. These factors are averaged to determine the total floor area of the target susceptible to fire damage. HE vulnerability is determined by estimating the percent of buildings in each plant falling into V1, V2, V3, V4, V5, and special classes, and then computing a weighted average vulnerability of the various plants. The results of this analysis are presented in the "Construction and Vulnerability" section of the Target Information Sheet, a sample of which is given on next page. *All the figures listed in this table are based on the condition of the target previous to any bombing attack.*

In the line of this table labeled "Portion of target (buildings and contents) susceptible to fire damage" the percentages recorded refer to the maximum percent of serious damage which can be caused by incendiaries; serious damage is structural damage plus severe internal fire damage to contents. These figures then give the maximum percent of damage to the target which can be expected from an incendiary attack. They are further interpreted in the line labeled "Susceptibility to incendiary attack, Buildings and Contents" in terms of "poor", "fair", "good". If the maximum percent of serious damage which can be caused by fire is 25 percent or less, the rating is "poor"; if the percent is in the range 26 percent to 40 percent, the rating is "fair"; if the percent is over 40 percent, the rating is "good".

CONSTRUCTION AND VULNERABILITY
(Refer to Illustration 90:25-3617, P4, P.)

The following table lists characteristics of the target prior to any attack. For approximate extent of destruction up to 15 April 1945 refer to Illustration No. 90:25-3617 P5.

	PRINCIPAL TARGETS						Other Industrial Areas*	Total Industrial Areas*
	90:25-382	90:25-697*	G*	H*	J*	M*		
Site area, 1000's of square feet	13085	530	310	120	1050	1170	13410	29680
Percent of site area built up	38%	40%	40%	30%	60%	20%	14%	27%
Total plan area of bldgs., 1000's of square feet	4994	210	120	40	630	230	1908	8132
*HE Vulnerability:***								
V1 (least vulnerable)	2%	10%	....	....	....	....	12%	4%
V2	43%	....	20%	....	....	....	....	27%
V3	7%	....	....	....	....	....	11%	7%
V4	48%	90%	80%	100%	100%	100%	76%	62%
V5 (most vulnerable)	....	....	....	....	....	....	....	....
Special (gas holder)	....	....	....	....	....	....	1%	....
IB Vulnerability:								
Combustibility of buildings:								
Fire resistant (R)	2%	10%	....	....	....	....	12%	4%
Noncombustible (N)	63%	20%	40%	10%	....	....	7%	42%
Combustible (C)	35%	70%	60%	90%	100%	100%	81%	54%
Portion of target (buildings and contents) susceptible to fire damage	50%	70%	65%	95%	100%	100%	75%	70%
Susceptibility to incendiary attack:								
Contents only:	Poor	Poor	Poor	Fair	Fair	Fair	Fair	Fair
Buildings and contents	Good	Good	Good	Good	Good	Good	Good	Good

*For targets so marked, all data are preliminary estimates only. Detailed structural analyses if prepared later may vary considerably from these preliminary estimates.

**For explanation of HE vulnerability classifications refer to JTG Memoranda M-3 (nontechnical) or M-8 (technical).

3. Target Information Sheet—Fire Plan Illustration—P5.

The susceptibility of the various portions of the concentration to fire damage is illustrated graphically on the Fire Plan attached as Illustration—P5 to the Target Information Sheet. On this Fire Plan plants rated "poor" on buildings and contents are colored blue, "fair" plants purple, and "good" plants red screen. The susceptibility of residential and mixed areas is shown by the same color scheme; the most congested areas (Zone R_1 and part of Zone X), rated "excellent", are colored red. Noncombustible areas such as rivers, parks, etc. are uncolored. Major and minor fire breaks are indicated by heavy and light broken lines, respectively. A sample Fire Plan is attached at the end of this memorandum.

C. WEAPONS RECOMMENDATION SHEET (see sample WR sheet attached)

1. Ground Density

The purpose of this sheet is to recommend the best weapons for use against a specific industrial concentration and to show the quantity of these weapons required for various levels of damage. Because of the uncertainties concerning the accuracy of bombing in area attacks, no attempt is made to express these force requirements in terms of tons dispatched or tons released over the target. Instead the requirements are expressed in terms of the density of bombs delivered on the ground within the target area. In Table I of the WR Sheet this quantity is called the "Ground Density". To convert this quantity to "tons dispatched" the following relation should be used:

$$\text{Tons dispatched} = \frac{(\text{Ground density}) \times (\text{Total area of target})}{\text{Percent of bombs dispatched which are expected to fall within the area of the target}}$$

2. Explanation of Table I

Table I is designed to show the ground densities required to achieve various levels of serious damage. For an undamaged target Table I appears as in the following sample:

TABLE I

Ground density in Tons/million sq. ft. — HE	Ground density in Tons/million sq. ft. — IB	Percent Serious Damage to Industrial Plants
Damage observed to 1 March, 19..		00
x	2.0	30
x	3.0	40
x	5.0	50
x	7.0	60
4	14.0	70

x Not to exceed 10 to 20 percent of the total load.

After damage has occurred this table needs revision to present the requirements in terms of the tonnage needed to raise the existing damage up to the desired level. The most reliable method for doing this is to prepare a new "Construction and Vulnerability" Analysis based on the damaged target. Table I should then be

JOINT TARGET GROUP, WASHINGTON, D. C.

WEAPON RECOMMENDATIONS SHEET

SHEET. . 90:25-3617 WR1
DATE. . . . . . 10 May 1945
PAGE 1

OSAKA URBAN INDUSTRIAL CONCENTRATION No. 1

OSAKA **JAPAN**

TARGET 90:25-3617
OBJ. AREA 90:25
OBJ. FOLDER . New Target
CATEGORY . . . . Mixed Ind. Conc.—URBAN AREAS

LAT. . . . . 34°41'N
LONG. . . . . 135°32'E
ALT. . . . . 30 feet

HIGH AND MEDIUM ALTITUDE ATTACKS

(See also 90:25-3617—TI and associated target illustrations.)

INTRODUCTION

This Weapon Recommendations Sheet applies to a high or medium altitude attack against designated industrial plants (see Table II at the right) within Osaka Urban Industrial Concentration No. 1 (see Illustrations 90:25-3617 P4, P5). The sheet is based on photography through 24 March 1945.

