IV. PRODUCTION PROCESSES

A. OIL GEOLOGY

Natural or crude oil and gas accumulate underground in porous beds of rock *(sandstone, limestone, dolomite,* etc.) over extremely long periods of time.

Since oil is lighter than water, and gas is lighter than oil, a separation by gravity occurs, with gas and oil accumulating in the upper levels of the rock reservoir or porous medium. In general, there are four types of conditions which cause oil pools to form *(anticlines, faults, sand lenses, changes in porosity).* In many oil pools, a combination of two or more will exist.

Crude oil is obtained by drilling wells into a porous bed of rock which contains "pools" of gas, oil, and water usually separated in that order by gravity. Oil accumulations vary greatly in size and productivity. Oil either flows or is pumped into tanks in the oil fields and from there is transported, usually through a pipe line, to a refinery or to loading facilities at tide water.

B. REFINING OF CRUDE OIL

Oil refineries receive and store crude oil in large tanks ordinarily having capacities of 35,000-85,000 barrels. This crude is run through various types of stills and towers in which it is heated. Various fractions are distilled off and then condensed into liquids of different specific gravities, which are separated and stored by product in tanks for final distribution to the consumer.

In more detail, crude oil is pumped into one of several different types of primary distillation units. The oldest type is the battery of shell stills in which the oil is progressively heated as it flows from one still to the next. In this process the most volatile fractions of the oil boil off in order of their volatility as the oil moves through progressively hotter units. Separation of the products of distillation is accomplished by means of running the condensed liquids into various "run down" tanks, each tank receiving only those oils which distilled between certain temperature limits. Batteries of shell stills are rectangular in shape, possibly 30 feet wide, varying in length with the number of stills. The more modern ones have low towers in associations.

More modern primary distillation units are generally called pipe stills. They secure an accurate separation of products by means of "fractionating" or "bubble" towers. Each pipe still has a furnace in which the crude oil is heated and vaporized before it is run to the tower. Successive fractions of the oil are drawn off by pipes at the side of the tower in the form of liquid as the vapor is cooled and condensed during its passage upwards through the tower.

For a more perfect and accurate separation of products, certain cuts or fractions are vaporized through "re-run" towers, in which the distillation process just described is done again more carefully, so that the final product varies in boiling range only within very small limits.

The gasoline made by the above primary or straight run distillation is marketed as motor gasoline or used as a base stock for aviation gasoline.

In more modern refineries a process called "cracking" is then applied to some of the heavier fractions obtained from straight run distillation. In this process the large molecules composing heavy oil are broken into small molecules such as are found in gasoline. In its most simple form (Thermal cracking), heat and pressure are applied to heavy oil and a lighter product is formed. When cracking is carried out in the presence of a catalyst, better results are obtained. The most modern cracking process is the "Cat (Catalytic) Cracker" used in the making of aviation gasoline. It is not known whether the Japanese are using this process, but they are actively using Thermal cracking.

Cracking stills or towers are heavier than pipe still towers since they operate under pressure. Cat Crackers are very large, often as much as 200′ tall supported by a framework of steel girders, and with associated furnaces and pump houses, make an impressive showing in a refinery area.

Due to demands for high octane aviation fuel, modern refining practice has developed many processes for producing aviation gasoline and for raising the octane number (a rating for the anti-knock efficiency of gasoline) of gasoline components. Such processes include Hydrogenation, Dehydrogenation, Polymerization and Alkylation of various refinery products.

Other parts of a modern refinery, varying with the type of crude oil used, are the paraffin and lube oil plant, asphalt plant, Edeleanu plant (solvent extraction), and many minor by-products works. There are always a boiler house and, most characteristic, many groups of tanks.

C. SYNTHETIC OIL

Oil can be produced synthetically by combining hydrogen and carbon in one or more of the known hydrogenation or hydrocarbon synthesis processes. The Germans have developed the making of synthetic oil to a greater degree than any other nation. Japan is attempting to use the German processes. It is not known definitely as yet what success she has had in her ambitious synthetic program, but it is probable that expansion will fall short of the German rate (about 20-25 percent per year). Photographs of Japanese synthetic oil installations examined to date indicate a low rate of progress. German synthetic processes are roughly grouped into the hydrogenation (Bergius) and the Fischer-Tropsch (hydrocarbon synthesis) processes, although there are many variations in the use of temperature pressure and catalyst.

(1) *Hydrogenation* (Bergius).—In this process (by which most of the German synthetic aviation gasoline was produced) the reactions take place under very high pressure and temperature and usually in the presence of a catalyst. Hydrogen gas is produced and purified in one of several ways and is combined under

high pressure with carbon in the form of either a coal or lignite paste or a low grade oil. The combination takes place in a hydrogenation stall, about 60-80 feet tall, which must be made of very high grade steel, similar to gun barrel, in order to withstand high pressures, which run from 3,000 to 9,000 pounds per square inch.

The output of the hydrogenation stalls can generally be divided into three products: methane gas, high-grade oil, and low-grade oil. The methane is used in the formation of hydrogen or as fuel; most of the high-grade oil is refined to gasoline; and the low-grade oil is rerun through the stalls or used as diesel oil or fuel oil.

The hydrogenation plants can be adjusted in many ways with varying degrees of efficiency to produce many products including high-octane blending agents for aviation gasoline, edible fats, lubricants, etc.

In general, a typical German hydrogenation plant includes a boiler and power house, gas generating and purifying equipment, gas holders, compressors and injector houses, hydrogenation stalls, a refinery, and tanks.

On the other hand, Japanese plants include the same component parts, but no two are arranged in identical plan and are all small. It appears probable that development is little more than in an experimental stage, none of the various modifications being sufficiently successful to be standardized.

2. *Fischer-Tropsch.* In a Fischer-Tropsch or hydrocarbon synthesis plant, a gas composed of CO and H_2 is made into an oil in a reaction chamber in the presence of a catalyst. Oil produced by this process is somewhat similar to a very waxy crude oil and, therefore, it must be refined. It is used mostly for the production of motor gasoline, gas and diesel oils, and fuel oil. Japanese capacity for Fischer-Tropsch oil is about seven-tenths of its hydrogenation capacity in comparison to German output of only one-quarter Fischer-Tropsch. Water gas is made by blowing steam over incandescent coke in gas generators. Hydrogen sulphide, organic sulphur, and carbon dioxide are removed from the gas in purifying columns and scrubbers. Close control must be maintained over the proportions of the remaining carbon monoxide and hydrogen. The purified mixed gas is pumped into reaction chambers (usually found in long, tall buildings —i.e., contact oven houses) and in the presence of a catalyst and under varying degrees of heat and pressure, an oil is formed.

In general, typical Fischer-Tropsch plants, Japanese as well as German, follow a standard pattern and include a boiler and power house, gas generating and purifying equipment, gas holders, contact oven houses, refinery, and tanks.

3. *Low temperature carbonization (L. T. C.)*—Low grade oil, gas, benzol, and poor coke are obtained by heating coal slowly at about 600° C. in the absence of air, in a process called low temperature carbonization (L. T. C.). This is done in a long tall building containing L. T. C. ovens. There is also a gas holder and some tankage found in association with the oven buildings and its coal and coke piles.

The tarry oils formed in this process, and the following one, can be cracked for additional gasoline, diesel and fuel oil. The benzol obtained may be added to gasoline in order to raise its octane rating. It is believed that a substantial amount of feed stock for Japanese hydrogenation plants also is derived from this source.

4. *High temperature carbonization.*—This process operates at a high temperature and produces good coke, some tar oils and benzol, with a much higher yield of gas than L. T. C. Consequently, it is used for making coke and in producing gas for municipal gas works. The tar produced can be used as feed stock for hydrogenation plants.

5. *Japanese procedure.*—In the late 1930's Japan instituted a program for the development of a large oil production. It is believed that this program has not developed according to plan, although Japan probably has a synthetic production (including L. T. C. oil) and shale oil production of about 8 million barrels per annum.

German practice has been referred to extensively because it has been thoroughly studied and because it is believed that Japan has attempted to pattern its synthetic program after that of Germany. It is not known how successful she has been in adapting German processes to her particular problems or in developing new methods of her own.

Photography of 13 out of 23 synthetic and shale oil plants has indicated that the Japanese are using modified hydrogenation processes at Nagoya (90:20-456), Yokkaichi (90:20-1684), Otake (90:30-2121), Tukuyama (90:32-674), Ube (90:32-1841), Fushun (93:3-41), Ssupingkai (93:3-43), and Chin-Hsi (93:3-203); the Fischer-Tropsch process at Amagasaki (90:25-1203), Omuta (90:35-1262), and Chinchow (93:3-175); and L. T. C. at Eian (84:1-126) and Wakamatsu (90:34-1123). There are no satisfactory photographs of the synthetic oil plants at Agochi (84:1-125) and Kirin (93:2-58), although the presence of a plant at Agochi is indicated in oblique pictures. The two large shale oil plants at Fushun are also covered by pictures.

The refinery and synthetic oil plant at Yokkaichi (90:20-1684) has several points of interest besides being the largest known refinery in Japan (6,600,000 barrels). Large gas holders in two parts of the plant, together with buildings of unusual characteristics, indicate hydrogenation of lower fractions of oil from the main refinery.

D. SHALE OIL

Japan has at least two plants with a total of 3,000,000 barrels capacity in which an oil similar to crude oil is distilled from oil shale. Since large deposits of oil shale are found in Manchuria and since the mining of this shale is made economic because it is removed as overburden in the process of mining coal, it is possible that Japan has other shale oil plants or may build them in the future.

After stripping oil shale from the coal bed, it is transported to the S. M. R. Shale Oil plant (93:3-40) and to the East Fushan Shale Oil Plant (93:5-202) both at Fushun, Manchuria, where it is crushed, then fed into retorts where it is heated to 350°-550° C. Heating is accomplished by means of hot flue gases plus producer gas injected into the upper half of the retort. By means of this heat, oil is distilled from the shale and is then condensed and run into storage tanks. Refining is accomplished as in a crude oil refinery.

Retorts used in this plant have a constriction in the middle, and after distillation has been accomplished in the upper half, the hot spent shale is dropped into the lower half where it is blown with steam to make producer gas.

Other methods for obtaining oil from oil shale are used in Sweden, Scotland, and Estonia but it is not believed that they are used by Japan.

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

SHEET ....P—V
DATE.......1 July 1945

V. PHYSICAL VULNERABILITY AND WEAPON RECOMMENDATIONS

A. INTRODUCTION

1. General

The following is written for the use of those persons who are engaged in selecting weapons, estimating force requirements, and formulating operational plans for attack on targets in this category. For such purposes the following questions must be answered.

1. What portion of a target should be the primary objective?
2. What is normally the best type, size, and fuzing of HE? In what circumstances should different types be used?
3. Should IB be used, either exclusively or mixed with HE? If so, what is the best size and type, and what is the optimum quantity?
4. What weight of attack is required?

This section deals with the physical characteristics of targets found in this category, the choice of primary objectives, the selection of weapons and the density required on the target for expectancy of a particular level of damage. For determination of force requirements, reference should be made to JTG M-8.

Because of differences in importance and vulnerability, the Petroleum Industry is divided into three subsystems for analysis. These subsystems are:

1. Synthetic and Shale Oil Plants
2. Oil Refineries
3. Oil Storage

Synthetic and shale oil plants and oil refineries are discussed here, while a complete discussion of the attack of oil storage is given under the category *Military Stores* in this binder to which reference should be made. However, the Summary, below, includes weapon recommendations for attack of oil storage.

For a description of the processes involved, reference should be made to the preceding parts of this *General Analysis* of the Petroleum Industry, and for a more detailed discussion of the physical characteristics of refineries to "Photo Industrial Study No. 2: The Petroleum Industry" AC/AS Intelligence, USAAF and PIC, Division of Naval Intelligence, Navy Department.

B. SUMMARY

1. General

In one target area may be found together oil manufacturing installations, refining equipment and storage facilities. A single weapon should be used for attack of such a target, selected to do maximum overall damage. The choice of weapon will depend on the relative economic importance and on relative physical vulnerability of the components of the target. With respect to physical vulnerability, storage is first, refining installations second, manufacturing last, as indicated in Tables 7, 10, and Table 2 of Part V1 of MS (P) (Military Stores—Petroleum.

2. Production

Four kinds of industrial plants associated with oil production can be attacked, namely:

1. Shale oil plants
2. Low pressure synthetic plants (Fischer-Tropsch)
3. High pressure synthetic plants (Bergius or Hydrogenation)
4. Refineries

A shale oil plant extracts crude oil from oil bearing rock, by heating the latter in large retorts. Synthetic oil plants produce crude oil by combining carbon (coal) or CO with hydrogen. Refineries take crude oil, obtained by any of the above processes or from oil wells, and separate it into its various useful fractions.

Although shale oil plants, low pressure synthetic plants and refineries employ different processes and contain different types of equipment, they have approximately the same resistance to attack. High pressure synthetic plants are somewhat more resistant because the equipment used in the later stages of the process is stronger, due to the higher pressures employed. However, the installations used in the early stages are of resistance comparable to that of the other types of oil producing plants.

Attack of oil producing plants is planned to do general damage to the special processing equipment. Three types of damage are expected: damage from direct hits on equipment, damage from blast and fragments from near misses, and damage due to fire. Important factors to be considered in weapon selection are the proportion of total area covered by installations, the existence of blast walls protecting equipment against near misses, and the possibility that the plant may not be in operation or has ample time to shut down and drain pipes and vessels in preparation for an attack.

3. Storage

Crude and finished products are normally stored in tank "farms", which are collections of cylindrical steel tanks. The tanks are generally between 75 and 150 feet in diameter and up to 40 feet high. They are usually separated by low earth or concrete dykes. In the ETO, blast walls for protection against near miss bombs have been extensively employed. Such walls were not evident on early Japanese photo cover, but recent cover shows that they are being constructed in a few places.

Attack can be by HE bombs or rockets. The object of attack must be to spill contents and start fires. For this, direct hits are necessary since near misses, unless very near, only create fragment holes, which are relatively easily repaired. Fire is the major cause of damage and is started by the HE weapons which rupture the tanks and pipes containing inflammable liquids.

Underground storage can be located on photo cover but is sometimes difficult to identify during attack. This fact, combined with the normal resistance of the target and the unlikelihood of getting fire-spread between storage units and makes underground storage a much less vulnerable target than surface storage. However, it is apparent that the Japanese are now putting a considerable portion of their oil stores underground; consequently, any serious attack on Japanese petroleum must involve the attack of underground storage.

TABLE 7

Weapon Selection

Target	Type of Attack	Recommended Weapons	Fuzing	Remarks
Oil Storage				
Surface Storage Tanks	Med. or High	100# GP	0.025/0.025	
	Dive	100# GP or larger	0.025/0.025	
	Low	HE Rockets	Inst	
Underground Storage	Med. or High	500# or Larger GP or SAP	0.1/0.1	Bomb to be capable of perforating roof cover. See Table 3, Part V of Mil. Stores—Oil
Synthetic Oil Plants	Med. or High	500# GP	0.025/0.025	
	Dive	500# GP	0.025/0.025	
Shale Oil Plants	Med. or High	500# GP	0.025/0.025	
	Dive	500# GP	0.025/0.025	
Refineries	Med. or High	500# GP	Inst/ND	For refineries without blast walls in which building density is less than 30%.
	Med. or High	250# GP	0.01/0.01	For refineries protected by blast walls or in which building density is more than 30%.
	Med. or High	250# GP	0.025/0.025	For refineries that are shut down prior to attack and with lines drained of oil products.
	Dive	500# GP	Same as for Med. or High Level	

C. SYNTHETIC AND SHALE OIL PLANTS

1. Target Characteristics

a. Synthetic plants are either high pressure (Bergius or hydrogenation process) or low pressure (Fischer-Tropsch process). The early stages of both processes are similar, consisting of the production and purification of gases. Following these stages in the low pressure plant are contact ovens, in which reactions between the gases take place. In low pressure plants the essential installations are:

1. Gas Generators
2. Gas Purifiers
3. Contact Ovens
4. Equipment for handling and processing gases, coal and oil

The contact ovens operate on a unit basis, and since there is a large number of ovens in a typical plant the loss of output resulting from damage is only proportional to the number of units damaged. They do not offer the same bottleneck to production that is offered by the gas generating and purifying equipment.

b. The final stage in the high pressure plant contains the hydrogenation stalls in which the combination of gas with coal takes place under pressure of the order of 3750 lb/sq in. or higher. The essential installations in high pressure plants are:

1. Gas Generators
2. Gas Purifiers
3. Hydrogenation Stalls
4. Equipment for handling and processing gases, coal, and oil

The hydrogenation stalls and the equipment associated with this stage in the process are designed to resist the high working pressures employed and are, consequently, very hard to damage.

The gas generators and purifiers are more vulnerable and are as vital to production as the same equipment in low pressure plants.

c. The essential part of a shale oil plant is the battery of retorts in which oil is extracted from oil bearing rock. Since these operate on a unit basis the loss of oil output achieved by damaging retorts is proportional to the number of units out of action.

In addition to the essential installations that are discussed above, all plants have a large amount of auxiliary equipment whose destruction adds considerably to the effectiveness of an attack. There may be mentioned, for example, storage tanks offering a useful fire hazard, fire fighting devices, boilers and heating and power plants, shops for production and repair of equipment, etc.

Many of the important installation of synthetic plants are housed in small, light, steel-frame structures covering from 15 to 20% of the plant area. These structures are not important in themselves, nor are they heavy enough to furnish debris capable of inflicting serious damage on the essential equipment inside.

2. Weapon Selection

Weapons are selected for maximum damage to essential installations. The 500 lb. GP bomb is considered the best weapon. Most installations are too resistant to be damaged by a 250 lb. GP except by a direct hit. On the other hand, the greater individual effectiveness of the 1000 lb. GP is more than compensated by the smaller number that can be carried. On this account it is also less effective in starting fires.

Since most installations are either within buildings or are of considerable height a fuzing of 0.025/0.025 is preferred.

The MAE (Mean Area of Effectiveness) of the 500 lb. GP bomb against typical essential installations (excepting the more resistant parts of high pressure plants) is approximately 10,000 sq. ft./ton. This is the area of plant requiring replacement or extensive repair. The 250 lb. GP and 1000 lb. GP will be somewhat less effective, having MAE's of about 8000 sq. ft./ton.

The recommended ground densities of bombs which, on the average, will produce various levels of destruction to synthetic and shale oil plants are given in Table 2. Fire damage is not included.

TABLE 8
Recommended Ground Densities
(tons per 1,000,000 sq. ft.)
for Attack of Synthetic and Shale Oil Plants

Bomb	Expected fraction of damage F*		
	F = .30	F = .50	F = .70
500 lb. GP	35	70	120
250 and 1000 lb. GP	45	90	150

*Calculated from

$$D = \frac{1,000,000}{M} \log_e \frac{1}{1 - F}$$

where D = density (tons/1,000,000 sq. ft.)
M = MAE of bomb (sq. ft./ton)

3. Force Requirements

a. *High level attack*

Force requirements are determined by the usual methods based upon operational factors and aiming accuracy.*

b. *Dive bombing*

The primary objectives are suitable targets for dive bombing attacks. Ground densities required are the same as for high level attack. However, the target area is smaller so that a smaller weight of attack will be required. Force requirements are determined by the usual methods based upon operational factors and bombing accuracy.*

D. OIL REFINERIES

1. Target Characteristics

Refineries contain a great many large and small steel vessels and an intricate system of piping. A characteristic feature is the absence of housing for many of the principal installations. Light, steel framed structures are used mainly to house pipe furnaces, compressor and pumping equipment, boilers and similar installations. The typical refinery consists of a number of separate units which progressively remove the desired factions from the crude oil. These units are usually compact and occupy only a small part of the entire plant area. The remainder is mostly occupied by tanks and incidental buildings.

The processing equipment of a refinery is of primary importance; this consists of the distillation and cracking units whose critical installations are shell stills, pipe stills, and fractionating and other columns. Most operating pressures are atmospheric or moderate so that equipment is not particularly heavy. Because of the nature of the process, it is unlikely that production will be stopped completely for long periods unless much essential equipment is destroyed. Refineries have a high degree of resilience and production can frequently be resumed by by-passing damaged equipment.

2. Weapon Selection

Maximum plant destruction is caused by fire. GP bombs have proven effective in disrupting vessels and piping, and igniting the spilled contents by both direct hits and near misses. Owing to the small proportion of the total target area covered by vital installations, however, it appears from available evidence* that bombs should be fuzed for maximum near-miss effect, rather than for penetration and consequent maximum destruction by direct hits. The opposite view has however also been put forward.** Where a high proportion of the total target area is covered by storage tanks, as will often be the case, delay fuzed weapons will cause more overall damage.

For near-miss effect, the recommended weapon is the 500 lb. GP bomb, fuzed inst/ND since it has a greater effective area per unit weight than the 250 lb. GP bomb. The still greater effective area of the 1000 lb. or larger bomb is not sufficient to offset the smaller number of direct hits. The 500 lb. GP bomb is most effective against unprotected refineries where building density is less than 30%. Where building density exceeds 30% or where blast walls are used, the 250 lb. GP bomb, fuzed 0.01/0.01, is preferred. This fuzing is a compromise between the instantaneous fuzing required for maximum near miss damage and 0.025 sec. for maximum direct hit damage. If plane loading characteristics are such that the ratio of the number of 250 lb. to 500 lb. bombs that can be carried is less than 3:2, the relative efficiency of the 250 lb. bomb is decreased and the 500 lb. GP bomb, fuzed 0.01/0.01, should be used instead of the 250 l.b GP. Where over 50% of the target area is occupied by storage tanks, it is recommended that weapon and fuze be selected for damage to the latter.

The recommendations above are intended to achieve maximum fire damage. Experience has shown that fire risk is lessened when a plant is not operating and the vessels and pipe lines are drained at the time of attack. Weapons are then best selected for maximum direct hit damage, and the 250 lb. GP bomb, fuzed 0.025/0.025 is recommended for refineries that are not in operation when attacked.

---

* See JTG M-8 for a discussion of these methods.

*AAF Evaluation Board—Oil Refineries—Ploesti—1 February 1945

**Bomb Damage Study, Leghorn Oil Refineries: Ordnance Officer Twelfth Air Force

Because experience has shown that the GP bombs are effective in releasing and igniting the inflammable contents, incendiary attack is not recommended.