An estimated 70 percent of the total floor area of the industrial plants can be destroyed by fire. For levels of damage up to 65 percent the recommended attack is primarily with incendiary bombs, with a minimum of high explosive to support the incendiary effort.

The ground densities recommended (see Table I) against the target area are believed sufficient to destroy residential and mixed zones surrounding the industrial plants.

WEAPONS AND FUZING

Incendiaries.

The preferred incendiary bombs are the AN-M69 6-lb, AN-M74 10-lb, or AN-M50 4-lb (all in aimable clusters). The AN-M47 70-lb incendiary is an alternative selection, and the AN-M76 500-lb bomb is not recommended.

High Explosives.

In support of an incendiary attack the most effective device is an explosive charge and/or white phosphorus cup incorporated in the incendiary bomb. If these are available, no auxiliary HE or fragmentation bombs will be worth the weight of incendiaries displaced.

HE or fragmentation bombs used in support of an incendiary attack should *in no case exceed 10 to 20 percent* of the total load.

As a major weapon. Incendiary attacks are expected to cause serious damage to about 65 percent of the area of industrial plants in the concentration. If it is desired to achieve percentages of serious damage above this level, the use of a combination of HE and IB is necessary (see Table I). The preferred HE weapon in this case is the 1000-lb GP, fuzed 0.01 N/ND T.* The 2000-lb and 500-lb GP, similarly fuzed, are alternatives. The 1000-lb GP is selected due to the preponderance of V4** buildings in the principal targets least susceptible to fire damage (see Table II below). Large blast bombs (4000-lb LC) probably would be equally or more effective against the targets in this concentration, and could be used if operational considerations permit.

* Use 0.1 N fuzes if 0.01 N fuzes are not available, and 0.01 T fuzes if ND T fuzes are not available. ND tail fuzing is recommended since most of the buildings have light roof material and are best damaged by blast effects.

** For a definition of V4 buildings see JTG M-3 (non-technical) or JTG M-8 (technical).

ATTACK DATA

Table I below gives the ground densities required to achieve up to 70 percent serious damage to the industrial plants in the target area.

TABLE I

Ground Density in Tons/Million Sq. Ft.		Percent Serious Damage to Industrial Plants
HE	IB	
***	2.0	30
***	3.0	40
***	5.0	50
***	7.0	60
4	14.0	70

*** Not to exceed 10 to 20 percent of the total load.

Table II below lists the principal plants in Osaka Urban Industrial Concentration No. 1 and the estimated percent of each subject to fire damage.

TABLE II

Industrial Plants			Estimated percent subject to fire damage #
Name	Number	Class	
Osaka Army Arsenal	90:25-382	Armament	45
Mitsubishi Copper Refinery	90:25-697	Non-ferrous metals	70
Tanaka Rolling Stock Co.	G	Road & RR Trans.	65
Japan A/C Machinery Co.	H	Machine Tool Ind.	95
Textile Mill	J	Armament	100
Segawa Heavy Industries Co.	M	Armament	100
Average Other Industrial Plants			75
AVERAGE ALL INDUSTRIAL PLANTS			70

#Revised 3 May 1945.

(193)

prepared as before except that the fractions of damage listed should be based on the total of the damage from the previous attack and that expected from the density to be achieved on the next attack. If the percent of previous damage was F′, and if the percent of the remaining target which is expected to be damaged by a substantial attack is F′, the total damage, F, is given by the formula:

$$F = F' + (1 - F') \times F''$$

Since such a detailed analysis requires a detailed damage assessment of the target and involves rather elaborate calculations it is desirable to develop approximate methods for revising Table I which can be readily applied in the field. This can easily be done in two important cases: (a) when the previous damage was concentrated on the combustible portion of the target as is the case for predominantly incendiary attacks; (b) when the previous attack damaged equal percentages of the combustible and noncombustible portions of the target as is frequently the case for a predominantly HE attack. The methods for revising Table I in these two circumstances are described below.

(a) Revision of Table I following a predominantly IB attack.

In this case a simple modification of Table I gives the desired result. By way of illustration suppose that 30% of the industrial area in the above concentration has suffered serious damage due to incendiaries. Then Table I is revised to read:

TABLE Ia

Ground density in Tons/million sq. ft.		Percent Serious Damage to Industrial Plants
HE	IB	
Damage observed to 1 March, 19..		30
x	1.0	40
x	3.0	50
x	5.0	60
4	12.0	70

x Not to exceed 10 to 20 percent of the total load.

Table Ia is calculated from Table I as follows. From a knowledge of the serious damage due to IB as of a given date, the ground density of IB responsible for that damage can be estimated. It may therefore be assumed that this density has already been delivered on the target, and this amount may be subtracted from the IB density required for higher levels of damage as shown on Table I. In the example above, 30 percent damage corresponds to a density of 2 tons/million sq. ft. of IB and this has been subtracted from each entry in Table I to calculate Table Ia.

(b) Revision of Table I following a predominantly HE attack.

Here it is assumed that equal percentages of the combustible and noncombustible portions of the target have been damaged. The method of revision is best explained by an example based on the target considered in Table I above. Suppose that a previous HE attack has caused 20 percent serious damage. Then Table I may be revised by applying the formula:

$$F = F' + (1 - F') \times F''$$

with $F' = 20$ percent and F″ being the percent of serious damage given in Table I. The result is Table Ib below:

TABLE Ib

Ground density in Tons/million sq. ft.		Percent Serious Damage to Industrial Plants
HE	IB	
Damage observed to 1 March, 19..		20
x	2.0	44
x	3.0	52
x	5.0	60
x	7.0	68
4	14.0	76

x Not to exceed 10 to 20 percent of the total load.

This method may also be employed following a mixed attack provided this attack has not substantially changed the relative proportions of the target which are combustible and noncombustible.

In preparing WR Sheets for publication JTG makes use of the most recent information concerning damage to the target and includes this in Table I. If additional damage occurs at a later date revisions may be made in the field according to the principles just discussed.

3. Explanation of Table II

Table II of the WR Sheet gives the percent of each of the important industrial plants which is subject to fire damage; in addition this figure is given for the average of the industrial plants of secondary importance and for the average of all industrial plants in the concentration. For an undamaged target these figures are the same as those listed on the Construction and Vulnerability Section of the Target Information Sheet under the heading "Portion of target (buildings and contents) susceptible to fire damage." When the target has been damaged by a previous attack, any necessary revisions (up to the date of the WR Sheet) are incorporated.

PART VI

THE INFLUENCE OF WEATHER ON THE EXTENT OF DAMAGE CAUSED BY INCENDIARY BOMBS

1. Although it has long been recognized in a general way that the weather must have some effect upon the ease of ignition and the rate of propagation of fires, until now little account has been taken of weather effects in planning incendiary bombing attacks. This has been due in part to the fact that, as explained below, the weather has relatively little influence on industrial targets, which constituted the chief concern of the air attacks on Germany. It has not been possible until recently to evaluate the effects of weather on urban area incendiary attacks, because the necessary experimental data and operational experience were not available.

2. The only weather features which are likely to have a significant effect on fire raising are, in order of importance:

a. Wind

b. Humidity

c. Precipitation (rain or snow)

The importance of any weather element in fire vulnerability varies considerably according to its relationship in *time* with the incendiary attack. For example, it is obvious that a high wind which prevails during the hours preceding an attack, but which does down as the attack develops, will be of no advantage in spreading the fire. On the other hand, a heavy rain a few hours before might substantially reduce the rate of propagation of the fire, even though the sky might have cleared completely by the time the attack developed. It is therefore worthwhile to consider separately the effects of weather during four critical periods, viz:

a. The three week period preceding the day of the attack.

b. The eight hour period preceding the attack plus the thirty minute period following the strike of bombs and

c. The four to eight hour period following the attack.

3. As to the effects of weather on incendiary attack of industrial installations, careful examination of the results of such attacks on German targets has failed to reveal any appreciable damage variation with weather. The greatest influence of weather factors is in promoting or retarding fire *spread* from one building to another, but industrial buildings are normally so segregated from each other by open ground or by fire walls that fire spread would not, under the best of circumstances, be expected to occur at all frequently. Hence, unfavorable weather is not an important detriment. The critical weather periods for incendiary attack on residential areas, or mixed residential/industrial areas will now be discussed.

a. The Three Week Period Preceding the Day of the Attack

From meteorological and wood-conditioning studies recently conducted, it has been determined that the *moisture content* of wood affects its ease of ignition and rate of fire propagation. The importance of moisture content is greatest with heavy structural members two inches or more in thickness, and least with thin sections, ("kindling") such as 1/4 inch paneling. The latter are apparently heated up by a fire and dried out very quickly, so that they burn fairly readily even with the maximum moisture content likely to be reached in any covered location. Larger members, when they contain more than about 15-16% moisture, are extremely difficult to ignite and are incapable of propagating a vigorous fire without the aid of "kindling". Variations in the moisture content in the range below 12% seem to have less influence, as this degree of dryness enables wood of any thickness to be ignited quite easily. The moisture content of wood depends chiefly upon atmospheric humidity, with which an equilibrium will always be set up providing the condition prevails long enough. There is a substantial lag between a change in humidity and a corresponding change in wood moisture content, however, and for this reason the average humidity over the preceding two to three week period will be of greater importance in determining the condition of wooden structural members than the humidity at any particular time. The relationship between moisture content and humidity has been found to be surprisingly constant for all the different species of wood, so that although there has been no opportunity to conduct trials with actual specimens of wood used by the Japanese in house construction, it is possible to state with reasonable assurance that an average relative humidity above 70% in winter, or 75% in summer, will produce an equilibrium moisture content greater than 15% and will appreciably increase the difficulty of *initiating* a vigorous fire. Even in this case, however, if a sufficient quantity of "kindling" is present, in any form characterized by large surface per unit volume, a good fire can be started despite the effects of moisture content, and this fire can overcome the retarding effect of moisture in heavier members and cause extensive destruction. It is, therefore, only in the *initial* stages of a fire that the humidity of the weather during the preceding three weeks is important. If a large enough bomb or a sufficient number of bombs are used to overcome this obstacle to fire initiation, humidity will be of minor importance in hindering spread. It is believed that one M-47 incendiary bomb will be capable of passing this point in Japanese houses without difficulty, and that owing to the prevalence in Jap houses of thin paneling and lightweight ceilings, M-69 bombs in sufficient numbers will enable spreading fires to develop under the most adverse conditions likely to be met with in Japan. It is doubtless true that on the eastern half of HONSHU the dry winter months are more favorable to incendiary attack than the summer months, and that during June, July, August, September and October a greater tonnage of bombs will normally be needed per unit area to insure widespread damage than at other times of the year.

b. Eight Hours Preceding Attack, and 30 Minutes Following

The humidity during this interval is, as previously explained, of no importance, and precipitation becomes the weather feature of greatest concern. A heavy rain during this period will not noticeably alter the *ease of ignition* of protected material inside a Japanese house, but should greatly hamper the spread of fire from one building to the next. The reason for this is obvious when it is recalled that a primary tactic in halting the spread of fire is to wet down all surfaces exposed to the direct radiation of heat from burning buildings. The outer walls of buildings, if soaked with moisture, will undoubtedly resist fire spread *longer,* and thus give time for the organized fire defenses to act. The lack of paint on the outer walls of Japanese houses will promote the absorption of moisture during a rain, and will therefore prolong the fire resistance of such buildings after the rain has ceased over a longer period than would be observed in western cities, where surfaces may become completely dry within an hour or so after rainfall has ceased. In this same connection it would appear that *snow* should not hamper the spread of fire to the same extent as rainfall, because the side walls of buildings, which are the chief surfaces exposed to heat radiation, would not become water soaked. Snow on the roof, if melted by a fire, would tend to run off through channels without wetting down the wooden structure to any great extent. Serious fire spread had occurred in American cities while the ground and buildings were covered with snow. During the 30 minutes after bomb fall, fires are being initiated and the envelopment of buildings by primary fires is proceeding. If a building is in a vulnerable condition at the time of strike, even the most extreme weather conditions can neither prevent nor measurably aid the spread of fire within the building in the absence of fire fighting measures.