The effectiveness of the 250 lb. and 500 lb. GP bombs are compared in Table 4. This comparison is based upon the observed radii at which there exists a 50% probability that the installations will be ruptured and fires started. They are not the true mean effective areas of destruction since fire damage is not included.

TABLE 9

Weapon Effectiveness for Refineries

Bomb	Effective Radius	Effect. Area per Ton*
500 lb. GP	35 ft.	15,000 sq. ft.
250 lb. GP	20 ft.	10,000 sq. ft.

*Based upon actual weights of bombs, TNT loaded.

The range of ground densities (in tons per million sq. ft. of target area) to achieve a 50% probability that a desired fraction of the plant be destroyed is given in Table 10.

TABLE 10

Ground Densities (tons per 1,000,000 sq. ft.) for Attack of Refineries

Bomb	Fraction of Plant F*		
	F = .30	F = .50	F = .70
500 lb. GP	25	45	80
250 lb. GP	35	70	120

*Computed by the formula used for Table 2.

Very considerable success has been achieved by the RAF in certain attacks of German refineries. These were characterized by (a) very heavy weights of attack and (b) the employment of about 1/3 (total weight) of 4000 lb. HC (light case) bombs. Since these attacks have not been thoroughly analyzed it is impossible, at present, to determine the relative effectiveness of large blast bombs.

3. Production Loss

Production loss is the best means of establishing effectiveness of weapons and required ground densities. This can be estimated by using the accumulated information obtained from the attacks of the Ploesti refineries.*

An approximate formula for the effectiveness of the 500 lb. GP bomb is:

$$L = 6T$$

where

L = effective loss in days of normal output

T = tons of bombs per million sq. ft. of target area

This formula is applicable to refineries that are subjected to repeated attacks, provided that sufficient time occurs between raids for repairs to be completed, and plant operation is near capacity.

An estimate of the level of damage to be aimed at can be made by relating the weight of attack for given levels of damage in Table 10 to the above formula. Production loss in days for each level of damage is given in Table 11.

TABLE 11

Production Loss in Refineries

Fraction of Damage	Production Loss in Days
.30	150
.50	300
.70	500

4. Force Requirements

a. High Level Attacks

To obtain force requirements necessary to achieve ground densities given in Table 10, the usual methods, based upon operational factors and aiming accuracy, must be followed.*

b. Dive Bombing

Although ground densities for dive bombing attacks are the same as for high level attacks, the primary targets can be attacked individually by dive bombers, resulting in a reduction in total weight of bombs required. Force requirements are calculated by the usual methods.*

---

*British Bombing Research Mission "Report on the Bombing of Ploesti"

* See JTG M-8 for a discussion of these methods.

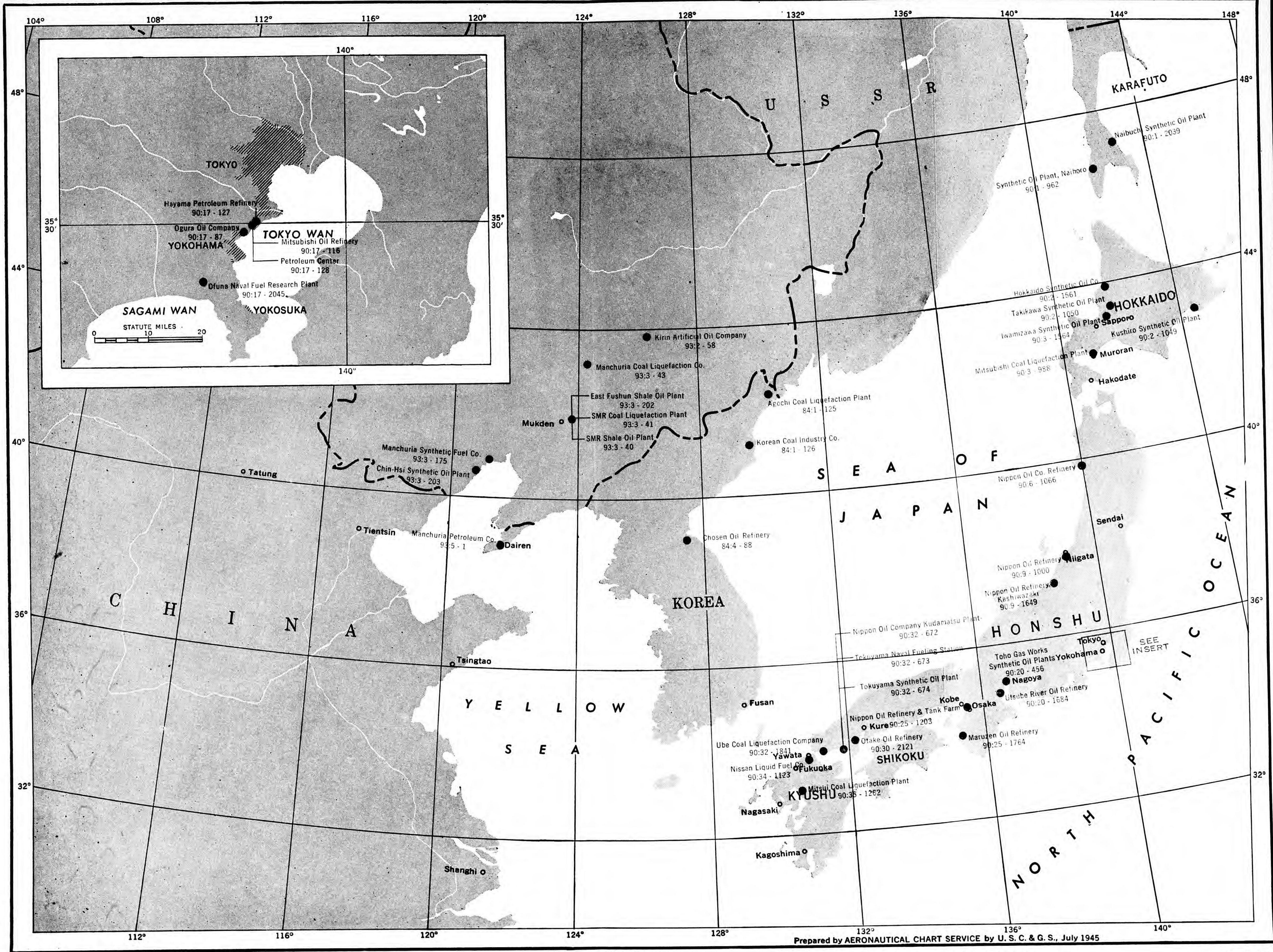
EPI—P
MAPS & TABLES

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

END PRODUCTS INDUSTRIES
PETROLEUM

CONFIDENTIAL

SHEET ....P—M1
DATE.......................22 June 1945



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

STATUTE MILES
100 0 100 200 300 400 500

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

CONFIDENTIAL

File No. **13,911**

TABLE 12-A

Japanese Synthetic and Shale Oil Plants, Inner Zone, 1 July 1945

Target No.	Name	Place	Type of Facility	Estimated Annual Capacity [1]	Percent of Inner Zone Capacity
84:1-125	Agochi Coal Liquefaction Plant	Agochi, Korea	Hy.?	350,000	4.6
84:1-126	Korean Coal Industry Co.	Eian, Korea	L.T.C.	70,000	1.0
90:1-962	Synthetic Oil Plant, Naihoro	Naihoro, Karafuto	L.T.C.?	105,000	1.4
90:1-2039	Naibuchi Synthetic Oil Plant	Naibuchi, Karafuto	L.T.C.?	210,000	2.8
90:2-1049	Kushiro Synthetic Oil Plant	Kushiro, Hokkaido	F.-T.?	200,000	2.8
90:2-1050	Takikawa Synthetic Oil Plant	Takikawa, Hokkaido	F.-T.?	350,000	4.6
90:2-1561	Hokkaido Synthetic Oil Co.	Rumoi, Hokkaido	F.-T.?	350,000	4.6
90:3-988	Mitsubishi Coal Liquefaction Plant	Wanishi-Muroran, Hokkaido	L.T.C.?	70,000	1.0
90:20-456	Toho Gas Works Synthetic Oil Plant	Nagoya, Honshu	L.T.C. + Hy.	210,000	2.8
90:20-1684	Utsube River Oil Refinery	Yokkaichi, Honshu	Hy.	385,000	5.0
90:25-1203	Nippon Oil Refinery and Tank Farm	Amagasaki, Honshu	F.-T.	280,000	3.6
90:30-2121	Otake Oil Refinery	Otake, Honshu	Hy.?	105,000	1.4
90:32-674	Tokuyama Synthetic Oil Plant	Tokuyama, Honshu	Hy.?	130,000	1.7
90:32-1841	Ube Coal Liquefaction Co.	Ube, Honshu	L.T.C. + Hy.	280,000	3.6
90:34-1123	Nissan Liquid Fuel Co.	Wakamatsu, Kyushu	L.T.C.?	70,000	1.0
90:35-1262	Mitsui Coal Liquefaction Plant	Omuta, Kyushu	F.-T.	280,000	3.6
93:2-58	Kirin Artificial Oil Co.	Kirin, Manchuria	Hy.?	350,000	4.6
93:3-40	SMR Shale Oil Plant	Fushun, Manchuria	Shale Oil Plant	2,000,000	26.3
93:3-41	SMR Coal Liquefaction Plant	Fushun, Manchuria	L.T.C. + Hy.	280,000	3.6
93:3-43	Manchuria Coal Liquefaction Co.	Ssupingkai, Manchuria	L.T.C. + Hy.	140,000	1.8
93:3-175	Manchuria Synthetic Fuel Co.	Chinchow, Manchuria	F.-T.	245,000	3.3
93:3-202	East Fushun Shale Oil Plant	Fushun, Manchuria	Shale Oil Plant	1,000,000	13.1
93:3-203	Chin-Hsi Oil Plant	Chin-Hsi, Manchuria	L.T.C. + Hy.	140,000	1.8
	Total			7,600,000	100.0

[1] In barrels, 42 U. S. gallons.

TABLE 12-B

Crude Oil Refineries in Japanese Inner Zone, 1 July 1945, annual capacities in thousands of barrels

Target No.	Name of Refinery	Location	Region	Refining Capacity	Cracking Capacity	Iso-Octane Capacity	Lube Oil Capacity	
							High Grade	Ordinary
90:3-1027	Nippon Oil Refinery, Karugawa	Karugawa	Hokkaido	132				
90:6-1066	Nippon Oil Co. Refinery	Tsuchizaki	No. Honshu	1320	330			
90:6-1067	Funakawa Oil Refinery	Funakawa		165				65
90:6-	Morohashi	Futada		17				7
90:6-	Niitsu Sekiyu (Marushin)	Hirazawa		65				65
90:6-	Ganshin Sekiyu	Hirazawa		53				20
90:6-	Asahi Petroleum Co.	Akita		17				7
90:6-	Nagai Morhashi	Okubo		17				7
90:9-	Kato Seiyusho	Shimo Gusa Futsu		33				13
90:9-	Suzuki Seiyusho	Unknown		50				20
90:9-	Wasyo Seiyusho	Kita Nakajima		33				13
90:9-	Kobayashi	Fukuro-machi		17				7
90:9-1000	***Nippon Oil Co.**	**Niigata**		**1000**	**330**			**155**
90:9-	Hayama Oil Co.	Niigata		66	**?**			25
90:9-	Asata	Niigata area		33				13
90:9-	Yamaguchi	Niigata-ken		6				
90:9-	Wada Refinery	Niigata-ken		50				20
90:9-	Maruzen Oil Co.	Niigata-ken		40				16
90:9-	Niitsu Tsuneyashi	Niigata area		50				20
90:9-	Hara	Niigata area		17				7
90:9-	Suzuki Refinery	Niigata-ken		3				
90:9-	Saito	Niigata area		33				13
90:9-	Tarkyo	Niigata		66				
90:9-	Seiji	Niitsu area		33				13
90:9-	Tatsuji Otaiu	Niitsu area		17				7
90:9-	Marushin Sekiyu (Niitsu)	Niitsu area		825	330	7		50
90:9-	Kato Seiyusho	Niitsu area		33				7
90:9-	Ishizaki Seiyusho	Niitsu area		50				20
90:9-	Maruzen Sekiyu	Niitsu area		40				16
90:9-1649	***Nippon Oil Refinery, Kashiwazaki**	**Kashiwazaki**		**1320**	**495**			**70**
90:9-	Niitsu Tsuneyashi	Nishinakadori		166				25
	Sub Total		No. Honshu	5635	1485	7		701
90:17-360	Edogawa Petroleum Storage	Tokyo	Cent. Honshu	85				35
90-17-911	Ogura Oil Co.	Tokyo		1155	660			70
90:17-2151	Joto Oil Refinery of Asahi Sekiyu Co.	Tokyo		165				
90:17-116	***Mitsubishi Oil Refinery**	**Kawasaki**		**2850**	**1000**	**36**	**70**	**70**
90:17-127	***Hayama Petroleum Refinery[1]**	**Kawasaki**		**1320**	**1000**	**15**	**165**	**85**
90:17-128	***Petroleum Center**	**Kawasaki**		**2000**	**400**	**18**	**70**	**100**
90:17-87	***Ogura Oil Co.**	**Yokohama**		**3300**	**1160**	**24**		**310**
90:17-90	Oriental Oil Co.	Yokohama		66				
90:18-2150	Shimizu Oil Refinery[4]	Shimizu		1650	660	18		70
90:20-	Uchida	Nagoya		43				17
90:20-1684	***Utsube River Oil Refinery[2] [5]**	**Yokkaichi**		**6600**	**1650**	**?**	**70**	**70**
90:25-1764	***Maruzen Oil Refinery**	**Shimotsu**		**1000**	**?**	**7**	**165**	**330**
90:25-2252	***Toa Oil Co., Shimotsu Refinery**	**Shimotsu**		**1000**	**?**	**7**	**70**	**85**
90:25-	Osaka Sekiyu	Funa-machi		165				
90:25-	Osaka Koyu (Yoshida?)	Funamatsu, Osaka						85
90:25-257	Maruzen Oil Refinery and Toyo Oil Refinery	Osaka		561				220
90:25-	Niitsu (Showa?) Sekiyo	Nakadori, Osaka		231				35
90:25-1203	***Nippon Oil Refinery and Tank Farm**	**Amagasaki**		**1650**	**500**		**70**	**85**
	Sub Total		Cent. Honshu	23841	7030	125	680	1667
90:29-2247	***Mitsuhama Oil Refinery[6]**	**Mitsuhama**	**Shikoku**					
90:30-2121	***Otake Oil Refinery[2]**	**Otake**	**S. Honshu**	**3300**	**1000**	**36**		**165**
90:32-670	Japan Paraffin Mfg. Co.[7]	Kudamatsu		400			70	
90:32-672	***Nippon Oil Co., Kudamatsu Plant**	**Kudamatsu**		**2500**	**660**			**85**
90:32-673	***Tokuyama Naval Fueling Station[3]**	**Tokuyama**		**3300**	**1150**	**20**		**165**
90:34-40	Asahi Oil Refinery	Hikoshima		165				
	Sub Total		S.W. Japan	9665	2810	56	70	415
84:4-88	***Chosen Oil Refinery**	**Genzan**	**Korea**	**1650**	**425**	**5**	**150**	**85**
84:7-215	Makino Island Refinery and Oil Storage	Fusan	Korea	65				
93:5-1	***Manchuria Petroleum Co.**	**Kanseishi**	**Manchuria**	**1650**	**660**		**100**	**165**
83:1-125	Maruzen Oil Installation	Shanghai	China					
	Sub Total		Continent	3365	1085	5	250	250
	Grand Total, Inner Zone			42506	12410	193	1000	3033

***Bold face type indicates targets on the A list, End Prdt. Ind., Petroleum.**

[1] May have small hydrogenation plant, see Table .. for capacity.

[2] Has hydrogenation plant. See Table .. for capacity.

[3] Hydrogenation plant adjoins this target.

[4] Believed owned by Toa Oil Co.

[5] Second Naval Fuel Depot.

[6] Under construction.

[7] Reported shale oil plant.

MILITARY STORES

MS—M
MUNITIONS

SECRET

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

M
MUNITIONS
18 JUNE 1945

MILITARY STORES

MUNITIONS

SECRET
By Authority of
The Commanding General
Army Air Forces
18 JUNE 1945
(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

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

SHEET . . . . **M–I**
DATE . . . . **18 June 1945**
PAGE **1**

MILITARY STORES
MUNITIONS

I. CURRENT DEVELOPMENTS

A. REQUIREMENTS AND SUPPLY

There have been no material recent changes in either the requirements or supply situations with respect to Japanese military ammunition and explosives.[1]

B. CHARACTERISTICS OF THE INDUSTRY

1. Extent and Location

To date 47 important ammunition and/or explosive storage areas, many of which are incidental to explosive manufacturing or ammunition loading establishments, have been definitely located and assigned target numbers. Fifteen to 20 additional small ammunition or explosive storage areas have been observed but disregarded as having only slight potential target value. Of the 47 storage targets 30 are located on Honshu, 6 on Kyushu, and 11 on the Asiatic continent.

Only 15 of these 47 targets are purely storage areas. Seventeen targets are primarily manufacturing plants producing military explosive materials, but including also incidental storage facilities which contain explosives and may possibly in some cases also contain finished ammunition. An additional 15 targets are primarily shell, bomb, or component loading establishments with incidental storage of considerable size. Characteristically, nearly every explosive manufacturing or loading establishment either includes, or has affiliated with it, a certain amount of either stored ammunition or explosive material.

The apparent geographic pattern of stored ammunition and explosives in Japanese territory is as follows:

a. One group of 30 storage areas is scattered along the E Honshu coast in a belt extending SW from N of Tokyo to Hiroshima, with concentrations in and near the cities of Tokyo, Nagoya, and Osaka.

b. A second group of 6 storage areas is dispersed along the E and W coasts of Kyushu near the cities of Nobeoka, Omuta, Oita, and Sasebo.

c. A third group of 11 continental storage areas may be found near the cities of Mukden, Fushun, Kirin, and Chinchow in Manchuria, and Konan and Heijo in Korea.

The above described geographical pattern may not be truly representative of all Japanese ammunition-explosive storage areas. The observed pattern is explained largely by the fact that aerial photography available for inspection follows the same geographic pattern. All air cover available through March 1945 was inspected, but by this date only a small part of the total area of Japan had been covered by aerial reconnaissance.

2. Size and Integration with Manufacturing Plants

Ammunition and explosive storage areas checked to date vary considerably in size. A large area is defined as one which contains more than 45 medium to large size revetted or dispersed buildings. A medium area is defined as one which contains between 25 and 45 medium or large size revetted or dispersed buildings. A small area is one containing less than 25 revetted or dispersed buildings of medium to large proportions.

On this basis, 23 of the 47 major ammunition or explosive storage areas are large size; 13 are medium, while 11 classify as small.

A cross classification of these storage areas, by extent of storage facilities and principal purpose of each installation, is given in Table I.

TABLE I

Japanese Ammunition Storage Areas, By Size and Major Function

Major Function		Total	Size		
			Large	Medium	Small
Storage	Japan	10	3	3	4
	Continent	5	2	2	1
Explosive Mfg.	Japan	13	10a	2c	1
	Continent	4	2b	2	
Loading	Japan	13	6	4	3
	Continent	2		1c	1
Totals	Japan	36	19	9	8
	Continent	11	4	5	2
GRAND TOTALS		47	23	14	10

a—Including 3 not certain (Inadequate air cover)
b—Including 1 not certain (Inadequate air cover)
c—Not certain (Inadequate air cover)

C. EFFECTS OF AIR ATTACK TO DATE

To date no large attacks on ammunition or explosive storage areas either in Japan proper or on the continent N of Shanghai have been made. Very slight damage to a few storage areas has been caused by bombs aimed at aircraft and urban area targets.

D. CURRENT PRINCIPAL TARGETS

The major known storage areas are listed in Table II. The relative potential importance of each area for air attack will obviously depend not only on its character and size, as shown in this table, but also upon the geographic relationship between each potential storage target and the scene of impending military operations.

---

[1] Ammunition, as used in this paper, includes bombs, grenades, and rockets as well as shells.

II. RELATION TO MILITARY STRENGTH

A. REQUIREMENTS

Japan's requirements for ammunition and explosives will obviously depend on the future character of the war. This is uncertain, but the probable general order of magnitude of ammunition requirements may be calculated by making reasonable postulates as to future strength and dispositions of the Japanese military forces, and by drawing inferences therefrom.

The Japanese may feel able to defend their home islands with as few as 30 divisions. In active defensive operations, these divisions might, on the average, expend 1 unit of fire per month. (Two units of fire per month constitute a "division-month" of ammunition supply — sufficient for the heaviest type of combat.) Under these assumptions, the average ammunition consumption by the entire Japanese ground force defending the home islands might be about 15 division-months per month. Under such conditions of active defensive operations, Japan would require in the home islands about 180 division-months supply of ammunition, i.e. 360 units of fire or 1,800,000 tons of intermediate steel, derived either from stocks or new production, in order to sustain combat for a year.

Requirements for continental defense can be calculated in a similar manner. If Japan can maintain a potential front-line force of 20 divisions in Manchuria, the requirements for one year's resistance will be 120 division-months of ammunition, i.e., 240 units of fire or 1,200,000 tons of intermediate steel.

B. SUPPLY

It is currently estimated that the Japanese have, both in Japan proper and on the continental portion of the Inner Zone, i.e. in North China, Manchuria, and Korea, about 175 division-months' supply of ammunition. This supply, if maintained intact, e.g. not lost to Allied air action, and fully utilized, i.e. fired rather than captured intact by Allied ground action or not brought to the front because of collapse of the transportation system, should prove adequate, when supplemented by new production at a rate of about 5 division-months per month, to sustain resistance for more than a year in the home islands alone or for 1 year in the home islands plus an additional 3 months on the mainland.