c. Eight Hours Following Attack

Heavy rainfall during this period will, of course, greatly restrict fire spread after the primary fires have been kindled, for the reasons already given. The weather feature of greatest interest at this time from a tactical standpoint, however, is *wind,* which until now has been of no significance. It may be said that wind is by far the greatest potentially favorable factor in promoting a conflagration and the production of really catastrophic damage. In fact, even when the favorable influence of all other factors is at the maximum, it is unlikely that fires will be uncontrollable indefinitely *unless* the wind velocity is greater than 15 miles an hour. The rate of fire propagation from building to building increases rapidly as the wind velocity rises from 15 to 30 miles an hour, and at the latter figure even a relatively small burning area, involving a group of ten or fifteen houses, constitutes a serious threat to the whole of the down wind area. An examination of the records on the most destructive conflagrations in America reveals that in nearly a fourth of them a high wind was the chief contributing factor, and in 58% of the cases it was rated as one of the important factors. It is not unlikely that a wind velocity of 30 miles an hour would be sufficient to make a conflagration possible even after a heavy rain. From an examination of the damage distribution in Tokyo following the attack of 10 March 1945 (coupled with announcements made by Japanese radio) it appears that a high wind was largely responsible for the fire damage being so extensive. It is, of course, to be appreciated that the spreading effect of wind is directional and that it can actually protect an area lying upwind of the point at which fires are initiated. There have been numerous instances of winds which have carried conflagrations over large areas and then shifted 180 degrees, so as to drive the fire back upon areas already destroyed, thereby effectively terminating it.

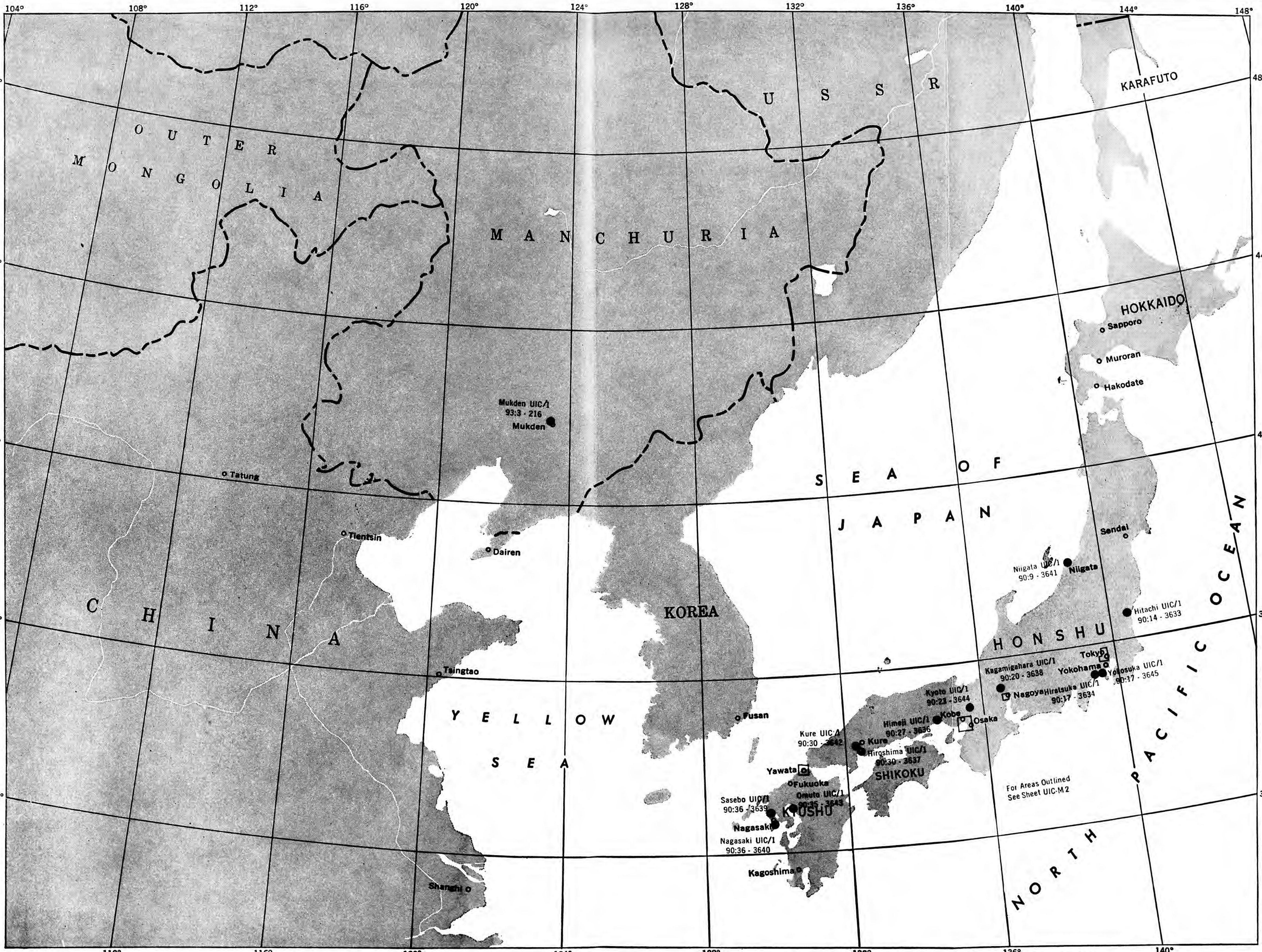
MIC—UIC
MAPS & TABLES

MIXED INDUSTRIAL CONCENTRATIONS

URBAN INDUSTRIAL CONCENTRATIONS

CONFIDENTIAL

SHEET UIC–M1
DATE . . . . 27 June 1945



Prepared by AERONAUTICAL CHART SERVICE by U. S. C. & G. S., July 1945

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STATUTE MILES
100 0 100 200 300 400 500