C. MILITARY EFFECTS OF ATTACK ON SUPPLY

Since Japan is believed presently to be producing no more than 5 division-months' supply of ammunition per month, it is clear that under the assumption that decisive land combat is not too long delayed existing ammunition stocks weigh much more heavily than possible future ammunition production in determining the possible length of Japanese resistance to Allied ground action. A steady drain on ammunition supplies, equal monthly either to a substantial part of current production, or to a small portion of stored reserves will be steadily required for training. If these non-combat requirements are regarded as deducted from potential production, it is likely that only 3 to 4 division-months' supplies per month, or 36 to 48 division-months in a year, can be added to stored reserves, even in the absence of any land combat. If training requirements are viewed as deductible from stocks, a view which accords more closely with actual practice, stocks still contribute more to Japanese potential reserve ammunition strength a year hence than does production in the same interval. This may be illustrated by the following calculations:

POTENTIAL JAPANESE RESERVE AMMUNITION STRENGTH,
1 YEAR HENCE
(in division-months of supply)

Present ammunition reserve strength	175 div. mo.
Add: Production for 1 yr. at 5 div. mo. per mo.	60 div. mo.
Less: Requirements for training for 1 yr.	12–24 div. mo.
Equals: Potential strength 1 yr. hence assuming no ground fighting in interim	211–223 div. mo.

Production contributes only a little more than ¼ to this potential future strength; nearly ¾ of the total originates in stocks already existing.

It may thus be concluded that air attack against ammunition stocks which succeeded in destroying between 50% and 70% of these reserves, might reduce the possible length and severity of Japanese resistance by almost an equivalent proportion of the total period of resistance.

III. CHARACTERISTICS OF AMMUNITION AND EXPLOSIVE STORAGE

A. LOCATION OF INSTALLATIONS

Ammunition storage is widely dispersed throughout Japan proper and the continent. Conclusive statements on the exact geographical pattern are not possible pending more complete photo coverage. It is now estimated that of the total Japanese reserve supplies of ammunition, estimated at 175 division-months, at least 50 division-months, or nearly 30%, are stored on the continent.

B. CONCENTRATION

It is believed that 80% of the Japanese Empire reserve supplies of ammunition are now contained in no more than 100 storage areas, about 30 of which are presumably on the continent. The 50 largest storage areas probably contain a fairly high proportion of the total reserve stocks, perhaps as much as 70%.

C. EXPOSURE TO URBAN AREA ATTACK

All the large ammunition and/or explosive storage areas are outside urban areas. A few small to medium storage areas may be found in urban locations such as near the old established arsenals in NW Tokyo.

D. INTEGRATION OF STORAGE AND MANUFACTURING

Storage of munitions in Japan is closely associated with explosive manufacturing and shell loading. Probably no more than ⅓ of all storage areas are entirely separate from manufacturing activity.

IV. PHYSICAL VULNERABILITY AND WEAPON RECOMMENDATIONS

A. PHYSICAL CHARACTERISTICS OF STORAGE AREAS

Ammunition falls into two classes, *fixed,* in which the projectile is attached to the propellant cartridge, and *separate loading.* The first normally includes all sizes smaller than 155 mm. In Japanese practice both types are stored in combustible containers, of wood for large calibers or of cardboard for the smaller.

Central ammunition stores in Japan consist of storage areas made up of collections of storage units. The storage units appear to be well standardized. Each unit consists of a light wood or steel framed shed with average dimensions about 40 feet x 90 feet (maximum observed 70 feet x 140 feet) with a light roof to protect the stores. These sheds may be well dispersed for protection, or may be surrounded by earth embankments about 120 feet x 180 feet on average. In the dispersed installations (seldom found in Japan proper but common on the continent) the degree of builtupness is of the order of ½ %. The density in the installations with earth embankments (typical of Japan proper) is of the order of 8 %. (These comprise nearly ½ of all installations examined.)

The highly built up installations vary in size. A small one contains less than 25 units (average about 15), a medium one contains from 25 to 45 units, while a large installation has more than 45 (average about 70).

B. PHYSICAL VULNERABILITY

Ammunition stores (not including bombs) are vulnerable to incendiary, to HE, and to strafing attack. The HE contained in projectiles is not particularly easy to initiate. The propellant, however, will burn readily and is comparatively easy to ignite. This will result in complete loss of stores. This, with the combustible nature of the packing make ammunition a good incendiary target. (This does not apply to bomb stores, whose susceptibility to fire is very small.)

Since no operational evidence is at hand as to the number of small IB's required to start a self supporting fire in a storage unit (3500 sq. feet) it is assumed that eight M50 IB or an equal weight of M69 IB are needed. This assumption is believed to be conservative. On this basis, it is possible to determine the densities required for various proportions of total number of units destroyed.

Ammunition is also vulnerable to strafing and to attack by small HE bombs (20-lb F and 100-lb GP). Strafing is considered too hazardous to the attacker to be recommended, except against isolated ammunition dumps. HE attack is fairly effective, even when only a part of a unit is destroyed, since the remaining material is likely to be injured somewhat, and in any event will have to be separated from the remnants of that destroyed—a very difficult and hazardous occupation. Both the 20-lb F and the 100-lb GP can be used against ammunition stores (the latter is also effective against bomb stores). The 20-lb F is not recommended against stores under roofs. An analysis of tests made by the Ordnance Officer, 12th AF[1] indicates that the effective area of the 20-lb F against stored ammunition is about 300 sq. feet and of the 100-lb GP about 1500-2000 sq. feet. From these figures it appears that one 100-lb GP or five 20-lb F per storage unit is required for effective attack. From this, it appears that HE attack will require from two to three times the weight of IB attack for equal effect.

C. WEAPON RECOMMENDATIONS AND WEIGHT OF ATTACK

Weapons recommended are the following:

(1) AN-M50 4-lb IB
(2) AN-M69 6-lb IB
(3) 100-lb GP fuzed 0.01/ND
(4) 20-lb F (not recommended against covered stores)

Densities needed are given in Table I for various expected proportions of the total number of units destroyed.

TABLE III

Ground Density (Tons/1,000,000 sq ft) for 30, 50, and 70% Expected Destruction of Storage Units

Weapon	F=0.3	0.5	0.7
M50-4#IB or M69-6#IB	2	4	6
100#GP or 20#F	5	10	17

---

[1] 1st and 2nd Reports, Ord. Off. HQ 12 AF "Tests of American Bombs Against German Ammunition Dumps," 15 June and 5 Aug 1944 (Conf.).

MS—M
MAPS & TABLES

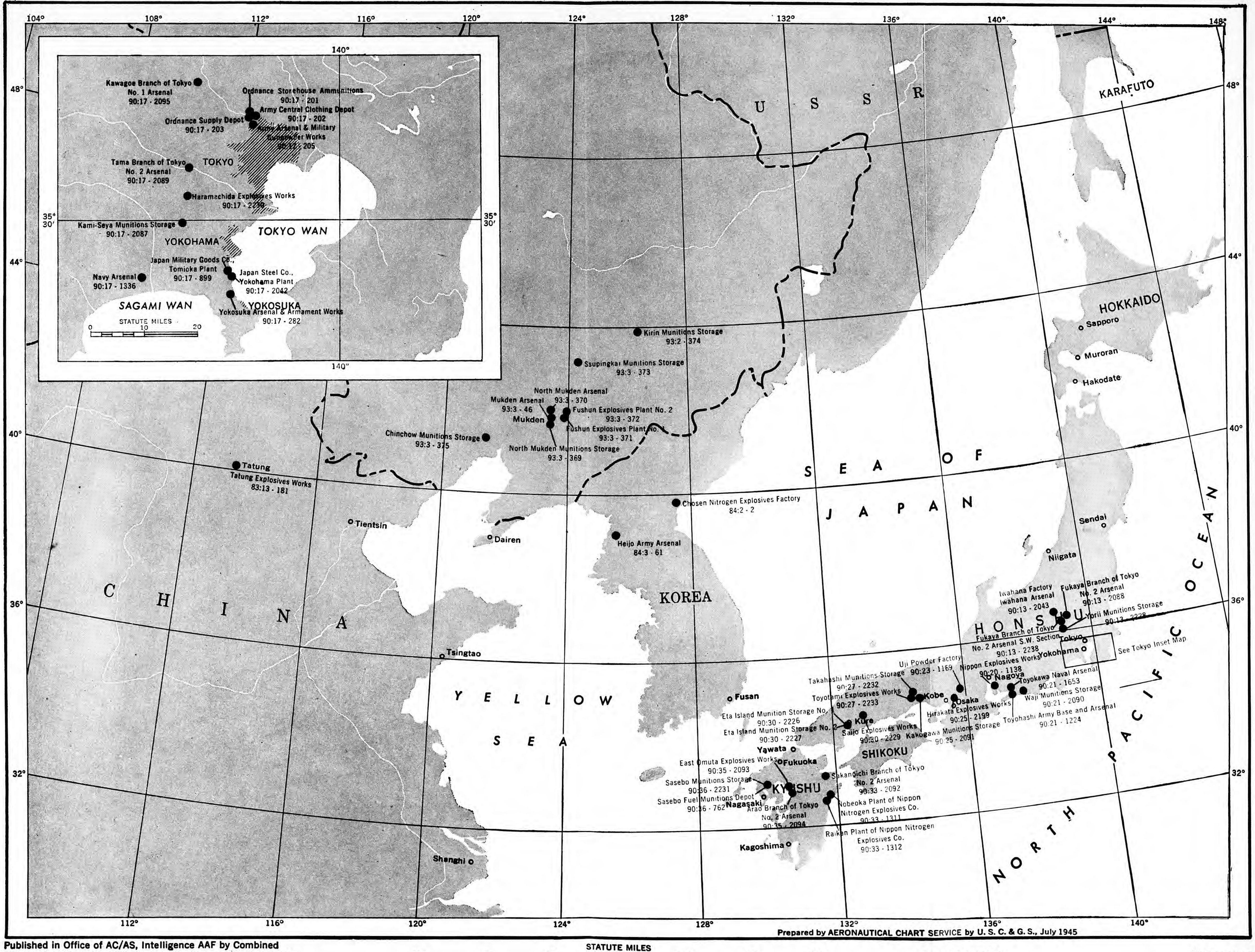
JOINT TARGET GROUP
Washington, D.C.
GENERAL LOCATION MAP

MILITARY STORES

MUNITIONS

CONFIDENTIAL

SHEET **M–M1**
DATE . . . . **28 May 1945**



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

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

CONFIDENTIAL

File No. 15,911

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

SHEET ....**MS-M-ST**
DATE.....**18 June 1945**

MILITARY STORES
MUNITIONS

Target	Name of Target	Primary Function
	JAPAN	
90:20-196	Chigusa Factory, Nagoya Arsenal	ML(SS)
90:17-201	Ordnance Storehouse—Ammunition (Tokyo)	MS(ML)
90:17-203	Ordnance Supply Depot (Tokyo)	LS?
90:17-205	Army Arsenal & Military Gunpowder Works (Tokyo)	LL(MS)
90:17-899	Japan Military Goods Co., Tomioka Plant	LL(SS)
90:20-1138	Nippon Explosives Works (Taketoyo)	LE(SS)
90:23-1169	Uji Powder Factory	LE(MS)
90:21-1224	Toyohashi Army Base & Arsenal	SS(SL)
90:27-1281	Dai Nippon Celluloid Co. (Aboshi)	SE(SS)
90:33-1311	Nobeoka Plant of Nippon Nitrogen Explosives Co	LE(MS)
90:33-1312	Raikan Plant of Nippon Nitrogen Explosives Co	ML(SS)
90:17-1336	Navy Arsenal (Hiratsuka)	LE(MS)
90:21-1653	Toyokawa Naval Arsenal	LL(MS)
90:20-1691	Takaki Factory, Nagoya Arsenal	SL
90:25-1723	Hirakata Factory, Osaka Army Arsenal	LL
90:30-1891	Japan Steel Co., Hiroshima Plant	ML
90:17-2042	Japan Steel Co., Yokohama Plant	SL(SS)
90:13-2043	Iwahana Factory, Tokyo Arsenal	LE(MS)
90:17-2087	Kami-Seya Munitions Storage	LS
90:13-2088	Fukaya Branch of Tokyo No. 2 Arsenal	LE(MS)
90:17-2089	Tama Branch of Tokyo No. 2 Arsenal	LE(MS)
90:21-2090	Waji Munitions Storage	MS
90:25-2091	Kakogawa Munitions Storage	SS(SL)
90:17-2092	Sakanoichi Branch of Tokyo No. 2 Arsenal	LL(MS)
90:35-2093	East Omuta Explosives Works	ME(SS)
90:35-2094	Arao Branch of Tokyo No. 2 Arsenal	LE(MS)
90:17-2095	Kawagoe Branch of Tokyo No. 1 Arsenal	LE?(MS?)
90:25-2199	Hirakata Explosives Works	LE?(MS?)
90:30-2226	Eta Island Munitions Storage No. 1	SS
90:30-2227	Eta Island Munitions Storage Area No. 2	SL?(SS?)
90:30-2228	Yorii Munitions Storage	MS
90:30-2229	Saijo Explosives Works	ME(SS)
90:17-2230	Haramachida Explosives Works	LL(MS)
90:36-2231	Sasebo Munitions Storage	LS
90:27-2232	Takahashi Munitions Storage	SS
90:27-2233	Toyotomi Explosives Works	ML(SS)
	CONTINENT	
84:2 -2	Chosen Nitrogen Explosives Factory	LE(MS)
93:3 -46	Mukden Arsenal	MS
84:3 -61	Heijo Army Arsenal	SS
84:6 -213	Eitoho Munitions Plant	SL(SS)
93:3 -369	North Mukden Munitions Storage	LS
93:3 -370	North Mukden Arsenal	ML?(SS?)
93:3 -371	Fushun Explosives Plant No. 1	ME(SS)
93:3 -372	Fushun Explosives Plant No. 2	ME(SS)
93:3 -373	Ssupinkai Munitions Storage	MS
93:2 -374	Kirin Munitions Storage	LE?(MS?)
93:3 -375	Chinchow Munitions Storage	LS

First Letter

L—Large—over 45 revetted or dispersed buildings
M—Medium—25-45 revetted or dispersed buildings
S—Small—under 25 revetted or dispersed buildings

Second Letter

S—Storage Area
E—Explosive Mfgr.
L—Loading Plant

( )—Secondary Function
?—Inadequate photographic coverage to support a firm conclusion.

(193)

JOINT TARGET GROUP, WASHINGTON, D. C.

SUMMARY TABLE

SHEET . . . . MS-M-ST
DATE. . . . 18 June 1945

MILITARY STORES
MUNITIONS

Target	Name of Target	Primary Function
	JAPAN	
90:20-196	Chigusa Factory, Nagoya Arsenal	ML(SS)
90:17-201	Ordnance Storehouse—Ammunition (Tokyo)	MS(ML)
90:17-203	Ordnance Supply Depot (Tokyo)	LS?
90:17-205	Army Arsenal & Military Gunpowder Works (Tokyo)	LL(MS)
90:17-899	Japan Military Goods Co., Tomioka Plant	LL(SS)
90:20-1138	Nippon Explosives Works (Taketoyo)	LE(SS)
90:23-1169	Uji Powder Factory	LE(MS)
90:21-1224	Toyohashi Army Base & Arsenal	SS(SL)
90:27-1281	Dai Nippon Celluloid Co. (Aboshi)	SE(SS)
90:33-1311	Nobeoka Plant of Nippon Nitrogen Explosives Co	LE(MS)
90:33-1312	Raikan Plant of Nippon Nitrogen Explosives Co	ML(SS)
90:17-1336	Navy Arsenal (Hiratsuka)	LE(MS)
90:21-1653	Toyokawa Naval Arsenal	LL(MS)
90:20-1691	Takaki Factory, Nagoya Arsenal	SL
90:25-1723	Hirakata Factory, Osaka Army Arsenal	LL
90:30-1891	Japan Steel Co., Hiroshima Plant	ML
90:17-2042	Japan Steel Co., Yokohama Plant	SL(SS)
90:13-2043	Iwahana Factory, Tokyo Arsenal	LE(MS)
90:17-2087	Kami-Seya Munitions Storage	LS
90:13-2088	Fukaya Branch of Tokyo No. 2 Arsenal	LE(MS)
90:17-2089	Tama Branch of Tokyo No. 2 Arsenal	LE(MS)
90:21-2090	Waji Munitions Storage	MS
90:25-2091	Kakogawa Munitions Storage	SS(SL)
90:17-2092	Sakanoichi Branch of Tokyo No. 2 Arsenal	LL(MS)
90:35-2093	East Omuta Explosives Works	ME(SS)
90:35-2094	Arao Branch of Tokyo No. 2 Arsenal	LE(MS)
90:17-2095	Kawagoe Branch of Tokyo No. 1 Arsenal	LE?(MS?)
90:25-2199	Hirakata Explosives Works	LE?(MS?)
90:30-2226	Eta Island Munitions Storage No. 1	SS
90:30-2227	Eta Island Munitions Storage Area No. 2	SL?(SS?)
90:30-2228	Yorii Munitions Storage	MS
90:30-2229	Saijo Explosives Works	ME(SS)
90:17-2230	Haramachida Explosives Works	LL(MS)
90:36-2231	Sasebo Munitions Storage	LS
90:27-2232	Takahashi Munitions Storage	SS
90:27-2233	Toyotomi Explosives Works	ML(SS)
	CONTINENT	
84:2 -2	Chosen Nitrogen Explosives Factory	LE(MS)
93:3 -46	Mukden Arsenal	MS
84:3 -61	Heijo Army Arsenal	SS
84:6 -213	Eitoho Munitions Plant	SL(SS)
93:3 -369	North Mukden Munitions Storage	LS
93:3 -370	North Mukden Arsenal	ML?(SS?)
93:3 -371	Fushun Explosives Plant No. 1	ME(SS)
93:3 -372	Fushun Explosives Plant No. 2	ME(SS)
93:3 -373	Ssupinkai Munitions Storage	MS
93:2 -374	Kirin Munitions Storage	LE?(MS?)
93:3 -375	Chinchow Munitions Storage	LS

First Letter

L—Large—over 45 revetted or dispersed buildings
M—Medium—25-45 revetted or dispersed buildings
S—Small—under 25 revetted or dispersed buildings

Second Letter

S—Storage Area
E—Explosive Mfgr.
L—Loading Plant

( )—Secondary Function
?—Inadequate photographic coverage to support a firm conclusion.

MS—P

M—S
PETROLEUM STORAGE

File No. 17,000

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

MS-P
1 JULY 1945

MILITARY STORES

PETROLEUM

SECRET
By Authority of
The Commanding General
Army Air Forces
1 July 1945
(Date) (Initials)

(193)

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

File No. 17,011

I. CURRENT STATUS AND DEVELOPMENTS

A. PRESENT POSITION

Details on Japan's petroleum stock position as of 1 July 1945 are given in Section II of this study and Section II of the General Analysis End Products Industries: PETROLEUM. Briefly stated, Japan's Inner Zone production of petroleum products is no more than 50 percent of requirements at the January 1945 rate. Stocks are believed to equal no more than 12 months supply at this consumption rate, with a particularly tight position in aviation gasoline.

It must be anticipated that in the face of this tight oil position the Japanese will slash consumption to a bedrock minimum and adjust their intentions accordingly. In the case of aviation fuel, a decision by the Japanese to employ available aircraft largely for suicide attacks would mean that available stocks, though critically short in terms of the requirements of a conventional airforce, would be quite adequate to support maximum suicide capabilities (limited by availability of aircraft and pilots) at least for the next nine months. This would be true even though all synthetic oil production were halted in the interim. It must further be anticipated that the Japanese will disperse to invulnerable locations sufficient stocks to support their present air intentions.

B. CHANGES IN INDUSTRY STRUCTURE

The principal development in petroleum storage is the removal of tankage which has been observed since the first cover of the Tokyo area in November 1944. From available air cover it is estimated that 14,200,000 barrels of capacity have fairly recently been dismantled. If these removed tanks have not been re-erected, the total tankage has decreased by the same amount. From present intelligence, tankage as of 1 June 1945 was 42,800,000 barrels, before allowance for destruction from air attack.

In all, removal or dismantle has been observed in 23 locations. Some installations have been completely obliterated. This has been noticeable in tank farms associated with pre-war refineries; and it has also occurred in installations such as the Azuma Oil Storage (Target 90:17-297) associated with the Yokosuka Naval Base.

The reason for this activity is not known. It is clear that the loss of N.E.I. resources and dwindling overall stocks were important in making some tankage superfluous. But it is not certain whether the dismantled tanks have been used as steel scrap, removed to entirely unknown locations, or used in recently expanded underground storage. Another possibility is their use as process tanks in new synthetic plants.

As a result of the removal, underground capacity is 22 percent of the total instead of 16 percent and there are only 19 areas (16 in Japan Proper) with more than 500,000 barrels above ground instead of 29. Storage capacity is becoming a less concentrated and relatively a more difficult target.

The current geographic distribution and concentration is shown in Table 1.

TABLE 1
Current Status of Japanese Oil Storage
Estimated Capacity and Number of Installations
15 June 1945

	Surface	Underground	Surface and/or Underground	Total
In Japan Proper				
Over 500,000 bbls.	16,959	8,835	1,200	26,994
No. of Locations	18	7	1	
50,000-500,000 bbls.	6,526	270	183	6,979
No. of Locations	30	1	1	
On Continent				
Over 500,000 bbls.	2,978	—	650	3,628
No. of Locations	4		1	
50,000-500,000 bbls.	2,504	—	—	2,504
No. of locations	18	—	—	—
TOTAL	28,967	9,105	2,033	40,105

Inner Zone Oil Storage Facilities Each Over 50,000 Bbls.
(thousands of barrels, 42 U. S. gallons)
15 June 1945

	Barrels	Percent
Kyushu	4,744	12
Southwest Honshu and Shikoku	13,068	33
Central Honshu	13,756	34
Northern Honshu	2,305	6
Hokkaido	100	—
Karafuto	—	—
Korea	2,072	5
Manchuria	1,565	4
North China	2,495	6
TOTAL	40,105	100

C. EFFECTS OF ATTACKS TO DATE

A significant part of Japan's storage capacity and stocks have been destroyed by the attacks of 10 May 1945. In all 150 tanks with 2,660,000-bbl capacity have been eliminated. The details are as follows:

Name of Target	Tanks Destroyed	Capacity Destroyed or Badly Damaged
Joto Oil Refinery of Asahi Sekiyu Co., Tokyo, 90:17-2151	1	35,000 bbls.
Otake Oil Refinery, Otake, 90:30-2121	78	700,000 bbls.
O Shima Naval Oil Storage, O Shima, 90:32-1884	14	1,190,000 bbls.
Tokuyama Naval Fueling Station, Tokuyama, 90:32-673	57	735,000 bbls.
TOTAL	150	2,660,000 bbls.

Notes:

(1) Joto Oil Refinery, Tokyo. Located in burned area of Tokyo as per photo sortie 3PR/5M77, 11 March 45.

(2) Otake Oil Refinery attacked on 10 May 1945 (Mission 165).

(3) O Shima Naval Oil Storage attacked on 10 May 45 (Mission 166).

(4) Tokuyama Naval Fueling Station attacked on 10 May 45 (Missions 163 and 164).

D. CURRENT PRINCIPAL STORAGE AREAS

The principal petroleum storage targets are indicated in Table II, which shows present capacity of each installation.

Some targets are relatively more important than others irrespective of capacity. Since even now Japan has 25,000,000-30,000,000 bbls. excess storage capacity, certain tank areas may well be more full than others. It is reasonable to suppose that underground installations are most likely to be full. The next most active areas are probably those associated with active military installations such as naval bases, and operating refineries such as Otake Oil Refinery (Target 90:30-2121) and Utsube River Oil Refinery (Target 90:20-1684). With current stocks at about 10,000,000 bbls, it is probable that many of the storage areas connected with pre-war refineries are empty.

If aviation fuel is the principal objective, the most likely locations of stocks would be at the active refineries (Targets 90:30-2121), Otake Oil Refinery, and 90:20-1684, Utsube River Oil Refinery, Yokkaichi, and near air bases such as Hiro Oil Storage, Hiro, (Target 90:30-2133). However, at least one half of aviation gasoline stores are probably dispersed at air fields, and the exact location of the balance is unknown.

II. RELATION TO MILITARY STRENGTH

A. USES

The major use for petroleum products is direct military consumption in aircraft, naval vessels, and army vehicles. In addition, there are some industrial needs for fuel oil in merchant vessels and factories. Lubricants are primarily industrial in use.

B. REQUIREMENTS

The requirements for petroleum products are considered in detail in End Products Industries: Petroleum—General Analysis. Since 1943 they have been drastically reduced. In 1942-1944 Japan was consuming approximately 50,000,000 bbls of petroleum products per year. In 1945 requirements are about 30,000,000 bbls. according to earlier estimates. Revised estimates will probably arrive at a considerably lower figure. Loss of much of the Japanese air force and navy have been the major reasons for this change.

C. SUPPLY

Japan's sources of petroleum products are now confined to inner zone production and stocks. Stocks are a vital part of the supply picture because they are needed to bridge a wide gap between current production and requirements. Current stocks estimated (as of 1 July 1945) of approximately 10,000,000 bbls. are only slightly lower than annual production of about 11,000,000 bbls.

Japan's position differs considerably as between the different products. Aviation gasoline is believed to be especially tight with the probability that consumption may have to be cut back even further to prevent practical exhaustion of supplies in early 1946. Such a cutback is consistent with the enemy's apparent intention to confine air operations largely to suicide missions. Stocks make up at least half visible supplies in the next 12 months. Motor gasoline supply is fairly comfortable with production plus stocks equivalent to 3 years requirements (for further details see Petroleum—General Analysis).

D. EFFECT OF ATTACKS ON STOCKS ON MILITARY STRENGTH

Destruction of stocks of petroleum products will always have some adverse effect on the enemy's military strength. The more difficult question is whether large scale attacks could be expected to have decisive effect on the efficiency of Japan's military forces. As will be shown in Section III of this report, storage capacity is greatly in excess of requirements, and much of it is underground. In the case of ground and sea forces decisive results could probably not be obtained from loss of a part of their supply of motor gasoline or fuel oil. Japan's ground forces are very lightly mechanized and motorized by western standards. Japan is not equipped for a war of movement and once larger scale land warfare begins, will be forced to depend largely on static defences and simple transport means regardless of gasoline availability. For example, the Japanese Army is estimated to have only 75,000 trucks available.

This factor plus the relatively large storage and ample current production of motor gasoline makes Japanese ground strength (in marked contrast to Germany) relatively invulnerable to attack on either basic oil production or stocks. Nevertheless, large scale destruction of oil stocks might contribute somewhat to the effectiveness of attacks designed to interdict rail and water movements.

Attacks on either fuel oil production or stocks would not have a major effect on the Japanese fleet which is already of little use to Japan in the defense of the home land.

Japan's shortage of aviation gasoline would be a serious handicap within a few months if the enemy attempted to employ his air force along conventional lines. Attacks on aviation fuel production and storage under these circumstances would reduce materially the efficiency of the Japanese Air Force. On the other hand, if it is the enemy's intention to hoard aircraft and pilots primarily for suicide use, fuel should not be a limiting factor within the next 9 months and it appears unlikely that attacks against fuel production or storage could achieve any significant reduction in such suicide effort.

The difficulties of attacking stocks of aviation gasoline and to a lesser degree of attacking stocks of other petroleum products is indicated in Section III.

III. CHARACTERISTICS OF PETROLEUM STORAGE

A. CAPACITY

Before attack and recent removal of tankage, Japan is believed to have had 57,000,000 bbls. storage capacity in the Inner Zone.[1] This estimate is based on aerial photography covering 51,000,000 bbls. of the total.[2] Previous estimates based largely on ground intelligence were considerably higher.

B. LOCATION

Before attack and removal of tankage, the greater part of Japan's Inner Zone storage of petroleum lay between Tokyo and Sasebo. There was 7,800,000 bbl. capacity on the continent including 1,625,000 in the Shanghai area and 2,100,000 in Korea. The capacity in Kyushu was 5,100,000 bbls., in SW Honshu (including Shikoku) 23,000,000 bbls., and 18,100,000 bbls. in Central Japan. See Table 2 below for details.

TABLE 2
Inner Zone Oil Storage Facilities Each Over 50,000 Bbls.
(thousands of barrels, 42 U.S. gallons)

	Barrels	Percent
Kyushu	5,100	9
Southwest Honshu and Shikoku	23,000	40
Central Honshu	18,100	32
Northern Honshu	2,900	5
Hokkaido	100	—
Karafuto	—	—
Korea	2,100	4
Manchuria	1,600	3
North China	4,100	7
Total	57,000	100

C. CONCENTRATION OF CAPACITY

Prior to attack and tankage removal, 87 percent of capacity was concentrated in 35 locations, each with 500,000 bbl. capacity or over.[1] Another 13 percent was concentrated in locations of 50,000 to 500,000 bbls. Unknown amounts are stored in drums, small tanks, etc. Of the total storage, 9,105,000 bbls. or 16 percent was underground. The breakdown of areas by size and characteristics follows:

TABLE 3
Estimated Storage Capacity and Number of Installations
1 November 1944

	Surface	Under-ground	Surface and/or Under-ground	Total
In Japan Proper				
Over 500,000 bbls.	34,703,000	8,835,000	1,200,000	44,738,000
No. of Locations	25	7	1	
50,000-500,000 bbls.	4,010,000	270,000	183,000	4,463,000
No. of Locations	23	1	1	
On Continent				
Over 500,000 bbls.	3,986,000	—	650,000	4,636,000
No. of Locations	5		1	
50,000-500,000 bbls.	3,129,000	—	—	3,129,000
No. of Locations	18			
Total	45,828,000	9,105,000	2,033,000	56,966,000

D. EXPOSURE TO URBAN AREA ATTACKS

A certain part of the storage capacity was located in urban areas, principally that associated with pre-war refineries. This tankage, however, is less likely to hold important stocks and is not highly vulnerable to attack other than with H.E.

E. INTEGRATION WITH OTHER FACILITIES

Petroleum storage is frequently associated with other facilities. Of the 21 installations in Japan Proper with more than 500,000 bbls. capacity, 7 are associated with pre-war refineries, 2 are associated with new refineries, 5 are part of a naval or military base, and 2 are nearby a synthetic plant. Only 7 are completely independent storage areas. Smaller storage areas are more likely to be separate installations.

F. CONCENTRATION OF STOCKS

Since storage capacity is so much greater than stocks, possibly four times as great, it cannot be assumed that all tankage locations have stocks. It is probable that almost all of the storage areas associated with pre-war refineries have little or no stocks. A greater than normal proportion of stocks are probably in underground locations. Stocks of naval fuel may be in such locations near navy stations. Aviation gasoline is at least in part (possibly ½) in dispersed locations at airfields. It is quite problematical how much, if any, of the aviation gasoline on hand could be destroyed by attacks on known storage installations. The best possibility of success would be obtained if current documentary or POW intelligence were available as to location of important stocks. Otherwise, many installations could be attacked without affecting aviation gasoline.

---

[1] Inner Zone includes home islands, Manchuria, Korea, and North China.

[2] In some cases the 1st photography shows evidence of tank removal. In such cases previous capacity must be estimated.

IV. PHYSICAL VULNERABILITY AND WEAPON RECOMMENDATIONS

A. INTRODUCTION

The following is written for the use of those persons who are engaged in selecting weapons, estimating force requirements, and formulating operational plans for attack on targets in this category. For such purposes the following questions must be answered:

1. What portion of a target should be the primary objective?
2. What is normally the best type, size, and fuzing of HE? In what circumstances should different types be used?
3. Should IB be used, either exclusively or mixed with HE? If so, what is the best size and type, and what is the optimum quantity?
4. What weight of attack is required?

This section deals with the physical characteristics of targets found in this category, the choice of primary objectives, the selection of weapons and with the density required on the target for expectancy of a particular level of damage. For determination of force requirements reference should be made to JTG M-8.

B. SUMMARY

Crude and finished products are normally stored in tank "farms", which are collections of cylindrical steel tanks above ground. The tanks are of many different sizes ranging from 20 to 120 feet in diameter, and up to 40 feet high. They are usually separated by low earth or concrete dykes. In the ETO, blast walls for protection against near miss bombs have been extensively employed. Such walls were not evident on early Japanese photo cover, but recent cover shows that they are being constructed in a few places.

Attack can be by HE bombs or rockets. The object of attack must be to spill contents and start fires. For this, direct hits are necessary since near misses, unless very near, only create fragment holes, which are relatively easily repaired. Fire is the major cause of damage and is started by the HE weapons which rupture the tanks and pipes containing inflammable liquids.

Underground storage can be located on photo cover but is sometimes difficult to identify during attack. This fact, combined with the normal resistance of the target and the unlikelihood of getting fire spread between units makes underground storage a much less vulnerable target than surface storage. However, it is believed that the Japanese are now putting a considerable portion of their oil stores underground; consequently, any serious attack on Japanese petroleum must involve the attack of underground storage.

TABLE 4
Weapon Selection—Oil Storage

Target	Type of Attack	Recom. Weapon	Fuzing	Remarks
Surface Storage	Med. or High	100# GP	0.025/0.025	
	Dive	100# GP or larger	0.025/0.025	
	Low	HE Rockets	Inst.	
Underground Storage	Med. or High	500# or larger GP or SAP	0.1/0.1	Bomb to be capable of perforating roof cover. See Table 3.

C. VULNERABILITY OF SURFACE STORAGE TANKS

1. Target Characteristics

Storage tanks are usually grouped in multiple units known as tank "farms". The tank farm is divided into cells by means of earth dykes or concrete walls 3 to 6 feet high. Each cell may contain one or more tanks; the purpose of this segregation is to reduce fire spread. The Germans have further protected their tanks with concrete blast walls, and there is evidence that the Japanese are now beginning to do likewise.

Tanks are usually constructed of steel plate. The most common type is cylindrical, with fixed roof for less volatile liquids or floating roof for highly volatile liquids. From available intelligence, it is concluded that most of the surface bulk oil storage in Japan is in tanks over 70 feet in diameter.

Oil storage tanks are best destroyed by fire which consumes the inflammable contents. A direct hit on a tank can be expected to ignite the contents of the tank. However, most effective destruction will result from an internal explosion which ruptures the side plates and spills the oil as well as igniting it. The burning contents, thus released, are capable of igniting adjacent tanks, particularly when the retaining dykes are broken or absent and tank spacing is less than one diameter, or when oil is being lost from nearby tanks.

2. Weapon Selection

A direct hit or a very near miss is required to rupture the tank side plates and release the inflammable contents. All HE bombs are effective when direct hits are obtained. To rupture the tank shell, the bomb must detonate inside the tank within a certain distance of the side walls. This limiting distance depends upon the thickness of side plates and the charge weight of the bomb. For the common thicknesses of side plates used in storage tanks it can be shown that the smaller HE bombs have larger effective areas per unit weight of bomb. Therefore, the small bombs give greater probabilities of releasing the contents as well as maximum fire bonus. The 100 lb. GP bomb is recommended.

Maximum spillage of oil will result when the tank is ruptured in the lower portion. With 0.025 sec delay fuzing, the 100 lb. GP bomb will detonate approximately 17 feet below the roof of a full tank when dropped from above 25,000 ft. altitude, and about 14 feet when dropped from 10,000 feet. This fuzing is, therefore, recommended.

Bombs which miss tanks destroy fire fighting equipment, produce craters and scatter debris, thus interfering with control of the fires that are started. Use of a small percentage of bombs fuzed long delay is recommended to discourage fire fighting personnel. Where possible, anti disturbance fuzed butterfly bombs should be used for the same purpose.

Although a small number of incendiaries dropped at the end of an attack may start a few additional fires among the pools of inflammable liquid spilled but not ignited, the amount of such gain is not believed sufficient to offset the additional damage that would be caused by the displaced HE bombs. Consequently the use of IB is not recommended.

One direct hit on a tank will rupture the side plates and/or set fire to the contents. Therefore, the effective area for the bomb is the area of the tank and is independent of the size of the bomb. Table 5 gives the required ground densities for a 50% probability of achieving various levels of effective destructions. The bonus resulting from fire spread from damaged to undamaged tanks is not included.

TABLE 5
Range of Ground Densities for Attack of Oil Storage
(Tons of 100# GP bombs per 1,000,000 sq. ft.)

Tank Diameters in Feet	Fraction of Tanks Expected to be Hit F*		
	F = .30	F = .50	F = .70
30	30	55	100
50	10	20	35
70	5	10	18
110	2	4	7
150	1[illegible]	2	4
200	0.7	1.5	2

*The values above are obtained from the formula:

$$D = \frac{115 \times 1{,}000{,}000}{2000} \cdot \frac{1}{M} \log_e \left(\frac{1}{1 - F} \right)$$

where D = required density in tons per million sq. ft. based upon actual weights of bombs, TNT loaded

M = area of tank

When operationally possible, low level attack with HE rockets will be effective. Instantaneous fuzing should be used and rockets should be aimed at the lower portions of tanks.

D. VULNERABILITY OF UNDERGROUND STORAGE

a. *Target Characteristics*

Buried tanks may be of steel or reinforced concrete with column supported concrete roof and earth cover. At Saipan, buried steel tanks, 220 feet in diameter, were found. These had reinforced concrete roofs, two feet thick, supported by steel I beams. Earth cover above the roof was 5 - 6 feet thick.

Recent photo cover indicates rather extensive construction of underground storage units in Japan. One installation, located near the shore, consists of steel tanks surrounded and covered by mud dredged from adjacent areas.

Underground storage is much less vulnerable than surface storage to attack. It can be located from photo cover, but may be difficult to identify during attack. Furthermore, the cover is generally thick enough to require fairly large bombs for perforation. Unless a bomb actually removes a large part of the cover the likelihood of a serious fire is very small since any fire that starts is easy to extinguish and the chance of fire-spread between units is negligible.

2. Weapon Selection

To be effective against underground storage a bomb must be able to perforate the concrete and earth cover (see Table 6 for performances of various bombs), explode inside and either crack floor or walls sufficiently to create seepage or enlarge the entrance hole and start a fire. In neither case can a large effect be expected since seepage will be slow, while any fires will be relatively easy to extinguish.

TABLE 6
Heights of (level) bomb release (in units of 1,000) feet for perforation of earth plus reinforced concrete (3,400 p. s. i.) heights less than 2,500 feet are not recommended because of likelihood of ricohe:

Bomb	100 GP		250 GP			500 GP			1,000 GP			500 SAP					1,000 SAP						
Concrete thickness (ft.) / Thickness earth (ft.)	0	(Lim) 1	0	1	(Lim) 1.5	0	1	(Lim) 1.5	0	1.5	(Lim) 2¼	0	2	3	4	5	0	2	3	4	5	6	7
0	....	5	....	3.5	5	....	3	4.5	....	4	5	....	3.5	8	14	25	....	2.5	5	9	14	22	30
2.5	2.5	10	2.5	6	8.5	2.5	6	8	2.5	5.5	9	2.5	6	12	20	....	2.5	4	7.5	12.5	17.5	30	....
5	5.0	25	2.5	9	14	2.5	8.5	12	2.5	8	13	2.5	8	15	30	....	2.5	5	10	15	30	....	....
7.5	7.5	....	6.5	12	30	4.5	12	16	3.0	11	25	....	....	....	....	....	....	....	....	....	....	....	....
10	....	....	10.5	22	....	7	21	30	5	20	....	4	15	30	....	....	3.0	10	15	30	....	....	....
15	....	....	....	....	....	12.5	....	....	10.5	....	....	7.5	30	....	....	....	5	15	30	....	....	....	....
20	....	....	....	....	....	30	....	....	20	....	....	10.5	....	....	....	....	7.5	30	....	....	....	....	....
25	....	....	....	....	....	....	....	....	....	....	....	20	....	....	....	....	10.5	....	....	....	....	....	....
30	....	....	....	....	....	....	....	....	....	....	....	30	....	....	....	....	17.5	....	....	....	....	....	....
35	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	25.0	....	....	....	....	....	....

NOTE

1,000 AP perforates about 25% more than 1,000 SAP.

1,600 AP perforates about 40% more than 1,000 SAP.

Increasing concrete strength to 5,000 p. s. i. decreases perforation by about 25%.

Decreasing concrete strength to 2,000 p. s. i. increases perforation by about 25%.

Dive bombing (60° or steeper) is equivalent to level release from about 1,500 feet greater altitude.

LIM indicates maximum concrete thickness perforable without break-up.

For earth thickness from 2/3 to 3/2 maximum indicated there is high probability of bomb coming to rest and detonating in contact with concrete slab. Such tamped explosions are almost as effective as when perforation occurs.

MS—P
MAPS & TABLES

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

TABLE II
MILITARY STORES: PETROLEUM
OIL STORAGE FACILITIES EACH OVER 500,000 BBLS.
(thousands of barrels, 42 U. S. gallons)

SECRET

SHEET . . . . MS-P—ST1
DATE. . . . . . . 1 July 1945
PAGE 1

Air Objective Folder and Target Number	Place	Name	Surface	Estimated Storage Capacity		Total	Remarks
				Under-ground	Surface and/or Under-ground		
Southwest Japan 90:29-2132	Yoko Shima	Yoko Shima Storage	880[a]			880[a]	Installation consists of 11—80,000 bbl. camouflaged tanks
90:29-2134	Omi Shima	Omi Shima Oil Storage	660[a]			660[a]	Installation consists of 12—55,000 bbl. tanks, all serviceable
90:30-659	Yeta Shima	Hitonese Oil Storage	520[a]	1,500[a]		2,020[a]	Installation consists of 14—35,000 bbl. and 12—2,500 bbl. serviceable surface tanks; also possible underground storage reservoir approximately 400′ x 700′ and 30′ in depth. Estimate does not include 12 partially dismantled tanks and 4 tanks removed, representing a loss of approximately 530,000 bbls. storage capacity
90:30-2121	Otake	Otake Oil Refinery	800[a]			800[a]	Pre-strike estimate 1,500,000 bbls. storage capacity. As result of air attack, approximately 700,000 bbls. storage capacity destroyed or rendered unserviceable
90:30-2133	Hiro	Hiro Oil Storage	2,905[a]			2,905[a]	About 120 tanks. Mud dredged from harbor is being pumped around tanks in an effort to bury them
90:32-2147	Tokuyama	Tokuyama Buried Oil Storage		2,500[a]		2,500[a]	Installation consists of 10-est. 250,000 bbl. buried tanks
90:36-545	Nagasaki	Kozaki Point Oil Storages	446[a]	60[a]		506[a]	14 serviceable surface tanks, various sizes. 2-est. 35,000 bbl. and 2-est. 10,000 bbl. tanks have been removed. 4 partially underground tanks
90:36-755	Sasebo	Sasebo Oil Storages	123[a]	670[a]		793[a]	Above ground storage capacity consists of 3—35,000 bbl. and 8 smaller tanks. Under ground capacity consists of 4—55,000 bbl. tanks and drum storage area est. 265′ diameter and 25′ high
90:36-1835	Yokose	Yokose Oil Storage	275[a]	2,500[a]		2,775[a]	At least 8 large surface tanks at this location
Total			6,609	7,230		13,839	
Central Japan 90:17-87	Yokohama	Ogura Oil Co. (Yokohama)	1,275[a]			1,275[a]	Only 12 large tanks remain intact. There are 11 tanks partially dismantled or removed, representing a loss of 880,000 bbls. storage capacity. In addition, 7—80,000 bbl. tanks are still under construction
90:17-116	Kawasaki	Mitsubishi Oil Refinery	872[a]			872[a]	About 115 serviceable tanks, various sizes
90:17-127	Kawasaki	Hayama Petroleum Refinery	600[a]			600[a]	About 95 serviceable tanks, various sizes
90:17-128	Kawasaki	Petroleum Center	1,230[a]			1,230[a]	About 100 serviceable tanks including 25 large and medium-size storage tanks. Estimate does not include 4—55,000 bbl. tanks partially dismantled and 20 empty sites, representing an aggregate loss of approximately 1,400,000 bbls. storage capacity
90:17-297	Yokosuka	Azuma Oil Storage	1,305[a]	630[a]		1,935[a]	Installation consists of 44 surface tanks in serviceable condition, and 7 underground tanks. Since 1 November 1944, 9 surface tanks representing approximately 315,000 bbls. storage capacity, have been completely dismantled: of these, 6 were partially dismantled at that time, and 3 were intact
90:17-2037	Koshiba Point	Koshiba Point Oil Storage		975[a]		975[a]	Installation consists of 17 underground tanks. There are excavations for 3 additional tanks
90:17-2038	Kawasaki	Army Oil Storage	550[a]			550[a]	Installation consists of 10—55,000 bbl. tanks. In addition, 11 tanks, partially dismantled, representing a loss of 605,000 bbls. storage capacity
90:20-1684	Yokkaichi	Utsube River Oil Refinery	1,868[a]			1,868[a]	Prior to strike, about 30 large surface tanks, various sizes, in serviceable condition. About 45 process tanks and 5 storage tanks partially dismantled or removed, representing a loss of approximately 455,000 bbls. storage capacity. Refined oil reported piped to underground tanks in Suzuka Mountains about 12 to 15 miles away
90:25-1203	Amagasaki	Nippon Oil Refinery and Tank Farm	1,250[a]			1,250[a]	About 100 serviceable tanks, various sizes
90:25-1764	Shimotsu	Maruzen Oil Refinery			1,200	1,200	Estimate based on pre-war data. At least 15 large storage tanks reported. Large refinery and tank farm owned by Toa Nenryo Sekiyu Co., also reported in or near Shimotsu
Total			8,950	1,605	1,200	11,755	
Northern Honshu 90:5-996	Ominato	Ominato Naval Base and Air Station	800			800	Estimate based on pre-war data
90:6-1066	Akita	Nippon Oil Co. Refinery	600			600	Estimate based on pre-war data
Total			1,400			1,400	
Manchuria 93:5-1	Kanseishi	Manchuria Petroleum Co.	769[a]			769[a]	7 serviceable tanks with floating tops, 415,000 bbls; 47 serviceable tanks with fixed tops, 263,500 bbls; 168 serviceable tanks, by-products and run-downs, 90,500 bbls. Estimate does not include 1 site 85′ diameter, excavation only, and 1 site 140′ diameter, graded and with foundation in place
Korea 84:4-88	Genzan	Chosen Oil Refinery	1,080[a]			1,080[a]	Tank farm area, 12 serviceable tanks, estimated capacity 785,000 bbls. Refinery area, 217 serviceable tanks, estimated capacity 295,000 bbls.
84:7-101	Chinkai	Chinkai Naval Base			650	650	Estimate based on pre-war data. 8 big tanks reported
Total			1,080		650	1,730	
China 83:1-124	Shanghai	Petroleum Center	609[a]			609[a]	Idemitsu Oil Storage, 4 serviceable tanks, 11,500 bbls; Japanese Army Oil Storage, 17 serviceable tanks, 321,000 bbls; Texas Co., 10 serviceable tanks, 248,500 bbls; Asiatic Petroleum Co., 23 serviceable tanks, 28,000 bbls. 23 tanks removed, capacity approximately 278,000 bbls.
83:1-126	Shanghai	Standard-Vacuum Oil Storage	520[a]			520[a]	Installation consists of 18 serviceable surface tanks, various sizes. 1—35,000 bbl. tanks removed. Estimate does not include 3 underground tanks reported in rear of storage area, large kerosene reservoir, and substantial stocks of 50-gallon drums
Total			1,129			1,129	
Total Inner Zone targets over 500,000 bbls.			19,937	8,835	1,850	30,622	