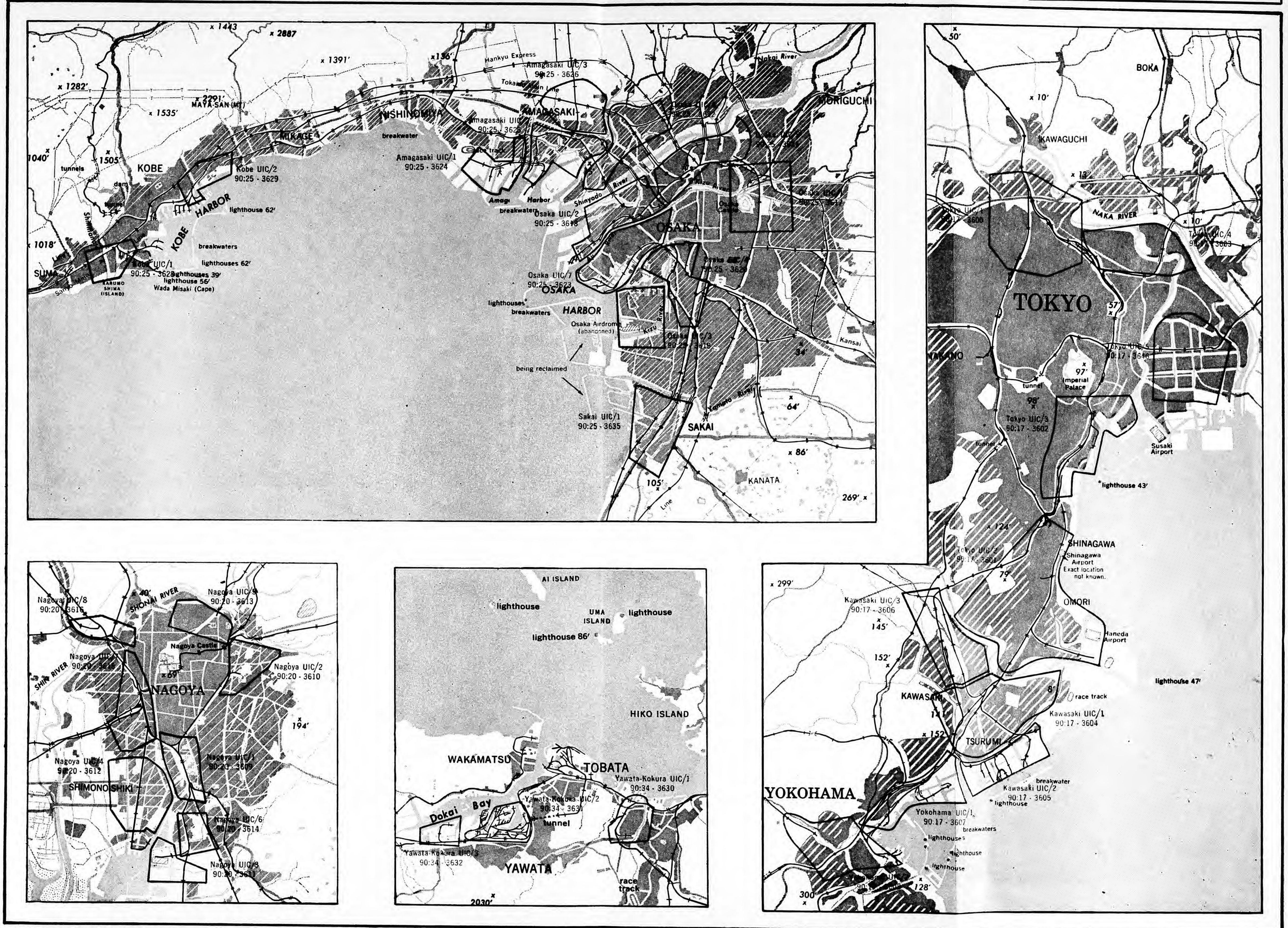
JOINT TARGET GROUP
Washington, D. C.
GENERAL LOCATION MAP