[a]Covered by aerial reconnaissance

(193)

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

TABLE II—(Continued)
MILITARY STORES: PETROLEUM
OIL STORAGE FACILITIES EACH OVER 500,000 BBLS.
(thousands of barrels, 42 U. S. gallons)

Air Objective Folder and Target Number	Place	Name	Surface	Estimated Storage Capacity Under-ground	Estimated Storage Capacity Surface and/or Under-ground	Total	Remarks
90:25-53	Osaka	Osaka Harbor	273[a]			273[a]	7 tanks, various sizes
90:25-258a and b	Osaka	Mitsubishi Oil Storage	100			100	Estimate based on pre-war data
90:25-260	Osaka	Rising Sun Petroleum Oil Storage	68[a]			68[a]	1 tank 90′ diameter; 4 tanks 50′ diameter; 2 smaller tanks
Total			2,001			2,001	
Northern Honshu 90:5-995	Nonai	Nonai Oil Storage	225			225	Rising Sun Oil Co. had 7 storage tanks here in 1941. Tanks reported concealed inside of frame buildings
90:9-1000	Niigata	Nippon Oil Refinery	450[a]			450[a]	About 100 tanks including 2 estimated 55,000 bbl. and 2 estimated 35,000 bbl. storage tanks
90:9-1649	Kashiwazaki	Nippon Oil Refinery	230[a]			230[a]	1—35,000 bbl. tank, 4—10,000 bbl. tanks, 8—6,000 bbl. tanks, and approximately 54 smaller tanks
Total			905			905	
Hokkaido 90:4-980	Hakodate	Fuel Oil Storage Hakodate Harbor	100			100	Estimate based on pre-war data
Manhcuria 93:3-214	Hulutao	Hulutao Oil Storage	165[a]			165[a]	3—55,000 bbl. tanks believed completed December 1944
93:5-6	Port Arthur	Naval Oil Storage	178[a]			178[a]	7 serviceable tanks, various sizes
93:5-197	Dairen	Jijoko Oil Storage Area	403[a]			403[a]	Earlier estimate 590,000 bbls. Downward revision based on more recent photography of better quality
93:5-215	Kanseishi	Kanseishi Oil Storage	50[a]			50[a]	Tank farm consists of 4 dispersed surface tanks with firewalls
Total			796			796	
Korea 84:1-none	Seishin		60			60	Estimate based on pre-war data. Nippon Oil, Royal Shell, Standard, and Texas Companies reported having facilities at this location
84:4-90	Bumpyo	Rising Sun Petroleum Co. Storage	165			165	Estimate based on pre-war data. At least 11 tanks reported
84:7-215	Fusan	Makino Island Rfny. & Oil Storage	117[a]			117[a]	16 serviceable surface tanks. Small oil refinery capacity not estimated
Total			342			342	
China 83:1-none	Chinkiang	Standard Vacuum Oil Co. Storage	120			120	Estimate based on pre-war data. Reported having 7 tanks
83:1-none	Chinkiang	Asiatic Petroleum Co. Storage	60			60	Estimate based on pre-war data. Reported having 6 tanks
83:1-none	Shanghai	Asiatic Petroleum Co. (Upper Wharf) Storage	80[a]			80[a]	3 serviceable tanks, various sizes
83:1-none	Wuhu	Standard Vacuum Oil Co. Storage	85			85	Estimate based on pre-war data. 5 tanks reported at this location
83:1-125	Shanghai	Maruzen Oil Installation	110[a]			110[a]	29 serviceable tanks, various sizes. At least 8 tanks camouflaged by disruptive pattern of paint
83:8-182	Hankow	Hankow Oil Storage Depot	250[a]			250[a]	Installation consists of 26 serviceable tanks, various sizes. 34 tanks partially dismantled or removed, representing a loss of approximately 920,000 bbls. storage capacity
83:11-76	Tsingtao	Oil Storage Area (Tsingtao)	244[a]			244[a]	Of 30 serviceable tanks, 3 with floating tops and 6 horizontal. The following tanks have been removed: 2—50,000 bbl. tanks; 1—24,000 bbl. tank; and 2—7,500 bbl. tanks
83:12-4	Taku	Asiatic Petroleum Co. (Taku)	119[a]			119[a]	5 serviceable tanks, various sizes
83:12-5	Taku	Japanese Oil Storage (Taku)	76[a]			76[a]	7 serviceable tanks, various sizes
83:12-9	Tangku	Standard Vacuum, Ta Hwa, Idemitsu Cos.	65[a]			65[a]	6 serviceable tanks, various sizes
83:12-21	Tientsin	Texas Co. (Tientsin)	157[a]			157[a]	Of 13 tanks, 8 horizontal
Total			1,366			1,336	
Total Inner Zone targets 50,000-500,000 bbls.			9,030	270	183	9,483	
Grand Total			28,967	9,105	2,033	40,105	

[a]Covered by aerial reconnaissance

SECRET

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

SHEET MS-P-ST2
DATE. . . . . . . 1 July 1945
PAGE 1

TABLE III
MILITARY STORES: PETROLEUM
OIL STORAGE FACILITIES EACH FROM 50,000 TO 500,000 BBLS.
(thousands of barrels, 42 U. S. gallons)

Air Objective Folder and Target Number	Place	Name	Surface	Estimated Storage Capacity		Total	Remarks
				Under-ground	Surface and/or Under-ground		
Southwest Japan 90:29-934	Itozaki	Itozaki Oil Storage	175			175	Estimate based on pre-war data. About 10 tanks, various sizes
90:29-2247	Mitsuhama	Mitsuhama Oil Refinery	368[a]			368[a]	About 60 tanks, various sizes
90:30-1907	Nishi Nomi Jima	Kanokawa Oil Storage	330[a]			330[a]	Only 6—55,000 bbl. tanks intact. 12 tanks partially dismantled, and 43 tanks removed, representing an estimated loss of 3,025,000 bbls. storage capacity
90:30-2135	Kurahashi Jima	Kurahashi Jima Oil Storage	330[a]			330[a]	Shows same trend toward dismantling of tanks that is evident in other large storage areas. At present only 6-55,000 bbl. tanks serviceable; 18 tanks partially dismantled and 6 tanks removed, representing an estimated loss of 1,320,000 bbls. storage capacity
90:32-40	Hiko Shima	Asahi Oil Refinery	335[a]			335[a]	32 serviceable tanks
90:32-669	O Shima	Hanano Waki Oil Storage	242[a]			242[a]	17 storage tanks, various sizes
90:32-672	Kudamatsu	Nippon Oil Co. (Kudamatsu)	200[a]			200[a]	25 storage tanks, various sizes. Photos indicate previous estimates excessive
90:32-673	Tokuyama	Tokuyama Naval Fueling Station	385[a]			385[a]	Immediately prior to strike, storage capacity estimated at 1,120,000 bbls. Post-strike cover indicates that all large storage tanks at east end of installation have been destroyed or structurally damaged
90:32-1884	O Shima	O Shima Naval Oil Storage	425[a]			425[a]	As a result of strike, only 5—85,000 bbl. tanks intact. Immediately prior to strike, 19 tanks serviceable, representing 1,615,000 bbls. storage capacity; 28 tanks partially dismantled or removed, representing 2,380,000 bbls. storage capacity
90:32-2148	Kudamatsu	Kudamatsu Tank Farm	385[a]			385[a]	Estimate does not include 3—55,000 bbl. tanks without tops and 6 tanks removed representing a loss of 495,000 bbls. storage capacity
90:34-1123	Wakamatsu	Nissan Liquid Fuel	63[a]			63[a]	Estimate does not include 2—6,000 bbl. tanks under construction and 4 sites approx. 60′ diameter
90:34-2149	Mutsure Shima	Mutsure Shima Tank Farm	128[a]			128[a]	7 storage tanks, all serviceable
90:35-665	Saitozaki	Saitozaki Petroleum Storage			183[a]	183[a]	Above ground storage capacity approx. 180,000 bbls. Estimate does not include 3—25,000 bbl. tank sites
90:36-762	Sasebo	Sasebo Fuel and Munitions Depot		270[a]		270[a]	Estimate includes 2—80,000 bbl. tanks, 1—55,000 bbl. tank, and 1 underground reservoir. All sites clearly visible from air
90:36-832	Nagasaki	Megami Point Oil Storages	71[a]			71[a]	Probably 3 serviceable tanks
90:36-2239	Nagasaki	Doinokubi Oil Storage	83[a]			83[a]	Installation consists of 4 serviceable tanks, various sizes
Total			3,520	270	183	3,973	
Central Japan 90:17-94	Kawasaki	Matsukata Oil Storage	452[a]			452[a]	22 tanks, various sizes. Estimate does not include 2—25,000 bbl. tank sites
90:17-130	Kawasaki	Assaishi Petroleum Co.	58[a]			58[a]	6 serviceable storage tanks. Refinery facilities have been removed
90:17-2151	Tokyo	Joto Oil Refinery of Asahi Sekiyu Co.	100[a]			100[a]	Prior to incendiary attack, 19 serviceable tanks, estimated capacity 135,000 bbls. At least one large tank destroyed
90:18-2150	Shimizu	Shimizu Oil Refinery	167[a]			167[a]	2—55,000 bbl. tanks; 2—15,000 bbl. tanks; 24 smaller tanks
90:20-none	Taketoyo	Taketoyo Tank Farm	200			200	Rising Sun Oil Co. had storage facilities here before the war. Reported Air Force fuel depot at this location
90:20-1685	Yokkaichi	Mitaki River Oil Refinery	243[a]			243[a]	46 tanks, various sizes
90:20-2152	Nagoya	Nagoya Breakwater Tank Farm	122[a]			122[a]	Estimate does not include 3 tank sites: 1—115′ diameter, 1—95′ diameter, 1—30′ diameter, representing a loss of approx. 90,000 bbls. storage capacity
90:22-2220	Maizuru	Oba Oil Storage Depot	88[a]			88[a]	1—55,000 bbl. tank; 4—6,000 bbl. tank; 18 smaller tanks. Estimate does not include 4—55,000 bbl. tanks partially dismantled and 11 tanks removed, representing a loss of 825,000 bbls. storage capacity
90:25-17	Kobe	Rising Sun Petroleum Oil Storage	130[a]			130[a]	7 serviceable tanks. Camouflage netting on at least 5 tanks

---

[a] Covered by aerial reconnaissance.

(193)

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

BASIC SERVICES AND UTILITIES

File No. 18,000

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

RRT
25 JUNE 1945

BASIC SERVICES AND UTILITIES

ROAD AND RAIL TRANSPORTATION

SECRET
By Authority of
The Commanding General
Army Air Forces
25 JUNE 1945
(Date) **(Initials)**

(193)

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

File No. **19,011**

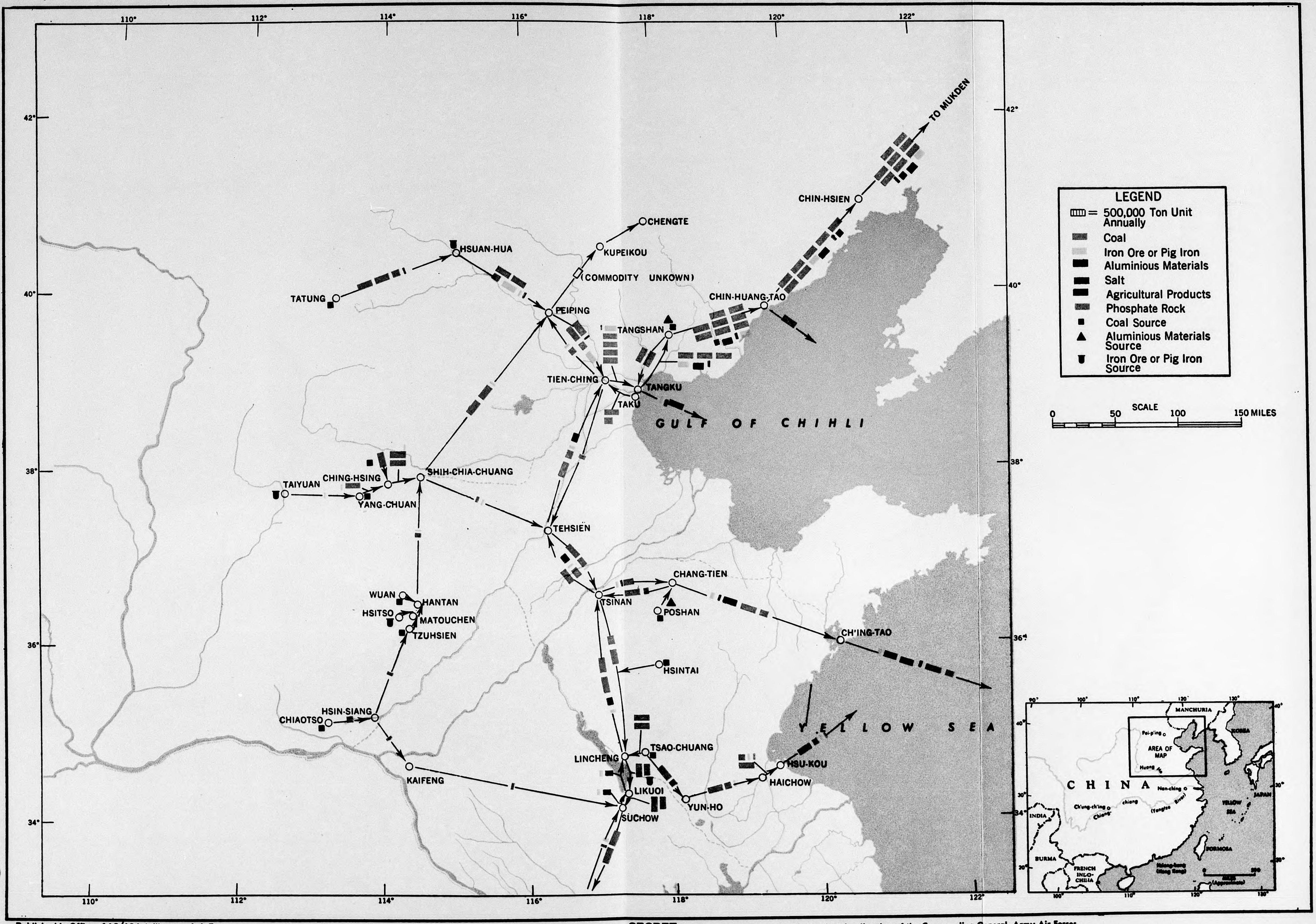
BSU–RRT
MAPS & TABLES

SECRET

**JOINT
TARGET
GROUP
WASHINGTON, D. C.**

APPROXIMATE NORTH CHINA FREIGHT FLOW SIGNIFICANT TO JAPAN

SHEET..................BSU-RRT—M1
DATE...................21 April 1945



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.

SECRET

Prepared at the direction of the Commanding General, Army Air Forces,
Aeronautical Chart Service, by the U. S. Coast and Geodetic Survey,
Washington, D. C. for AC/AS Intelligence. April 1945.

File No. 19,911

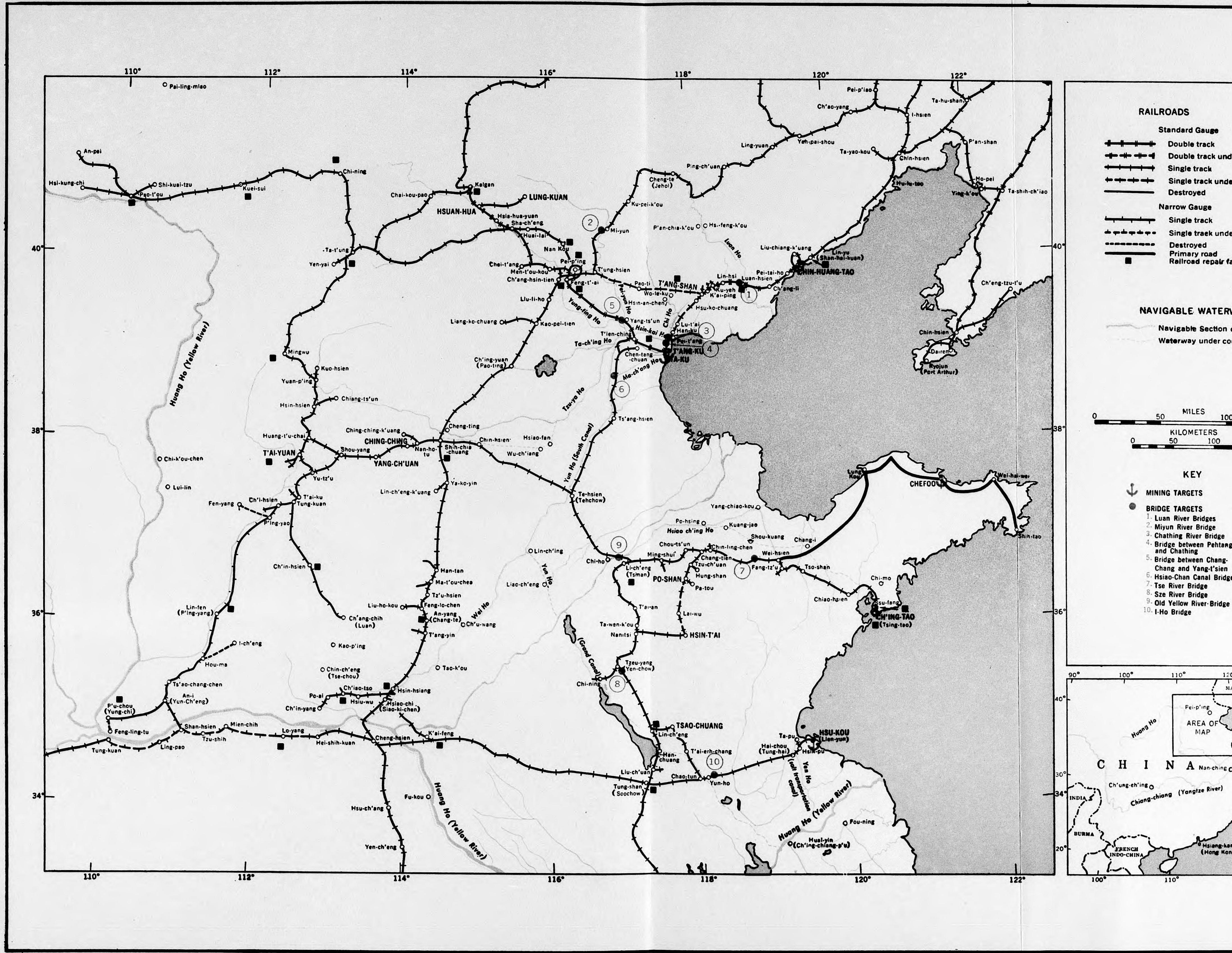
JOINT TARGET GROUP
WASHINGTON, D. C.

TARGET MAP SHOWING RAILROADS AND PRINCIPAL PORTS OF NORTH CHINA

SECRET

SHEET.................BSU-RRT—M2

DATE................21 April 1945



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.

SECRET

Prepared at the direction of the Commanding General, Army Air Forces,
Aeronautical Chart Service, by the U. S. Coast and Geodetic Survey,
Washington, D. C. for AC/AS Intelligence. April 1945.

File No. 19,913 [redacted]

BSU
SHIPPING

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

S
18 JUNE 1945

BASIC SERVICES AND UTILITIES

SHIPPING

SECRET
By Authority of
The Commanding General
Army Air Forces
18 JUNE 1945
(Date) (Initials)

(236)
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

File No. 21,011

IV. PHYSICAL VULNERABILITY AND WEAPON RECOMMENDATIONS

A. SHIPS

The following table gives weapon recommendations for attacking various types of ships.