MIXED INDUSTRIAL CONCENTRATIONS

URBAN INDUSTRIAL CONCENTRATIONS

CONFIDENTIAL

SHEET .... UIC—M2
DATE .... 22 June 1945



STATUTE MILES

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File No. 43,913

JOINT TARGET GROUP, WASHINGTON, D. C.
SUMMARY TABLE

MIXED INDUSTRIAL CONCENTRATIONS

SELECTED URBAN INDUSTRIAL CONCENTRATIONS

Name	Target	Approx. size (sq. mi.)	Industrial Bldg. Area (000 sq ft)	% Industrial buildings and contents susceptible to fire damage	Description
Tokyo UIC/1	90:17-3600	10.6	15,962	80	Principally important as the site of the main plants of the Tokyo Arsenal, this area also contains plants producing precision instruments and arsenal components.
Tokyo UIC/2	90:17-3601	12.0	[1]	[1]	One of the heavily industrialized districts of Tokyo, this area contains numerous plants producing machine tools, aircraft and ordnance components, precision instruments, general industrial machinery, RR equipment, and light diesel engines.
Tokyo UIC/3	90:17-3602	6.2	[1]	[1]	The area contains several important plants producing aircraft instruments and components, machine tools, and electronic equipment, as well as a number of plants manufacturing optical precision instruments and ordnance components. The area also includes the Shinagawa Marshalling Yard and extensive storage areas.
Tokyo UIC/4	90:17-3603	6.0	[1]	70[2]	The area contains several plants producing aircraft and ordnance components, general industrial machinery and intermediate steel products. It also includes important freight and marshalling yards.
Tokyo UIC/5	90:17-3646	6.6	[1]	[1]	Tokyo's largest concentration of diversified manufacturing facilities, this target area includes some 200 identified factories, most of them small to medium plants. Principal products manufactured are electrical equipment, ordnance and aircraft components, machinery and machine tools, marine engines, special steel alloys and intermediate products, rubber and leather goods, chemicals, and wooden products. The area includes a very heavy concentration of general metal working capacity.
Kawasaki UIC/1	90:17-3604	6.7	12,313	55	Principally important as the site of three major electronic plants, this area also contains plants producing aircraft components, rubber tires, wire and cable, light diesel engines and general industrial machinery.
Kawasaki UIC/2	90:17-3605	3.0	19,167	45	The area contains a concentration of heavy industry, including heavy electrical equipment, machine tools, marine engines and shipbuilding, integrated iron/steel/fabricating works, synthetic oil equipment, chemical fertilizers, petroleum refining and storage, large power plants, and military storage.
Kawasaki UIC/3	90:17-3606	5.2	8,691	70	The area contains important electronics and radio plants, machine tools and precision components factories, as well as the extensive Tsurumi Shunting Yard.
Yokohama UIC/1	90:17-3607	2.8	[1]	35[2]	Principally important for auto and truck assembly, oil refining and storage, alumina and basic chemicals, the area also contains shipyards, electrical equipment plants and military storage areas.
Yokohama UIC/2	90:17-3608	3.5	[1]	[1]	The area contains an important shipyard, electrical and communications equipment plants, small chemical plants, and extensive freight yard and waterfront storage areas.
Nagoya UIC/1	90:20-3609	2.0	4,932	63	Principally important as the site of the largest (Atsuta) factory of the Nagoya Arsenal, this area also includes several aircraft components and instrument plants, one large and several small ordnance parts plants, an alloy steel works, a sizeable electrical equipment factory and several medium size machinery and machine tool plants.
Nagoya UIC/2	90:20-3610	2.6	7,887	45	Site of the key Mitsubishi Aircraft Engine Works, the Mitsubishi Electric Mfg. Co. and the Chigusa factory of the Nagoya Arsenal, this area also includes machine tool and ordnance parts plants and the Nagoya water filtering plant.
Nagoya UIC/3	90:20-3611	2.0	[1]	[1]	In addition to the great Mitsubishi Aircraft Works Assembly Plant, this area includes the two largest factories of the Daido Electric Steel Co., a large steam power plant, electro-chemical plants, a medium size shipyard and several small machinery and machine tool factories.
Nagoya UIC/4	90:20-3612	3.2	4,348	50	In addition to the Aichi Aircraft Engine Works, the large Sumitomo Duralumin Mill and the Toho Synthetic Oil Plant, this area contains aircraft parts factories, and numerous small machinery and machine tool plants.
Nagoya UIC/5	90:20-3613	1.9	3,030	80	This area contains several of the principal components plants of the Mitsubishi Aircraft Co., as well as machine tool and textile plants.
Nagoya UIC/6	90:20-3614	2.0	3,580	80	In addition to the large Okamoto Aircraft parts factory, this area contains several aircraft machine tool plants and general machinery factories and a textile mill converted to aircraft parts production.
Nagoya UIC/7	90:20-3615	3.7	3,850	80	This area covers the Nagoya RR Station, freight yard and repair shop, as well as aircraft parts plants and ordnance factories.
Nagoya UIC/8	90:20-3616	1.9	3,470	70	This area includes one of Mitsubishi's largest aircraft parts works, a very large, integrated aircraft and ordnance parts plant, electrical equipment and liquid fuel plants.
Osaka UIC/1	90:25-3617	4.0	8,132	70	In addition to the main plant of the Osaka arsenal, the area contains a large copper refinery, several machinery plants, ordnance components factories and textile mills.
Osaka UIC/2	90:25-3618	3.5	13,610	60	Site of the important dural sheet and aircraft propeller plant of Sumitomo, this area also includes two large Sumitomo electrical equipment plants, a large locomotive plant, chemical dye and drugs plants, shipyards, textile mills, machinery plants and several power stations.
Osaka UIC/3	90:25-3619	3.0	[1]	75[2]	This area contains a large number of factories, the most important of which include shipbuilding and repair, marine engines, iron and steel, machine tools and general industrial machinery, chemical fertilizers and ordnance parts.
Osaka UIC/4	90:25-3620	3.1	[1]	[1]	In addition to several small shipyards, this area includes machine tool factories, small diesel engine works, and textile plants.
Osaka UIC/5	90:25-3621	4.0	[1]	[1]	Site of the extensive Osaka RR Station, this area also includes a number of large machine tool plants, electrical equipment plants, small aluminum and copper works, paper and textile factories.
Osaka UIC/6	90:25-3622	3.6	[1]	70[2]	This area includes a large number of miscellaneous factories, the most important of which produce machine tools and bearings, industrial chemicals, electrical equipment and textiles.
Osaka UIC/7	90:25-3623	3.5	[1]	[1]	Principally important as the site of the extensive Osaka harbor storage facilities, this area also includes a number of small shipyards, large lumber storages and wood-working plants, small machinery and machine tool factories and general industrial machinery works.
Amagasaki UIC/1	90:25-3624	1.8	7,578	50	This area contains three major types of installations, large synthetic oil plants, the Kawanishi Aircraft Works and three very large steam power stations. Also included are several iron and steel and chemical plants.
Amagasaki UIC/2	90:25-3625[3]	4.1	[1]	40[2]	This area includes a large number of miscellaneous factories, the most important of which produce intermediate steel products, aircraft and ordnance parts, chemicals, general industrial machinery, machine tools, gears and warheads for the BAKA.
Amagasaki UIC/3	90:25-3626	5.0	[1]	65[2]	Principally important as the site of a large aircraft propeller works, this area also includes electrical equipment plants, small ordnance parts plants, chemicals and textile factories.
Kobe UIC/1	90:25-3628	1.6	4.030	70	Important primarily as the site of the large Kawasaki Locomotive and Car Works (which also produces ordnance), this area includes plants producing electronic tubes, machine tools, electrical equipment and aircraft parts.
Kobe UIC/2	90:25-3629	1.1	5,510	50	This area includes the large Kobe and Kawasaki iron and steel works, a large rubber tire plant, several plants producing railway and shipyard fittings, and electrical equipment.
Yawata UIC/1	90:34-3630	1.5	4,189	36	Site of the large Kokura Arsenal, this area also includes a large RR shop, chemical plants, a steel mill and two large power stations.

(Cont'd on Page 2)