TABLE I

Weapons Recommended for Attack of Merchant Ships[1]

Altitude of Attack	Preferred Weapon	Fuze	Alternate Weapon	Fuze
Large Naval Auxiliaries, Ocean Liners, Large Tankers and Merchant Ships—8000 Tons and Larger				
Masthead...........	100 GP	None /4–5	500 GP	None /4–5
Low................	1000 GP[2]	0.1 / .1	500 GP	0.1 / .1
Dive or Glide........	1000 GP	0.1 /0.025	500 GP	0.1 /0.025
Medium.............	1000 GP	0.1 /0.025	500 GP	0.1 /0.025
High...............	1000 GP	0.1 /0.025	500 GP	0.1 /0.025
Moderate-sized Naval Auxiliaries, Merchant Ships and Tankers—4000 to 8000 tons				
Masthead...........	1000 GP	None /4–5	500 GP	None /4–5
Low................	1000 GP	0.1 /0.025	500 GP	0.1 /0.025
Dive or Glide........	1000 GP	0.1 /0.025	500 GP	0.1 /0.025
Medium.............	1000 GP	0.1 /0 025	500 GP	0.1 /0.025
High...............	1000 GP	0.1 /0.025	500 GP	0.1 /0.025
Small Merchant Ships, Tankers, Large Self-Propelled Barges and Similar Craft—1000 to 4000 tons				
Masthead...........	500 GP	None /4–5	250 GP	None /4–5
Low................	500 GP	0.1 /0.01	250 GP	0.1 /0.01
Dive or Glide........	500 GP	0.1 /0.01	250 GP	0.1 /0.01
Medium.............	500 GP	0.1 /0.01	250 GP	0.1 /0.01
High...............	500 GP	0.1 /0.01	250 GP	0.1 /0.01
Small Craft—Under 1000 Tons (E-Boats, Fishing Boats, Barges, Sampans, ICT's, etc.)				
Masthead...........	100 GP	None /4–5	250 GP	None /4–5
Low................	100 GP	0.1 /ND	250 GP	0.1 /ND
Dive or Glide........	100 GP	0.1 /ND	250 GP	0.1 /ND
Medium.............	100 GP	0.1 /ND	250 GP	0.1 /ND
High...............	100 GP	0.1 /ND	250 GP	0.1 /ND

[1] Taken from "Selection of Bombs and Fuzes for Destruction of Various Targets" (War Dept. Field Manual FMI-110 and Navy Dept. FTP 224, dated 9 April 1945)

[2] Above 7000 feet use .025 sec. delay tail fuze.

B. PORTS AND PORT FACILITIES

1. Physical Characteristics

Port facilities fall into four main categories as follows:

(1) Facilities necessary to create and maintain a sheltered area.
  (a) Breakwaters
  (b) Harbor locks and gates
  (c) Dredges
(2) Facilities necessary for loading and unloading cargo.
  (a) Lighters and tugs
  (b) Shallow water quayage
  (c) Deep water piers and wharves
  (d) Cranes
(3) Storage facilities.
  (a) Warehouses
  (b) Open storage areas
(4) Transportation facilities.
  (a) Railroad yards and spurs
  (b) Access roads.

C. Facilities that create a port (breakwaters, harbor locks and gates) are relatively invulnerable, especially to high altitude bombardment, either because of their construction or because of their small size. Dredges, vital to the maintenance of a port, compare with small merchant ships in size and vulnerability. Of the facilities for loading and unloading cargo, cranes and specialized loading and unloading equipment are particularly vital. Cranes and coal loading gantries or fixed conveyors present a very difficult target because of their small area and considerable strength. Heavy damage to such equipment could usually be expected to result from direct hits with 500 GP or larger bombs and this will be difficult to repair. Loss of coal handling equipment will very seriously reduce port cargo handling capacity. Conveyors and elevated or depressed railroad structures associated with the coal loaders are more vulnerable and present a considerably larger area ranging from 650 to 1000 feet in length by 40 to 150 feet in width, but are easier to repair. Effective attack would depend on securing multiple hits.

For a discussion of the attack of storage facilities reference should be made to General Analysis, *Military Stores* and to Weapons Memorandum, *Typical Military Targets,* Part IV (M-12).

A discussion of the vulnerability of rail transportation facilities is given in *Road and Rail Transport.*

2. Weapon Recommendations and Weight of Attack

Since no individual portion of a typical target appears to be particularly vulnerable to attack, the most effective bomb and fuzing should be chosen for producing overall damage. For this purpose the recommended weapon is the 500 GP fuzed 0.01/0.01, which will be effective against cranes, most types of ships, and other special equipment. A high level attack directed specifically against cranes and coal handling equipment would require heavy tonnages for a high probability of destruction; but if higher precision attacks with dive bombers or RAZON are possible, this equipment would be a desirable primary objective.

If there is enough combustible material present either in the form of structures or stores, incendiaries should be used with the HE. The preferred IB and the density required will depend on the amount, resistance, and distribution of the combustible portions of the target and on the level of damage desired. Reference should be made to JTG M-8.

The sinking of ships at piers, wharves and quays is likely to add significantly to general dislocation and delay. Denial of facilities adjacent to the sunken ships will result, especially where specialized loading and unloading equipment is used.

Experience in the ETO shows that recovery from attacks producing general damage in ports is fairly rapid (usually a few hours to a few days). It is therefore necessary that repeated attacks be made on port facilities to insure a lasting effect. Repeated attacks should be more effective than occasional very heavy attacks.

Annual bulk cargo carrying capacity on this basis would be as follows:

192,000 g. r. t. — 15% for layups =
163,200 g. r. t. × 1.25 × 15 = 3.06 million metric tons per year.

(b) Vessels 250–20 g. r. t.—(i) *Tonnage available for cargo carriage.*—Full powered vessels in this size range totalled 288,000 g. r. t. on 20 January 1945 and auxiliaries 582,000. Of these tonnages, 163,000 and 232,000 respectively were in units of 100 g. r. t. or more.

Of the full powered craft, at least 25,656 g. r. t. fell into one of the specialized classes mentioned above in paragraph *(a)* (i).

About 50,000 g. r. t. or half of the total shipping in the 100–500 g. r. t. class shown by Op 16 FE as allocated to army and navy use, has been allowed for the 100–250 g. r. t. block. No data is available for the 20–100 g. r. t. block other than that hundreds of such craft have been requisitioned. If the same ratio between total tonnage in the size range and military and naval requisitions is applicable, a deduction of 38,000 g. r. t. follows.

On this basis full powered tonnage in the 250–20 g. r. t. range is not likely to exceed 175,000 g. r. t.

The deductions applicable to full powered craft do not, with the exception of fishing craft, apply to auxiliaries.

Vessels in the 250–100 g. r. t. block have been identified as fishing type craft to the extent of at least 25,686 g. r. t. The data available do not allocate these between full powered and auxiliary units and there is no indication that auxiliaries are included.

There are no data on the percentage of the tonnage in the 100–20 g. r. t. range constituted by fishing vessels. Comments made above as to the improbability of large scale diversion of fishing craft in the 1,000–250 g. r. t. class to cargo carriage apply with equal force to vessels in the 250–20 g. r. t. range.

The tonnage of 250–20 ton vessels definitely identified as fishing craft is only a small portion of the total fishing tonnage in this size range. The residual of 730,000 g. r. t., calculated by the use of these figures, therefore, merely represents the known top limit on the number of vessels of this size available for economic traffic. While, as noted, data from which a precise determination of the true figure could be made is lacking, it would be reasonable, judging from the size and importance of the fishing industry in Japan generally and the fact that two-thirds of the fish catch is made in local waters by smaller craft, to reduce this residual by 50 to 60 percent in appraising enemy capabilities.

(ii) *Cargo carrying capacity of the tonnage available.*—Sampling of gross-net tonnage ratios in the 2,000–3,000 ton size range and the 250–100 ton range indicates that the gross tonnage to deadweight tonnage ratios should not be very different for the two sizes so far as full-powered vessels are concerned.[5] A ratio of 1 to 1.25 is therefore believed to be conservative.

Auxiliary-powered vessels, of course, have a net tonnage which more closely approaches gross tonnage than that of full-powered vessels.[6] A gross to deadweight ratio of 1–1.6 has been taken as a fair basis for figuring bulk cargo capacity.

Speed of full-powered vessels in the 250–20 g. r. t. size range has been taken as 7 knots which is a downward adjustment of the 8-knot average for vessels in this class in use by the Army. Data is lacking on speeds of Japanese auxiliary-powered vessels. A speed of 3 knots seems a reasonable assumption.

The 250–20 g. r. t. class of vessels if used for cargo carrying would be employed in coastal waters and for choice predominantly in the sheltered waters of the Inland Sea. Prisoner of war and other reports indicate that vessels of about 200 g. r. t. were being used in the Inland Sea coal trade in 1941-43. Use of vessels in the 250–100-ton range on coastal runs,[7] in trade between Hakodate and Aomori and even in carrying coal and iron between the mainland and Japan[8] have also been received. Insofar as the enemy attempts to maintain traffic with the mainland by use of craft in the 250–20 g. r. t. class, he is likely to route the vessels between south Korean ports and the Shimonoseki Straits area so as to shorten the run as much as possible.

On these assumptions, annual bulk cargo movement per 10,000 g. r. t. of vessels available has been calculated for three runs which should be typical of those attempted by craft of this size range, i. e., Muroran-Shiogama, Shimonoseki-Kobe and the Tsushima Strait run.

These routes involve round trip distances of 600 (nautical) miles, 480 miles, and 250 miles, respectively.

On the Muroran-Shiogama run, there will be an average of 290 days a year with seas no more than 9 feet high[9] and this has been taken as a fair figure for the number of operational days per year to be expected for the full-powered vessels in question. For auxiliaries this figure has been further reduced by 40 days.

On the Inland Sea weather conditions are unlikely to be a serious problem except in the severest weather. Hiroshima averages only 2 days a year with winds of over 35[10] m.p.h. and Kobe but 5.[10] At Shimonoseki, the average is 31[10] and since this is one vital terminal for the traffic under discussion, conditions at this point have been taken as controlling; 330 operational days annually have accordingly been allowed for this run.

Traffic across Tsushima Strait must contend with prevailing winds from northerly quarters during the winter season. There are, however, an average of 275 days a year when seas in the Strait are no more than moderate[11] and on which operations should be possible for full-powered vessels. For auxiliaries, a further adjustment of 40 days has been made.

On the basis stated above, the annual bulk cargo

---

[5] The sampling has been only partial and is not claimed to be statistically conclusive. This is occasion for further research on this point.

[6] Since their propelling machinery, being smaller in relation to the size of vessel, takes up less of the total volume of the vessel.

[7] A POW report (14J-957-NA) states that early in 1944, 80 250 g. r. t. wooden ships were carrying coal from Muroran to Shiogama. Reports of expansion of rail connections to Shiogama broadcast in the fall of 1944 tie in with this.

[8] ONI 49, Change 16, p. 35.

[9] Janis 81, Ch. III, p. 7.

[10] Janis 84 Ch. V, p. 45.

[11] Janis 84, Ch. III.

VI. — POTENTIAL OF VESSELS UNDER 1,000 G. R. T.

1. General

Statistics generally quoted as to the Japanese shipping position deal with vessels over 1,000 g. r. t. Until recently these have furnished adequate data for an appraisal of the relationship between shipping and Japan's war potential. As the total tonnage of vessels of over 1,000 g. r. t. has dwindled under the impact of naval and air attack, and as Japan has been stripped of its overseas conquests at an ever accelerating rate and thrown back more and more on its own resources and those of the nearby Asiatic mainland, the question of the extent to which the enemy can meet his needs for marine transport with vessels under 1,000 g. r. t. has, however, become of much increased significance. This significance is greatly augmented on the one hand by the shortness of the voyages now involved in maintaining economic traffic (which reduces the need for the advantages of speed and sea-keeping qualities inherent in the larger vessels) and on the other by the possibility of mining atack in Japanese waters on all engine driven vessels over 250 g. r. t.

This appendix does not claim to be a definite study of small shipping potential. It does indicate that, on the face of the rather inadequate intelligence which is now at hand, the 1.6 million tons of vessels between 1,000 and 20 g. r. t. plus a substantial tonnage of barges do have the potentiality if fully employed and not attacked, of considerably alleviating the effects of mine blockade and sinkings of larger craft. Further collection and analysis of evidence on the question is indicated. The more important factors are discussed below.

2. Engine Driven Vessels

Engine-driven vessels have been considered in two categories, those from 1,000 to 250 tons, which can be attacked by present types of ground mines, and craft under 250 tons which generally cannot be so attacked.[1]

(a) 1,000–250 g. r. t.—(i) *Tonnage available for cargo carriage.*—As of 20 January 1945 there were afloat vessels totalling 380,000 g. r. t. in this size range.[2]

Of this tonnage 50,766 tons are identified as specialized vessels, dredges, car ferries, whale killers salvage, picket and rescue boats, "honey" barges and so forth which would have to be excluded as potential cargo carriers.

At least another 21,538 tons is made up of fishing vessels. These could carry bulk cargo if necessary though their comparatively small hatches would lead to slow loading and unloading. Since, however, these vessels if not taken over by the army or navy are contributing to the already straitened food supply, their diversion would increase the deficit to be made up by imports. In theory, they could probably bring in more calories and even more proteins if employed in hauling soy beans from Manchuria than in fishing, but it is likely that any substantial shift of this tonnage to cargo carrying would be made only under conditions of the most extreme pressure.

A portion of the balance of 307,696 g. r. t. undeterminable but probably not in excess of 115,000 tons is allocated to Army and Navy use.[3]

These exclusions from the 380,000 ton total leave around 192,000 g. r. t. available for cargo carriage.

(ii) *Cargo carrying capacity of tonnage available.*—Only an approximation of the magnitude of the weight of cargo ships in the 1,000–250 class available for economic traffic might carry is possible. Among the variables which affect any such calculation are, distance to be run, speed of vessel under various conditions of wind, sea, and current, cleanness of the ship's bottom and degree of maintenance of her engines, turn-around time in port (which will be affected by port congestion, availability of dock labor, bunkering efficiency, and so forth), convoy practice if on a convoyed run, ratio between gross and deadweight tonnage of individual ships, and nature of the cargo carried.

Without having attempted a lengthy statistical analysis, inspection of tabulated characteristics of gross and net tonnages and discussion with officers of the United States Maritime Commission indicates that the gross to deadweight tonnage ratio is only slightly lower in the 1,000–250 g. r. t. class than in the medium cargo vessels. A ratio of 1 to 1.3–1.5 (depending on the nature of the cargo) is generally accepted for the latter. Accordingly a ratio of 1 to 1.25 has here been taken for the smaller vessels.

Speeds in this class are, of course, more likely to be affected by adverse weather. For this reason and because the Army is likely to have requisitioned the better vessels, the average cruising speed of 9 knots shown by Op 16 FE for army transports of this size is probably too high for this port of the merchant fleet generally. Eight knots is a more likely figure.

Japan and Yellow Sea mainland ports are within 500 nautical miles of either the northern or southern open ports in Japan. Transit time at 8 knots on a 1,000-mile round voyage will run to almost exactly 5 days. Allowing a week in port at each end would result in a total turn-around time of 19 days. Weather conditions should not interdict operations for more than 65 days per year. Given 300 operational days per year, 15 round trips annually could be made.[4]

---

[1] According to Office of Chief of Naval Operations, Mine Warfare Sections.

[2] Unless otherwise noted, tonnage afloat figures in this Annex are taken from a report dated 22 January 1945 on distribution of small ships in the Japanese merchant marine supplied by Op 16 FE, CNO.

[3] This allocation is not hard and fast but fluctuates with military and naval requirements. As far as areas other than the mainland are concerned the former have recently declined drastically. As far as mainland needs are required military and economic cargo needs are complementary since the movements are in opposite directions.

[4] Japanese Staff Logistics Manual gives the same figure.

carrying capacity of full-powered and auxiliary vessels on the stated runs would be about as follows:

Shiagama-Muroran:

Full-powered Craft:

Transit time = 600 (n. mi.) ÷ 7 (knots) = 85.7 hrs. = 3.5 days.

Time in port—3 days at Muroran (coal loading time would be virtually negligible since mechanical loaders can handle 500 tons per hour), 5.5 days at Shiogama (there is a bridge-crane for the unloading of coal at this port).[12]

Total turn-around time = 3.5 + 3 + 5.5 = 12 days.

Round trips per year = 290 (operational days) ÷ 12 + 24.

Annual bulk cargo movement per 10,000 g. r. t. = 24 (round trips) × 10,000 (g. r. t.) × 1.25 (gross to deadweight tons) = 300,000 tons.

Auxiliaries:

Transit time = 600 (n. mi.) ÷ 3 (knots) = 200 hours = 8.3 days.

Time in port—(as above) = 8.5 days.

Turn-around time = 8.3 + 8.5 = (rounded) 17 days.

Round trips per year = 250 (operational days) ÷ 17 (days per round trip) = 14.7.

Annual bulk cargo movement per 10,000 g. r. t. = 14.7 (round trips) × 10,000 (g. r. t.) × 1.6 (gross to deadweight tons) = 233,600 tons.

As noted, it is reported that in early 1944, the Japanese had allocated eighty 250 gross ton standardized wooden vessels to haulage of coal between Muroran and Shiogama. 80 × 250 = 20,000 g. r. t. On the above basis this amount of vessels could deliver 600,000 tons of coal to Shiogama annually.

Inland Sea:

Full-powered Craft:

Transit time—480 (n. mi.) ÷ 7 = 68 hours = (rounded) 3 days.

Time in port = Other than coal = 14 days Coal—3 at Wakamatsu[13] + 6 for unloading = 9 days.

Turnaround time, 12-17 days.

Round trips per year = 330 (operational days) ÷ 12-7 (days) = 27 to 19.

Annual bulk cargo movement per 10,000 g. r. t. = 19-27 (round trips) × 10,000 g. r. t. × 1.25 (gross to deadweight tons) = 237,500 to 337,500 tons.

Auxiliaries:

Transit time = 480 ÷ 3 knots = 160 hours = (rounded upwards) 7 days.

Port time (varied as above) 9 to 14 days.

Turn-around time, 16 to 21 days.

Round trips per year = 300 (330—30 days) ÷ 14—21 = 14 to 18.75.

Annual bulk cargo movement per 10,000 g. r. t. = 14—18.75 (g. r. t.) × 10,000 (g. r. t.) × 1.6 (gross to deadweight tons) = 224,000 to 300,000 tons.

Tsushima Straits:

Full-powered Craft:

Transit time = 250 (n. mi.) ÷ 5 (knots) = 50 hours = (rounded), 2 days.

Time in port, 14 days.

Turnaround time, 16 days.

Round trips per year = 275 (operational days) ÷ 16 (days) = 18.

Annual bulk cargo movement per 10,000 g. r. t. = 18 (r. t.) × 1.25 = 225,000 tons.

Auxiliaries:

Transit time = 250 (n. mi.) ÷ 3 (knots) = 83 hours = (rounded), 3.5 days.

Time in port, 14 days.

Turnaround time (rounded upward), 18 days.

Round trips per year = 235 (operational days) (275—40) ÷ 18 = 13.

Annual bulk cargo movement per 10,000 g. r. t. = 13 (r. t.) × 10,000 × 1.6 = 200,800 tons.

3. Sailing Vessels

(a) *Tonnage available.* — Information concerning Japanese sailing vessels is, as might be expected, scanty. The Japan Times Yearbook for 1943[14] puts the total tonnage of this type of vessel in 1940 at 1,112,254 g. r. t. The data on engine-driven vessels in the same publication appears to be somewhat of an understatement of the actual tonnage. And the sailing vessel figure corresponds closely with that in ONI 49, Change 16, prior to the revision on 20 January 1945. That revision, however, gives the following round figures for three size ranges:

Over 100 g. r. t.	100,000
20—100 g. r. t.	300,000
5—19 g. r. t.	60,000

ONI estimates that about 75 percent of the sailing tonnage is composed of fishing craft. The latter almost certainly fall at the low end of the size range. If this allowance is correct, around 115,000 to 278,000 g. r. t. are avaiable for cargo haulage in coastal waters.

(b) Cargo carrying capacity. — Sailing vessels are best adapted, so far as Japan is concerned, to the movement of bulk cargo in the Inland Sea and the appraisal in this Annex of their capabilities is based on their being so used.

Estimate of speeds to be expected must be based mainly upon judgment since data on actual experience in these waters is not at hand. Study of weather data for the Inland Sea indicates that moderate and fairly continuous winds persist through most of the year (average wind velocities at Shimonoseki, Hiroshima and Kobe are as follows, 8, 4.3, and 5.6 knots). There are calms at Hiroshima on an average of only 7 days per year. The data for winds over 35 m.p.h. has already been cited. The winds predominantly have a northerly or southerly component in this area which favor sailing passages in an east-west direction. An overall passage speed of 1.25 knots has been allowed so as to cover delays while waiting for tides or adverse winds.

Since sailing vessel cargo space is not reduced by propulsion machinery, the gross to deadweight tonnage ratio is estimated to be not less than 1 to 2.

Annual cargo capacity for the Inland Sea run for the estimated tonnages available would therefore be about as follows:

Transit time = 480 (n. mi.) ÷ 1.25 (knots) = 384 hours ÷ 24 (hours) = 16 days.

Time in port = 14 days.

Turn-around time = 30 days.

Round trips per year = 300 (operational days) ÷ 30 (days per r. t.) = 10.

Annual bulk cargo movement:

115,000 g. r. t. = 10 × 115,000 × 2 = 2.3 million tons.
278,000 g. r. t. = 10 × 278,000 × 2 = 5.56 million tons.
10,000 g. r. t. = 10 × 10,000 × 2 = 200,000 tons.

4. Barges

(a) Tonnage available.—There are no statistics on the subject. Persons familiar with Inland Sea shipping before and during the war report that there was a very substantial movement of bulk cargo, including coal, by barge. Barges ranged up to 500 tons in size and tows contained up to six units.

There are at least 22,000 g. r. t. of tugs in Japan.

(b) Cargo carrying capacity.—Speed in this category is also problematical. Office of Defense Transportation,[15] on the basis of long experience with coal tows on inland waters, including a difficult canal pas-

[12] Janis 85, Ch. VI.

[13] Which has large mechanical coal loading facilities.

[14] Domei Jiji Nankan (Tokyo 1943), p. 284-288.

sage, between New York and Boston (a distance closely comparable to that between Shimonoseki and Kobe) has estimated turnaround time with crane unloading at around 21 days.[16] Though American tugs are more powerful than Japanese, American barges are several times as large. Moreover, delays occur on the New York-Boston run owing to difficulty in getting into and out of the Cape Cod canal in weather which would permit continued passage in less confined waters. The navigational hazards in the Inland Sea appear to be less.

A gross to deadweight tonnage ratio of 1 to 2 is stated to be conservative for barges.

Annual bulk cargo capacity per 10,000 g. r. t. would on the above basis be as follows:

Round trips per year = 300 (operational days) ÷ 21 (days per round voyage) = (rounded) 14.
Annual capacity per 10,000 g. r. t. × 14 × 10,000 × 2 = 280,000.

5. Summary and Conclusion

The following table indicates in millions of metric tons possible annual Inland Sea bulk cargo movement by vessels in the 250–20 g. r. t. range in the various categories assuming the above calculations are valid approximations of capabilities.

G. R. T. allocation	Full-powered	Auxiliary	Sail	Barge
100,000..............	[1] 2.43	[1] 2.25	2	2.8
200,000..............	[2] 4.86	4.50	4	5.6
300,000..............	[2] 7.29	[2] 6.75	[2] 6	[1] 8.4
400,000..............	[2] 9.72	[2] 9.00	[2] 8	[1] 11.2

[1] Calculated on a minimum basis.

[2] These tonnages would be applicable in the indicated class only if there was very substantial building or fishing conversions.

The above figures as to capacities of various types of vessels of less than 1,000 g. r. t. are not to be taken as an indication of net additional marine transport capacity which is now idle and which could be called into play in case cargo movement in larger vessels were interdicted. It is probable that most small tonnage which can carry cargo has already been pressed into service. Photographs of Korean and Japanese ports indicate considerable activity on the part of such craft as standardized wooden coasters.

The pattern of economic traffic carried in small vessels is only partially known. Bulk cargo such as coal, iron ore, and beans is undoubtedly a major component but the extent to which low priority traffic which could be dispersed with in an emergency is unknown.

Certain points do emerge clearly. If the Japanese are able to allocate 200,000 g. r. t. of vessels in the 250-class to the Kyushu-Honshu coal trade, they should be able to move at least 4 to 5.6 million tons of coal annually to Honshu. This would be sufficient if combined with rail tunnel and car ferry capacity (Annex B), to move all coal available for export from Kyushu to Honshu.

If this allocation could be increased to around 400,000 tons, the load on rail facilities could be very substantially decreased but complete substitution for the railroad would require 175,000 g. r. t. of full-powered craft, 200,000 g. r. t. each of auxiliary and sailing craft and 100,000 g. r. t. of barges. It is doubtful if the Kyushu ports could handle the more than 4,500 vessels which would be involved and they certainly could not without creating a congestion which would not only greatly increase turn-around time but offer vulnerable bombing targets.

---

[15] Charles Kellers—Regional Director—Water Division, ODT, New York City.

[16] Since the above was written intelligence has come to hand indicating that the towage turnaround time between Kanda and Kobe was 21 days until the completion in 1944 of mechanical coal loading facilities at Kanda which reduced the turnaround to 15 days.

BSU–S
MAPS & TABLES

BSU
ELECTRIC POWER

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

EP
28 JUNE 1945

BASIC SERVICES AND UTILITIES

ELECTRIC POWER

SECRET
By Authority of
The Commanding General
Army Air Forces
28 June 1945
(Date) (Initials)

(193)

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

File No. 23,011

I. CURRENT STATUS AND DEVELOPMENTS

A. PRESENT POSITION

Allied attacks during the first half of 1945 against Japan's shipping industry, and cities has had the effect of reducing materially the requirements for electric power of the reduction in industrial activity.

On the supply side, Japan's electric power generating and distribution lines in major city, has been relatively untouched by air attacks to date. The probable intensification of coal shortages in the same period, however, has undoubtedly reduced further the utilization of steam generating capacity.

In summary, Japan's supply of power still remains adequate to satisfy current requirements except in isolated instances where disruption of local power lines has probably precluded temporarily the distribution of available power within certain urban zones. Such cities as Tokyo, Osaka, Nagoya, and Kobe may well have available considerably more electric power than can be distributed and consumed locally at present.

B. CURRENT PRINCIPAL TARGETS

Joint Target Group is currently engaged in preparing detailed programs of attack whereby power supply available to major industrial areas of Japan might be reduced by as much as 75 percent. The general method would involve:

a. Interdiction of power flow into major industrial centers from outlying hydro plants by destroying key high voltage transformer and switching stations on each major transmission line feeding into the industrial area, thereby eliminating the necessity of attacking a much larger number of hydro plants; and

b. Destroying all significant steam power plants within the area of interdiction.

The preliminary research suggests that something on the order of 90 major transformer and switching stations plus 30-40 steam plants would reduce by 75 percent the power supply for the entire area including all Honshu south of Nugata and Sendai. Details will be provided in forthcoming JTG studies.

II. RELATION TO MILITARY STRENGTH

A. INDUSTRIAL POWER USES

The dependence of industry upon electricity is relatively greater in Japan than in most other countries. Well over 90 percent of Japan's industrial machinery is electrically driven. Her electrolytic and electrothermal processes are highly developed, causing a heavy portion of all power to be consumed by the basic materials industries. Closely associated with industrial activity are the extensive uses of electricity for urban and interurban transportation, and for lighting almost every commercial establishment and private residence.

Electric power is intimately related to the production of almost every military product. Tremendous amounts of power are required, for example, for making the aluminum that enters into combat aircraft, for processing steel going into aeroengines, and for driving the machinery which fabricates these materials into finished aircraft. Government arsenals are substantial users of electric energy for production of arms and munitions, and shipyards likewise use considerable power in the production, repair, and servicing of naval and merchant vessels. A large fraction of war plant workers get to work on electrically operated railways. Electric lighting permits round-the-clock operation of war plants.

B. POWER REQUIREMENTS

The evidence available does not permit accurate estimates of power consumed by each type of industrial or other use. To show the general magnitudes involved, however, Joint Target Group has built up the set of power consumption estimates presented in Table I. These should be regarded as extremely rough. A total of 47 billion kilowatt-hours of energy consumed during 1944 within the entire Inner Zone is accounted for.

Several significant conclusions may be drawn from Table I. First, it is evident that, under present war conditions, the basic materials industries as a group account for a large share of total energy consumed, reflecting the larger use of power per unit of output in these industries than in the fabricating industries. The metal, chemical, and coal mining industries together represent one-half of total power consumption accounted for. The medium and lighter industries (machining group and the consumer and miscellaneous industries group), on the other hand, account for only one-third of the total.

Second, although a few broad industry groups represent a large share of total consumption, no single industry accounts for more than a relatively small fraction of the total. The largest single consumer is aluminum which, together with alumina, uses about 16 percent of the total accounted for. Coal mining, chemical nitrogen, ordnance, and calcium carbide follow, with totals ranging from less than 4 percent to over 8 percent.

In summary, electric power is a vital ingredient of every important industry, but no one industry accounts for a large portion of total consumption. Any large reduction in power supply would be felt most severely in the basic raw material industries.

C. POWER SUPPLY

Intelligence reports over the past few years have contained numerous references to power shortages in Japan which call for interpretation.

First it must be recognized that "shortage" is a relative matter. Any well balanced war economy is filled with shortages of every variety. This merely reflects the fact that all productive resources have been put to work, and more could be used if they were available. A shortage assumes serious proportions only when a particular item becomes so scarce, relative to other productive resources with which it is normally used, that it prevents the full use or expansion of these others and thus, by itself, becomes a major limiting factor on overall war production. The important question in regard to the Japanese power industry, then, is whether a shortage of electric energy has materially hampered the growth and maintenance of Japanese military strength; not merely whether there has not been enough power produced to support relatively unessential economic activities.

It seems clear that installed generating capacity has been quite ample to support total Japanese war production. If there have been shortages, they have resulted from comparative shortages of coal and waterflow which caused an under-utilization of installed capacity. These factors may be examined separately.

The evidence suggests that rainfall and, hence, waterflow in Japan during the past few years, and particularly in 1939, has been somewhat lower than normal. To offset the resulting loss of hydro output, the Japanese would have had to use steam plants at a higher rate than normally. But there is good reason to believe that the enemy did not choose to spend as much coal for electric power generation as would have been necessary to fulfill all power requirements (including low priority and nonessential activities). Plenty of coal for this purpose existed, as did the transportation facilities for hauling it, but there were important competing uses which would have suffered if the coal and transportation had been allocated for power generation. To deprive these other uses would, in the estimation of Japanese industrial and military planners, entail greater injury to Japan's war strength than would a lower level of steam power generation. Thus, the less essential uses of power were forced to suffer, sometimes heavily, at least in certain areas and at particular times of the year.

Examination of intelligence reports of power shortages fails to provide any convincing proof that important Japanese war production has been significantly curtailed by insufficient supplies of electric power. It is believed that the large amount of Japanese publicity on power shortages can best be explained by the following factors:

(a) The effort to save coal and transportation for purposes regarded as more important to the war than the least important uses of power.

(b) Use of power rationing by the government as an instrument of economic control for the purpose of releasing not only power but manpower and materials from nonessential uses to war production.

(c) Use of power shortage propaganda by the government to encourage reduction of consumer uses of power, and to gain public acceptance of direct curtailment controls.

(d) Government use of publicity on power shortages as a convenient measure to explain away production deficiencies and other shortages actually resulting from other causes.

D. ECONOMIC AND MILITARY EFFECTS OF ATTACKING POWER PLANTS

The objective in attacking power plants is to reduce the supply of electric energy to important consuming industries, thereby reducing the output of these industries and achieving a reduction in the flow of military supplies.

If generation of all power were virtually stopped, the bulk of Japanese industrial activity would be quickly halted. The difficulties of estimating the precise economic effects of a *partial* cut in power supply, however, are very great. Since the consumption pattern of electric power is extremely diverse, with no one industrial use accounting for a large share of total consumption in most areas, the economic impact of a relatively small cut in power output (e. g. 25 percent), is likely to be spread over a wide range of consuming industries. While this will certainly force a reduction in the general level of combined industrial activity—to which the supply of electric power is closely geared—it is not generally possible to predict with any degree of certainty what the effect on output of any specific product will be. It is clear, however, that the Japanese would have considerable latitude in making adjustments in power consumption which would minimize the impact of power shortages on highest priority production. It must be anticipated that a very substantial reduction—at least 40 to 50 percent—in the power supply of any industrial area must be achieved before high priority production begins to be affected significantly. A reduction of at least 75 percent must be achieved to assure critical effects on production.

In view of the considerable capacity cushion in Japan's electric power system—discussed in detail in Part III—a given percentage cut in power output will require a more than proportionate cut in total generating capacity.

Reduction of activity in enemy industries other than electric power, brought about by Allied air or sea action, forces a decline in the general level of industrial activity and in power requirements. If attacks on the power industry are to supplement the economic loss imposed by these other types of attack, rather than merely duplicate such loss in large measure, then power output must be forced downward faster than the requirement for power is falling off. Otherwise, power attacks represent a relative waste of air effort.

III. STRUCTURE OF JAPAN'S ELECTRIC POWER INDUSTRY

A. GROWTH OF THE POWER INDUSTRY

The growth of the Japanese power industry in the last decade, particularly since 1937, has been remarkable. In this period Japan mastered the construction of power generating equipment of all sizes. Thus, while in 1930 all large generators and turbines had to be imported, in 1941 the Japanese had become self-sufficient in all heavy electrical equipment and built the largest hydroelectric turbine in the world. In the effort to exploit natural water power resources, every stream in Japan —from smallest creek to largest river—has been minutely surveyed for possible power sites. Most of the best sites have now been developed and further enlargement of the hydro system has become quite limited. Steam plants have been constructed with total capacity much greater than can be fully utilized with available coal supply.

The physical size of the Japanese electric power industry has now reached very large proportions, as suggested by the available estimates for Japan Proper alone. The principal physical installations which provide Japan Proper with electric power are: more than 1,200 generating plants (hydro and steam), an equal number of step-up transformer stations at generating plants, about 20,000 miles of transmission lines, several hundred stepdown transformer stations, innumerable distributor substations, and more than 200,000 miles of distribution lines.

B. POWER SUPPLY AREAS

For purposes of air attack, the power industry of the Japanese Inner Zone must be regarded as a collection of more or less separate target systems, each comprising a "power supply area." Within each supply area there is a relatively complete network of transmission and distribution lines connecting all generating plants, transformer stations, and power consumers. This permits a high degree of flexibility in sending power from any generating plant inside the area to any industrial consumer tied into the area network.

The possibilities of exchanging blocks of power between contiguous supply areas, however, are severely limited and in some cases non-existent. This is due to geographic separation of the areas, low capacity of inter-area transmission lines where they exist, and difficulties of converting 50 and 60 cycle current for shipment between areas having different cycle systems.[1]

The following primary power areas dealt with in this study comprise over three-quarters of Inner Zone installed capacity.[2]

Name of Supply Area	Prefectures Included	Characteristics
1. Honshu...... (Tokyo-Osaka-Nagoya)	All Honshu above the line Himeji-Tottori and below the line Niigata-Sendai.	Most important power area comprising 65 percent of total Japan Proper capacity and 43 percent of Inner Zone. Somewhat more hydro than steam capacity but steam is very important in dry season. Wide diversity of power consumers including a large proportion of Japan's most important war production.
2. Manchuria..	Entire Area of Manchukuo.	Second largest area, containing 13 percent of Inner Zone capacity. Steam capacity predominates but hydro and steam output balance. No significant seasonal variations. Nonferrous metals the largest consumer, followed by coal, ordnance, chemicals, and iron and steel.
3. North Korea	All Korea north of Keijo	Third area in size, with 9.4 percent of Inner Zone capacity. Great preponderance of hydro, but no significant seasonal fluctuations because of water storage reservoirs. Nonferrous metals and chemicals the largest consumers.
4. West Kyushu	Nagasaki Saga Fukuoka (west part) Kumamoto (west part) Kagoshima (west part)	Fourth in size, with 6.2 percent of Inner Zone capacity and 8.3 percent of Japan Proper. Steam capacity two-thirds of total; accounts for one-half of wet season and two-thirds of dry season output. Diversified industrial consumption; coal, nonferrous metals, and chemicals are important users.
5. North Kyushu	Yawata-Tobata-Kokura strip.	Relatively small, with only 3.2 percent of Inner Zone capacity and 4.5 percent of Japan Proper. Almost entirely steam, highly concentrated in a few large plants. Large proportion of output consumed by actitivities associated with iron and steel production. Included as primary area because of strategic importance.

Areas of secondary importance, accounting in the aggregate for less than one quarter of Inner Zone capacity and not discussed in detail here, include:

1. Karafuto.
2. Hokkaido.
3. Shikoku.
4. Eastern Kyushu.
5. Tohoku.
6. Chugoku.
7. South Korea.
8. Occupied China.
9. Formosa.

C. SEASONAL ROLES OF HYDRO AND STEAM PLANTS

The swiftly flowing streams of Japan, upon which hydro-electric plants rely for motive power, decline considerably during the dry season (usually totaling 3 to 4 months per year, including December, January, February, and part of August). Since the topography in general does not permit the construction of large water storage reservoirs, it has been necessary to construct steam plants to supplement hydro output in dry seasons and to meet peak load requirements at any time of the year. Thus, during much of the year the Japanese have a duplicate set of generating plants available to serve the same consumers, especially in Honshu.

---

[1] Power areas are defined geographically by the degree of integration with the power facilities of contiguous territory. Thus, for example, North Kyushu and Honshu are distinct power areas since the line capacity for transmitting current between them is very limited. On the other hand, the territory around Tokyo and that including Osaka-Nagoya, previously regarded by JTG as separate power areas particularly because of their cycle differences, are now treated as a single power area on the basis of further study. It now appears that the existence of substantial double-frequency equipment and high capacity interconnecting transmission lines make all Honshu a single power area.

[2] Inner Zone—N. of and including Formosa; in China N. of Yangtse River.

The relative importance of hydro and steam output and capacity varies considerably from area to area. In all cases, however, the dry season usually forces only a partial reduction in hydro output. Conversely, a certain amount of steam output continues throughout the year.

Ordinarily, the wet and dry seasons from year to year run a fairly even course. Occasionally, however, an abnormally dry year restricts considerably the annual output of hydro plants, shifting a heavier burden to steam plants and even then creating shortages in certain areas.

Hydro plants in Honshu carry most of the "base load" in the wet season and as much of it as possible in the dry season. They are always operated as near full available capacity as water flow and power demand permit, since their cost of operation is very low. Steam plants, on the other hand, are more costly to operate because of heavy coal consumption. Thus, a considerable portion of steam capacity is held in reserve most of the time, though the more efficient steam plants are frequently used for carrying peak loads in the wet season and handling a share of the base load in dry seasons. The main exception in Japan Proper is the Northern Kyushu Area where large steam plants located relatively close to coal mines carry virtually all of the base load throughout the ear. Similarly in Manchuria, steam plants carry the greater share of the year around base load.

A distinction must be made between the modern steam plants and the older, smaller, and much less efficient ones which use 2 to 3 times as much coal per unit of power generated. This latter capacity is only used under the most pressing circumstances.

In view of the present tightness of Japanese coal supplies, particularly "steaming coal" appropriate for power use, it is to be assumed that every effort is being made to minimize the use of steam plants. This can be accomplished in part (a) by eliminating least essential power users, particularly in the dry season, (b) by shifting some of the output of certain large power consuming industries (e. g., aluminum and chemicals) from dry to wet season, and (c) by ironing out daily power peaks as much as possible in order to increase the load factor of hydro plants and minimize use of steam plants for handling peak loads. It is probable that, overall, installed steam capacity in the Inner Zone is utilized at a considerably lower rate today than in earlier periods.

D. POWER CAPACITY AND OUTPUT

Complete and authoritative data on Japan's power industry are not available for the period since 1937. Consequently it has been necessary to make very rough estimates of current capacity and output.[1] The estimates presented in this study have been based on assumptions most favorable to the Japanese and probably are on the high side. This is particularly true of the estimates for steam power generation since there is good reason to believe that shortage of coal has encouraged the enemy to use steam generation capacity well below normal rates. The summary of these estimates presented in Table II are subject to later modification and in general should be regarded as maximum.

Maximum total generating capacity in the Inner Zone at the end of 1944 is estimated at 16,880,000 KW, comprised of 52 percent hydro and 48 percent steam capacity. The five primary power supply areas are estimated to account for 12,740,000 KW (76 percent of the Inner Zone total) broken down between 55 percent hydro and 45 percent steam. The large Honshu supply area of Osaka-Nagoya-Tokyo alone represents 43 percent of the Inner Zone total. It will be noted from Table II that the ratio of hydro to steam varies considerably from one area to another, with hydro being of greatest importance in Honshu and North Korea.

Maximum total power generated in the five primary supply areas during 1944 is estimated at 53 billion gross kilowatt hours, or 78 percent of the Inner Zone total. This amount of gross power, comprised of 70 percent hydro and 30 percent steam, is equivalent to approximately 45 billion KWH of net power consumed after allowing a 16 percent reduction for distribution losses.

E. GENERATING CAPACITY CUSHION

It is believed that Japan at present is failing by a considerable margin to make full use of available electric generating capacity. The unused portion represents a potential economic cushion of protection against damage by air attacks to Japan's electric power industry.

In the event of damage to a portion of Japan's generating capacity it is doubtful that hydro plants could be operated at any higher rate than at present. It is estimated that during the season of highest water flow installed hydro capacity is operated at about 90 percent of full potential, the remaining 10 percent being accounted for by breakdown and occasionally inadequate water flow. Under lowest water flow conditions there is generally only enough water to operate the hydro system at 25 to 30 percent of capacity.

Steam generator plants contain a substantial capacity during the wet season, many of them averaging only 20 percent or less of capacity operation. In the dry season, however, they are utilized to about 90 percent of capacity, if coal is available, in order to offset the decline in hydro output. In such supply areas as Northern Kyushu where steam capacity carries the year-around base load, there is much less steam plant cushion.

The extent to which Japan would enjoy a power capacity cushion depends upon the character of damage to the power system. It is clear that the cushion would be much less in the dry season than in the wet season under any circumstances. Elimination of the wet season cushion could be achieved by destruction of steam plants. If only a fraction of steam plants in an area were destroyed, the remaining fraction could be operated at a higher rate during the wet season by diverting coal from damaged plants. Similarly, if damage were concentrated in a particular zone, it might be possible to transfer power from adjacent zones to satisfy high priority requirements of the deficit zone.

One of the major questions regarding Japan's present power capacity cushion is the availability of coal to operate steam plants at full capacity. It must be presumed that under emergency conditions, additional coal

---

[1] Estimates of capacity and production used in this study have been derived mainly from analyses prepared by Research and Analysis Branch, Office of Strategic Services.

would be made available for this purpose at the expense of other coal consuming industries.

F. CONCENTRATION OF GENERATING CAPACITY

Compared with other major industries, Japan's electric power industry has a relatively low degree of capacity concentration in large plants. Concentration of steam capacity is considerably higher than hydro capacity. Besides a very substantial number of relatively large generating plants, Japan's power industry has a tremendous number of very small plants which in the aggregate account for a significant fraction of total capacity. This is particularly true of small hydro plants.

An attempt has been in this study to present a rough quantitative measures of concentration of installed capacity. These estimates, given in Table III, in themselves give a somewhat incomplete picture and tend to understate the degree of concentration. It should be notd, first, that a large generating plant is generally more imporant than equivalent capacity in numerous small plants and, second, that a given amount of hydro capacity is usually more important to the Japanese than equivalent steam capacity, although there are notable exceptions.

As indicated in Table III, 23 steam plants (each 20,000 KW or larger) account for more than ¾ of steam capacity in the important Tokyo-Osaka-Nagoya supply area, whereas 67 hydro plants represent only slightly over ½ of all hydro capacity in the area. Together, 90 hydro and steam plants, 20,000 KW and larger, account for slightly over 3/5 of total installed capacity in the area.