JOINT TARGET GROUP, WASHINGTON, D. C.
SUMMARY TABLE

MIXED INDUSTRIAL CONCENTRATIONS

SELECTED URBAN INDUSTRIAL CONCENTRATIONS

CONTINUED

SHEET . . . . UIC–ST
DATE . . . . 25 June 1945
PAGE 2

Name	Target	Approx. size (sq. mi.)	Industrial Bldg. Area (000 sq ft)	% Industrial buildings and contents susceptible to fire damage	Description
Yawata UIC/2	90:34-3631	1.1	[1]	35[2]	This area includes virtually all of the great Yawata plant of Japan Iron Works, and most of its affiliated by-products factories.
Yawata UIC/3	90:34-3632	1.0	[1]	30[2]	This area includes a sizeable alumina plant, a large industrial chemicals and synthetic oil works, and several machinery and electrical equipment plants.
Hitachi UIC/1	90:14-3633	1.6	[1]	45[2]	This target concentration includes 4 of the 5 Hitachi Engineering Co. plants in this locality and virtually all supporting industrial, storage and residential facilities. These 4 integrated units represent a major segment of Japan's electrical equipment industry, including one of three principal sources for heavy equipment and important capacity for insulated cable, control gear and indicating instruments. The fifth Hitachi unit, located 1 mile S of this target concentration, is reported producing A/C components.
Hiratsuka UIC/1	90:14-3634	3.8	[1]	80[2]	The area includes three important armament and aircraft targets, related industries and supporting residential facilities. The Hiratsuka Navy Arsenal is a major development and manufacturing center for explosives. Other principal installations are engaged in aircraft propeller and fuselage production, aircraft armament reconditioning and assembly, and special steel fabricating.
Sakai UIC/1	90:25-3635	3.0	[1]	70[2]	The target concentration includes virtually all of Sakai, industrial suburb of Osaka and site of important ordnance and marine engine factories as well as many smaller machinery, metal-working and chemical plants. At least three of the city's large textile mills have been reported producing aircraft and ordnance components.
Himeji UIC/1	90:27-3636	3.8	[1]	75[2]	The area includes all of Himeji proper and contains a sizeable fighter aircraft assembly plant of Kawanishi aircraft, several former textile mills now converted to aircraft parts and rubber tire production, a number of small miscellaneous plants and two army garrison and supply depots.
Hiroshima UIC/1	90:30-3637	5.0	[1]	70[2]	The area includes the extensive military storage and trans-shipment facilities of the Ujina port of embarkation, other storage depots adjoining the E Hiroshima RR station as well as several grinding wheel factories and textile mills (one of which is reported producing munitions).
Kagamigahara UIC/1	90:20-3638	1.4	[1]	55[2]	The area contains the Kawasaki and Mitsubishi A/C assembly plants, related components plants and numerous modification and overhaul shops, storages, hangars, etc. which extend along the N side of the large Kagamigahara Airbase.
Sasebo UIC/1	90:36-3639	1.2	[1]	60[2]	The area includes the Sasebo Naval Arsenal and Engineering Department, extensive munitions and general supply depots, and a number of small factories producing electrical ordnance components.
Nagasaki UIC/1	90:36-3640	3.1	[1]	45[2]	With the exception of the actual shipbuilding and repair yards, the area contains virtually all of Nagasaki's industry including both plants of the Mitsubishi Steel and Arms Works, the Akunoura Engine Works, Mitsubishi Electric, several other small factories and most of the port's storage and trans-shipment facilities.
Niigata UIC/1	90:9-3641	2.7	[1]	65[2]	The area contians the bulk of Niigata's industry including both the priority machine tool plant and the diesel engine factory of the Niigata Iron Works, several small oil refineries and chemical plants, woodworking plants and a number of new war plants. Also included are the extensive port storage and trans-shipment facilities.
Kure UIC/1	90:30-3642	2.6	[1]	25[2]	The area contains all the major facilities of the Kure Naval Base, including the arsenal, shipyard and the principal supply depots. Also included are a number of small ship and ordnance parts plants.

Name	Target	Approx. size (sq. mi.)	Industrial Bldg. Area (000 sq ft)	% Industrial buildings and contents susceptible to fire damage	Description
Omuta UIC/1	90:35-3643	3.1	[1]	45[2]	This area includes Japan's two largest zinc refineries and all the Omuta chemical plants, together with supporting residential, storage and transport facilities. One of Japan's major chemical centers, the Omuta complex includes large coke by-products installations producing fertilizers and basic chemicals for explosives, a synthetic oil works and important plants for manufacture of synthetic and other chemical equipment. One high-explosives works is located within the target area and another 1 mile south.
Kyoto UIC/1	90:23-3644	7.1	[1]	70[2]	The area contains the bulk of Kyoto's industry, including plants producing a wide variety of light electrical equipment (such as gun directors and fire control mechanisms, and dry batteries), radio equipment, aircraft engine components and precision ordnance parts, fine machine tools, finished textile products, household furnishings and foodstuffs.
Yokosuka UIC/1	90:17-3645	1.2	[1]	50[2]	With the exception of the shipyard, oil storages and administrative offices, the area contains all of the naval base's important production and storage facilities. It includes the naval arsenal, the large Japan Steel ordnance works, the naval aircraft factory and research center and extensive aircraft repair and maintenance facilities, together with large supply and munitions depots.
Mukden UIC/1	93:3-216	7.3	[1]	75[2]	The target area includes the West Mukden industrial district, largest Mainland concentration of diversified manufacturing facilities. The district contains over 200 factories producing aircraft and ordnance parts, intermediate steel products, machinery, machine tools and light electrical equipment, chemicals, building materials, textiles, etc. Also included are a large aircraf treplacement depot, the Mukden RR Yards and Shops and several important military storage areas.

[1] Will be made available later.

[2] Preliminary estimates.

[3] Combined with 3627 and expanded. 3627 cancelled.

(193)

JOINT TARGET GROUP, WASHINGTON, D. C.

SUMMARY TABLE

TABLE 6

MIXED INDUSTRIAL CONCENTRATIONS: URBAN INDUSTRIAL CONCENTRATIONS

Current Status: (To 15 June 1945)

SECRET

SHEET . . . . UIC—ST2
DATE. . . . . . .4 July 1945
PAGE 1

Cities and Urban Industrial Concentrations	Actual Tons Dropped in Area Attacks[1]	Extent of Damage	Current Target Value for Area Attacks		Comment
			High	Low	
TOKYO Tokyo UIC/1 90:17-3600	13,392	Moderate	X		Priority targets only slightly damaged; non-priority targets severely damaged; considerable housing undamaged.
Tokyo UIC/2 90:17-3601		Heavy	X		Most priority targets damaged, but waterfront industrial districts at N and S ends as well as remaining housing only slightly damaged.
Tokyo UIC/3 90:17-3602		Heavy		X	Most of combustible targets damaged; relatively undamaged waterfront industrial/storage area probably too small for area attack.
Tokyo UIC/4 90:17-3603		Heavy		X	Several important targets only slightly damaged, but remaining area probably too small for area attack.
Tokyo UIC/5 90:17-3646		Complete		None	Entire target area almost completely destroyed; remaining plants on periphery of target area are too isolated for area attack.
KAWASAKI Kawasaki UIC/1 90:17-3604	1,577	Heavy		X	Several priority targets only slightly damaged but have low combustibility; most of lower priority targets and housing heavily damaged.
Kawasaki UIC/2 90:17-3605		Slight	X		Most priority targets relatively undamaged; general combustibility low but area has high target value.
Kawasaki UIC/3 90:17-3606		Moderate		X	Most significant targets in northern part relatively undamaged, but too isolated for area attack; targets in southern part heavily damaged.
YOKOHAMA Yokohama UIC/1 90:17-3607	2,696	Slight	X		Most priority targets relatively undmaged; general combustibility low but area has high target value. Several important targets relatively undamaged but too isolated for area attack; bulk of area completely destroyed.
Yokohama UIC/2 90:17-3608		Heavy		None	
NAGOYA Nagoya UIC/1 90:20-3609	9,993	Heavy		X	Most targets heavily damaged; remaining installations have low combustibility and almost all are damaged.
Nagoya UIC/2 90:20-3610		Heavy		X	Priority targets heavily damaged; remaining installations damaged and combustibility is low.
Nagoya UIC/3 90:20-3611		Moderate		X	Priority targets heavily damaged; most of remaining installations damaged and combustibility is low.
Nagoya UIC/4 90:20-3612		Moderate		X	Priority targets only moderately damaged but too isolated for area attack.
Nagoya UIC/5 90:20-3613		Moderate	X		Several important targets only slightly damaged; remaining installations relatively isolated but have fair combustibility.
Nagoya UIC/6 90:20-3614		Complete		None	All priority targets heavily damaged.
Nagoya UIC/7 90:20-3615		Moderate	X		North and SW parts of area only slightly damaged; remaining area contains several significant targets and considerable housing.
Nagoya UIC/8 90:20-3616		Slight	X		Target area has received little damage; priority targets not damaged.
OSAKA Osaka UIC/1 90:25-3617	10,019	Moderate	X		NW and SW parts of area heavily damaged, but Osaka Arsenal, groups of small factories and residential districts in remainder of area relatively undamaged.
Osaka UIC/2 90:25-3618		Moderate	X		Doubtful target for area re-attack; important targets only slghtly damaged but of fair to low combustibility; other small groups of factories remain.
Osaka UIC/3 90:25-3619		Moderate		X	Northern part heavily damaged, several significant targets along S and SE side relatively undamaged but have low combustibility.
Osaka UIC/4 90:25-3620		Moderate		X	NW part heavily damaged; SW part only slightly damaged but has very low target value.
Osaka UIC/5 90:25-3621		Heavy		X	Entire area heavily damaged; remaining installations too isolated for area attack.
Osaka UIC/6 90:25-3622		Slight	X		Area has been lightly damaged throughout, but large districts of relatively dense industrial/residential occupancy remain.
Osaka UIC/7 90:25-3623		Heavy		X	Bulk of area destroyed; few remaining installations in S part have low target value.
AMAGASAKI Amagasaki UIC/1 90:25-3624	830	Moderate	X		Aircraft and other installations in W part of area heavily damaged by precision attack, but remaining installations have high target value although of low combustibility.
Amagasaki UIC/2 90:25-3625		Slight	X		Residential districts moderately damaged but industrial facilities only lightly damaged and have good combustibility.
Amagasaki UIC/3 90:25-3626		Moderate		X	Centrally located industrial facilities at least moderately damaged; remainder probably too isolated for area attack.
KOBE Kobe UIC/1 90:25-3628	5,519	Moderate		X	Most targets damaged; remaining installations have low target value.
Kobe UIC/2 90:25-3629		Heavy		X	Area heavily damaged; priority targets only slightly damaged but have low combustibility and are relatively isolated.
HAMAMATSU (Entire Urban Area Recommended for Attack)	1,893	Heavy		X	Entire area heavily damaged in attack of 6/18/45; remaining targets too isolated for area attack.
YAWATA-KOKURA Yawata UIC/1 90:36-3630	. . . . . .	None	X		Target area undamaged; has high target value.
Yawata UIC/2 90:34-3631		None	X		Target area undamaged; has high target value.
Yawata UIC/3 90:34-3632		None	X		Target area undamaged; has high target value.
Sakai UIC/1 90:25-3635	None	None	X		Target area undamaged; has high target value.
Kyoto UIC/1 90:23-3644	None	None	X		Target area undamaged; has high target value.
Kure UIC/1 90:30-3642	None	Unknown[2]	X		Naval arsenal at S end of target area reported damaged by precision attack; remaining area believed suitable for area attack.[2]
Hiroshima UIC/1 90:30-3637	None	None	X		Target area undamaged; has secondary target value (area includes mainly military storages).
Himeji UIC/1 90:27-3626	None	Unknown[2]	X		Kawanishi AC plant reported damaged by precision attack; remaining area probably retains secondary target value.[2]
Nagasaki UIC/1 90:36-3640	None	None	X		Target area undamaged; has high target value.
Sasebo UIC/1 90:36-3639	None	None	X		Target area undamaged; has moderate target value.
Omuta UIC/1 90:35-3643	Unknown[4]	Unknown[4]	X		Target area reported damaged; priority targets probably only lightly damaged and area believed to retain moderate target value.
Yokosuka UIC/1 90:17-3645	None	None	X		Target area undamaged; has high target value.
Hiratsuka UIC/1 90:17-3634	None	None	X		Target area undamaged; has high target value.
Hitachi UIC/1 90:14-3633	None	Slight	X		One of important Hitachi electrical works destroyed by precision attack; remaining area retains moderate target value.
Kagamigahara UIC/1 90:20-3638	None	Unknown[4]		X	Target area damaged by precision attacks; current target value uncertain; probably has very low target value for area attack.
Niigata UIC/1 90:9-3641	None	None	X		Target area undamaged; has high target value.
Mukden UIC/1 93:3-216	None	None	X		Target area undamaged; has high target value.
(Tons Dropped in Other Area Attacks Through 6/15/45)[3]	554				
Total Tonnage	46,473				

[1] Tonnage figures compiled from final mission reports through 9/22/45. Figures for 9–15 taken from preliminary mission reports.
[2] Reported damaged by precision attacks, but photo cover not yet available for assessment. Current status estimated tentatively.
[3] Includes attacks against alternate urban area targets (Kagoshima, Shizuoka, Miyakonojo, Omura, Imabari and Miyazaki.)
[4] Attacked after 15 June 1945. Tonnage dropped not yet known and photo cover not available for assessment.

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