In North Kyushu, where it is believed hydro capacity is of little or no importance, six large steam plants are estimated to account for nearly ¾ of total capacity. In Manchuria, 16 generating plants (3 hydro and 13 steam) are estimated to contain about 4/5 of the area total installed capacity.

G. INTERDICTION OF POWER TRANSMISSION

It is clear that destruction of a high proportion of total generating capacity (75 percent or more) in most supply areas would require attack on a large number of individual plants, the bulk of them hydro plants, many of which would be difficult to reach and locate. A promising alternative method of cutting the supply of power to major industrial centers is a program of attack involving:

(1) Destruction of a relatively small number of high voltage transformer and switching stations on all main power transmission lines which carry energy from numerous outlying hydro plants into main consuming areas, and

(2) Destruction of all significant steam plants within the zone of power interdiction which do not feed through the above transformer stations.

The concentration of high voltage transformer and switching station capacity is much greater than the generating capaciy whose output is transmitted through these stations. Precise quantitative measurement of transformer station concentration is not yet available. Preliminary research on Honshu suggests, however, that the following approximate numbers of targets must be eliminated (within a short space of time) to cut off 75-80 percent of the power available to each industrial area:

Tokyo	20 substations	5 steam plants
Osaka	14 substations	8 steam plants
Nagoya	10 substations	2 steam plants
All Honshu south of the line Sendai-Niigata	90 substations	30-40 steam plants

If such a program were undertaken, it would be of the utmost importance to locate and destroy *all* targets indicated in order to achieve full interdicion of power flowing ino major industrial areas.

H. RESILIENCE

The major factor which would determine the time required to return damaged power plants to full capacity would be the number of plants requiring repair at the same time. At one extreme, for example, if a third or more of total generators, turbines, and boilers in the seven primary areas required major repair or replacement, it is highly unlikely that more than a small portion of this third of capacity could be recommissioned before the end of the war. On the other extreme, if only three or four power plants in the entire Inner Zone required extensive repairs and replacements, it must be assumed that the enemy could achieve this in a relatively short time, perhaps less than 6 months. The recovery times given below for individual items of equipment are necessarily rough and are based on the assumption of relatively moderate total damage to the power industry—in the neighborhood of 10 percent of total installed capacity.

Serious damage to the penstocks would take from two to several months to repair, the length of repair time depending on problems of transportation and the availability of suitable penstock plate.

Serious damage to turbogenerators would put the equipment out of commission for from 3 to 6 months. If totally destroyed, Japanese ability to replace such equipment would depend, first, on the size of the equipment and, second, on the ability to transfer comparable units from other less vital power plants. In view of the fact that Japanese heavy electrical manufacturers are now heavily engaged in production of ordnance and munitions, the manufacture of new generating units, 25,000 kilowatts and over, would probably take at least 6 months. The enemy's ability to shift equipment from other plants is probably very limited because the more modern plants cannot spare them while the older plants contain obsolescent units which could be installed and operated in the newer plants only after a considerable readjustment in boiler pressure, speed, and other factors —if, indeed, such installations could at all be made.

Replacement of boilers would take at least 6 months. Salvage and repair work on damaged boilers might well take a comparable length of time. Large capacity modern boilers would be difficult to replace at all.

Serious damage to transformers would put them out of commission for 2 months or longer. Slight damage could be repaired in a matter of days. Total replacement of destroyed transformers of 20,000 kilovolt-ampere size or larger, would require at least 6 months.

The heavy electrical equipment industry is the major source of resilience for the electric power industry. Destruction of a few minor heavy electrical equipment plants in conjunction with a program against the power system would greatly impair Japan's ability to restore the power supply.

IV. PROCESSES AND PHYSICAL EQUIPMENT

Electric energy is produced by the application of mechanical force, transmitted by "prime movers" to electrical generating equipment. The generators develop electric energy by the interaction of the revolving armature against the stationary magnetic field which is wound close to the outward frame of the generators. In modern stations, the voltage at which power is generated is high, ranging from about 3,300 volts to 13,200 volts (in exceptionally large plants the voltage may run up to 15,600 volts). The speed of the generators in modern steam-electric plants ranges from 1,500 to 3,000 revolutions per minute; that of generators in hydroelectric plants ranges from 125 to several hundred revolutions per minute. Nearly all the generated power is alternating current, since only A. C. power lends itself to economical transmission.

A. HYDROELECTRIC PLANTS

1. Location and Flow of Power

Japanese hydroelectric plants are located in rural, mountainous sections which abound in short, swift rivers. About 83 percent of them are located on the main island of Honshu and about 72 percent in the Toyko and Osaka-Nagoya power supply areas of this island. In the typical case power generated at such plants is transmitted to consumers over a distance from 100 to 300 miles. This transmission usually involves "stepping up" the voltage of the generated power, by means of transformers at the plant site, to 154,000 volts, and sending the energy from the primary to the secondary substations; reduction of voltage to 22,000 volts and send the energy to tertiary substations; reduction of voltage to 2,300 volts at the tertiary substations and sending power to pole transformers, or industrial transformers, where it is reduced to 100 or 200 volts for commercial or civilian use. Railroads commonly receive their power direct from secondary substations and reduce it, with their own transformers, to 1,500 volts required for their operations. High voltage transmission reduces losses, because electric losses are directly proportional to magnitude of the current which is reduced as the voltage is increased. (Capacity, measured in kilowatts, is the product of voltage and current, the latter measured in amperes.) Average losses in hydroelectric transmission are about 15 percent of the gross power generated at the stations.

2. Physical Lay-out and Equipment

Almost all hydro plants in Japan proper are of the aqueduct type. In this type of installation the stream flow is diverted by a shallow dam to an intake gate and the water then flows through the aqueduct to some high point in the nearby terrain and is then led to a small artificial pond called a forebay or a water tank called surge tank. From this point the flow, controlled by head gates, passes down the hill through typically long and large steel pipes called penstocks. Each of the penstocks furnishes waterfall to a turbine which is usually set in concrete below the main floor of the power house. The shaft of the turbine extends upward through the main floor and is coupled with the generator, the casing of which is set upon the main floor. After the water has passed through the turbine it flows out of the power plant and is referred to as "tailrace." In a few high-head plants both turbine and generator are mounted side by side on a short horizontal shaft on the main floor. Some aqueduct-type hydroelectric plants have storage reservoirs. The most prominent among them are the Choshin and Fusen plants in Korea and the Jitsugetsutan plants in Formosa. Among the hydroelectric plants, only a few have the dam type installation in which waterfall is obtained by the construction of a high concrete storage dam with the power plant located at the base of the dam. The water is taken in at the top of the dam or at some distance on the shore behind the dam and may be led directly to the plant by pipes or penstocks which are set into the dam structure proper. Most prominent among such installations are those of the large Suiho and Kirin hydroelectric plants in Korea and Manchuria.

Besides turbines and generators, the basic equipment of hydroelectric plants includes banks of transformers which are usually found just outside the power plant building, in the transformer yard. This yard also contains steel towers strung with transmission lines, oil circuit breakers, and, as a rule, lightning arresters. (These last are much smaller in size than transformers.) The buildings containing the turbines and generators are usually of reinforced concrete construction, two or more stories high.

B. STEAM PLANTS

The steam plants, all coal burning, are always located near large bodies of water required for transportation of fuel and for a supply of condenser water. In Manchuria some plants obtain coal by rail from nearby mines and use force draft towers for condenser water. An installation consists of a station building with coal storage on the one side and an outdoor substation on the other side. The station building has three adjoining sections, boiler house, generator bay and electrical gallery. Stations vary between two extreme types: (1) The old, equipped with low pressure boilers, houses in a load-bearing wall structure three stories high and (2) the modern, dating from 1926 and of far greater importance, equipped with high pressure boilers, housed in a steel frame structure six or seven stories high. Characteristic of its identifiable features are (1) waterfront location, (2) coal pile of approximately the same size as the station building, (3) extreme height of the building, (4) a few fat stacks.

C. HIGH VOLTAGE TRANSFORMER AND SWITCHING STATIONS

The function of the substations is to maintain the even and efficient flow of energy over long distance transmission lines at high voltages or to step-down and equalize the voltage near the consuming end of the transmission line. Usually the power flowing through a particular transformer station is channeled in from numerous generating plants.

The substations of critical importance whether switching stations, transformer stations or combination of both, are generally situated in flat, open country surrounding urban centers. They are square to rectangular in shape reaching in some cases an overall area of 500,000 square feet. The site usually includes: a small building housing the condensers and switch panel; the outdoor switch gear (buscars and trusses supported on a rigid frame network of light steel poles); one row or more of transformers; and a nearby row of circuit breakers.

The incoming high voltage transmission lines are brought to a terminal tower adjacent to the station and leave from a similar tower or towers.

V. PHYSICAL VULNERABILITY AND WEAPON RECOMMENDATIONS

A. INTRODUCTION

The following is written for the use of those persons who are engaged in selecting weapons, estimating force requirements, and formulating operational plans for attack on targets in this category. For such purposes the following questions must be answered.

1. What portion of a target should be the primary objective?
2. What is normally the best type, size, and fuzing of HE? In what circumstances should different types be used?
3. Should IB be used, either exclusively or mixed with HE? If so, what is the best size and type, and what is the optimum quantity?
4. What weight of attack is required?

This section deals with the physical characteristics of targets found in this category, the choice of primary objectives, the selection of weapons and with the density required on the target for expectancy of a particular level of damage. For determination of force requirements reference should be made to JTG/M/8.

A. STEAM POWER GENERATION

1. Primary Objectives

The station building of a steam power plant contains boilers, turbo-generators and control equipment. Of these three, the boilers are usually the primary objective not so much because of their influence on power generation but because they are somewhat more vulnerable than turbo-generators. The center of station building is the aiming point; however, bombs and fuzes are selected for damaging the boilers.

The ratio of number of boilers to number of turbo-generators range from about 4 to 1 for the older plants to 2 to 1 for the modern plants. The floor area occupancy of boiler equipment is 30-50% while that of turbo-generator is considerably less. Significant damage is to the equipment rather than to the structure housing it.

2. Vulnerability to HE

a. Boilers

The main area of effectiveness of 500 GP bombs against boilers and their auxiliary equipment is approximately 12000 sq. ft./ton. Other bombs are somewhat less effective on an equal weight basis.

The fuzing recommended is 0.1/0.025, in order to allow sufficient penetration.

b. Turbo-generators

The effective area for the 500 GP against turbo-generators is about the same as against boilers. Turbines are extremely resistant to blast and fragments since cases are of cast steel one to two inches thick. Turbo-generators are supported on very heavy steel-concrete columns, usually two stories high. Only a very near detonation can be expected to damage these supports. Confined detonation beneath the floor is out of the question since the latter usually is of reinforced concrete four or five feet thick. However, the generators and the delicate automatic control devices are highly vulnerable to fragment damage, especially if equipment is in operation.

Since this equipment is normally located about 30-40 feet below roofs heavy enough to actuate inertia fuzes, the 0.025 fuze is best. The recommended weapon is 500 lb. GP fuzed 0.1/0.025, (as for boilers).

3. Vulnerability to IB

Since no part of an installation is combustible, IB are not recommended.

4. Vulnerability to Other Airborne Weapons

Strafing and rocket attack are not recommended against steam electric plants.

5. Weight of Attack

a. Required ground densities of HE

The following table shows the ground densities of 500 GP bombs in tons per million square feet with a 50% probability of achieving various levels of damage to boiler equipment of typical construction:

TABLE 1

Ground Densities of 500 lb. GP Bombs for Various Levels of Damage

Level of damage	.30	.50	.70
Tons/1,000,000 sq. ft.	35	60	100

Although modern boiler installations are designed for unit operation of each boiler and its auxiliaries, certain equipment such as coal handling facilities, parts of the feed water system, and steam header sections may be common to the operation of all boilers. Thus a level of damage of the order of .50 may correspond to 100% production loss.

b. Force requirements

1. Level bombing

To determine force requirements necessary to achieve the ground densities above indicated, the usual methods of computation based on operational factors and on bombing accuracy must be followed.*

2. Dive and glide bombing

The number of hits required to achieve the desired level of damage can be obtained by multiplying the required ground density by (1) the area of target in millions of square feet and by (2) the number of bombs per ton.

C. POWER TRANSMISSION

1. Primary Objectives

In the large step-down substations, the transformers and oil circuit breakers are the primary objectives. This

---

*For a discussion of these methods see JTG Memorandum 8 (M-8).

equipment, located in the open, is likely to be protected by walls of concrete or brick which are effective protection against blast and fragments. Transformers are rather large units (usually 8 to 15 feet in diameter), arranged in an orderly row. Circuit breakers, which are smaller units are found in a row next to the transformers. The two rows of equipment extend the full length of the substation, and occupy a space about 100 ft. wide.

2. Vulnerability of Substations to HE

This equipment is vulnerable to fragments or projectiles capable of perforating the steel cases of transformers and circuit breakers. Normally, one perforation that cuts a winding is enough to put a transformer out of service.

Where blast walls are used, the effective areas of bombs are limited by the spacing of walls. The effective areas of small bombs can not be expected to exceed the area enclosed, and for 260 Frag, an area of 1000 square feet per bomb (15000 sq. ft./ton) is expected. Bombs smaller than 260# Frag are not effective. A near miss by a 500 GP or larger bomb can be expected to destroy walls adjacent to the explosion and to damage the equipment protected by them. It is expected that the efficiency of the 500 GP in this case (weight for weight) will be about the same as that of the 260 Frag.

Where no blast walls exist, the area within which a given bomb will be effective can be determined from knowledge of its fragmentation pattern. The following table gives estimated effective areas for certain bombs in the absence of blast walls. These areas (based on data in WD TM 9-1907) are those over which, on the average, one perforation of ½″ mild steel per 10 square feet will occur. An allowance has been made for the effect of shielding.

TABLE 2

Effective Area Against Unprotected Transformers

Bomb	Sq. ft./bomb	Sq. ft./ton
260-lb F AN-M81	3000	25000
500-lb GP AN-M64	10000	40000
1000-lb GP AN-M65	15000	30000

In general, the 500 GP fuzed Inst/ND is recommended for attack of substations.

3. Vulnerability to Fire

The oil contained in transformers and circuit breakers may be ignited by HE or by electrical short circuits caused by fragments. IB is not recommended.

4. Vulnerability to Other Airborne Weapons

Substation installations are vulnerable to strafing and rocket attacks. This type of attack is particularly desirable when blast walls give protection against horizontally moving bomb fragments, but not against projectiles that are directed slightly downward.

5. Weight of Attack

a. Required ground densities of HE expected, on the average, to result in the indicated levels of damage to substation installations.

TABLE 3

Densities—Tons/1,000,000 sq. ft.

Level of damage................F=	.30	.50	.70
Effective area sq. ft./ton			
15000..........................	25	46	80
25000..........................	14	27	48
30000..........................	12	23	40
40000..........................	9	17	30

The level of damage sought should not be less than .50.

b. Force requirements for level bombing attacks.

These can be determined by the usual methods of computation and will depend on operational factors and on bombing accuracy expected.*

c. Dive and glide bombing

The number of hits required to achieve the desired level of damage can be obtained by multiplying corresponding ground density by (1) the area of objectives in millions of square feet and (2) the number of bombs per ton.

Since the transformers and circuit breakers occupy only a relatively small fraction of the area of an installation these should be carefully identified on cover before attack. It is the area of the strip occupied by these units which should be used in calculating force requirements. The method of calculation is outlined in JTG Memorandum 88.

---

*For a discussion of these methods see JTG Memorandum 8 (M-8).

TABLE 1

Electric power consumption pattern Japanese Ioner Zone—1944

Consumption category	Energy consumption (in million kilowatt-hours)	Percentage of total energy consumption accounted for (percent)	Consumption category	Net Energy consumption (in million kilowatt-hours)	Percentage of total energy consumption accounted for (percent)
Metals	12,000	25.5	Machining industries	8,800	18.7
Aluminum	6,300	13.4	Ordnance	3,000	6.4
Open-hearth steel	1,370	2.9	Other munitions and supplies	2,100	4.5
Alumina	1,300	2.8	Machinery and machine tools	1,000	2.1
Electric steel	1,200	2.6	Naval and merchant shipbuilding	970	2.0
Magnesium	660	1.4	Aircraft	930	2.0
Copper	530	1.1	Other machined products	800	1.7
Pig iron	360	.8			
Zinc	120	.3	Consumer and miscellaneous industries	6,300	13.4
Lead	100	.2	Small light and power (residential, municipal, commercial, small workshops)	4,500	9.6
Chemicals	9,000	19.2	Coal mining	3,800	8.1
Chemical nitrogen	3,230	6.9	Transportation (electric railways, tramcars, city and intercity)	2,600	5.5
Calcium carbide	1,800	3.8			
Rayon	1,220	2.6	Total energy accounted for	[1] 47,000	100.0
Chlorine	910	2.0			
Other chemicals	1,840	3.9			

[1] Equivalent to approximately 56 billion *gross* kilowatt hours.

Table 2

Installed capacity and power generated by electric supply areas, Japanese Inner Zone.

Inner zone supply areas (primary supply areas)	Installed capacity (end of 1944)					Gross power generated (1944)				
	Capacity in million kilowatts			Percentage of total		Output in billion kilowatt-hours			Percentage of total	
	Hydro	Steam	Total	Hydro	Steam	Hydro	Steam	Total	Hydro	Steam
Tokyo-Osaka-Nagoya	4.47	2.82	7.29	61	39	24.1	5.9	30.0	80	20
Manchuria	.66	1.56	2.22	30	70	4.0	4.3	8.3	48	52
North Korea	1.50	.12	1.62	93	7	7.1	.4	7.5	95	5
West Kyushu	.39	.67	1.06	37	63	2.1	2.5	4.6	46	54
North Kyushu	.0	.55	.55	0	100	.0	2.6	2.6	0	100
Total of primary supply areas	7.02	5.72	12.74	55	45	37.3	15.7	53.0	70	30
Total of secondary supply areas	1.75	2.39	4.14	42	58	12.1	2.7	14.8	82	18
Total inner zone supply area	8.77	8.11	16.88	52	48	49.4	18.4	67.8	73	27

TABLE 3

Concentration of capacity by power plant size groups in primary areas

[100,000 kilowatts]

	Tokyo-Osaka-Nagoya			West Kyushu			North Kyushu			Manchuria			North Korea			Total of all primary areas		
	Hydro	Steam	Total	Hydro	Steam	Total	Hydro	Steam	Total	Hydro	Steam	Total	Hydro	Steam	Total	Hydro	Steam	Total
Total installed capacity in area	4470	2820	7290	390	670	1060	00	550	550	660	1560	2220	1505	120	1625	7025	5720	12,745
A. Plants 50,000 kilowatts and over:																		
1. Number of plants	10	15	25	0	3	3	0	3	3	2	7	9	12	0	12	24	28	52
2. Combined installed capacity	860	1943	2803	0	326	326	0	229	299	630	923	1553	1287	0	1287	2795	3421	6216
3. Percentage of total installed capacity in area (separate for hydro and steam)	19.2	69.0	38.4	0	48.6	30.8	0	54.4	54.4	95.4	59.2	70.0	85.4	0	79.1	39.8	59.8	48.8
B. Plants 20,000 kilowatts and over:																		
1. Number of plants	67	23	90	0	5	5	0	6	6	3	13	16	16	1	17	86	48	134
2. Combined installed capacity	2321	2219	4540	0	390	390	0	411	411	660	1139	1799	1436	22	1458	4417	4181	8598
3. Percentage of total installed capacity in area (separate for hydro and steam)	51.9	78.7	62.3	0	58.2	36.8	0	74.7	74.7	100	73.0	81.0	95.4	18.8	89.7	62.9	73.1	67.5

PART VI—PHOTO INDUSTRIAL STUDY

REPRINT

FOREWORD

This annex is one of a series to be issued for selected Japanese industries covered by AIR TARGET OBJECTIVE FOLDERS. It relates to photographic interpretation of the industry and attempts to set forth material in which both the photo interpreter and target analyst are interested.

Other sections of the folders do not usually provide stereograms, ground photographs, or drawings which frequently are the simplest and most helpful means of describing typical characteristics of an industry to persons unfamiliar with it. A selection of this material is thus given in this annex where it might be readily available for use with other sections of the folder. It is organized for use by photo interpreters under the headings of recognition, functional analysis, and structural analysis; in some cases other headings may be added.

The attention of readers is directed to the excellent series of publications entitled PHOTO INDUSTRIAL STUDIES published jointly by Office of the Assistant Chief of Air Staff, Intelligence, Hq., U. S. Army Air Forces and Photographic Interpretation Center, Division of Naval Intelligence, Navy Department. Annexes prepared by JTG contain material extracted from publications of this series which have already been issued.

The Japanese electric power industry as discussed in this annex consists of three Sections, which are Section 1—STEAM ELECTRIC STATIONS, Section 2—HYDRO ELECTRIC STATIONS, and Section 3—SUBSTATIONS.

TABLE OF CONTENTS

REPRINT

LIST OF FIGURES

LIST OF TARGETS APPEARING IN FIGURES

Target No.		Figures No.
90.10— 881	Inawashiro Hydro Plant #1	25, 27
90.13—1059	Saku Hydro Electric Plant	26
90.16—1505	Oi Hydro Plant	23
90.17— 110	Tokyo Elec Pr Gen Sta, Tsurumi Plant	2
90.17— 111	Kawasaki Elec Pr Plant for Jap Govt RR	2
90.17— 230	Senju Steam Power Station	14
90.17— 493	Tokyo Steam Power Plant, Kawasaki	2
....	Azushi Switching Station	37
....	Musashino Substation	32
90.20— 195	Nagoya #1 Steam Power Plant	4
90.20—1144	Seto Hydro Electric Station	24, 28, 29
90.20—1598	Nagoya #2 Steam Power Plant	7
90.20—1614	Kaneyama Hydro Plant	21
90.20—2076	Imawatari Hydro Electric Station	22
90.25— 536	Amagasaki Steam Power Plant	3
90.25— 540A	Kansai Kyodo Steam Power Plant #1	3, 8, 12, 15
90.25— 540B	Kansai Kyodo Steam Power Plant #2	3
90.25—1629	Amagasaki Transformer Station	33, 36
90.25—1630	Osaka Transformer Station	34
90.25—1631	Yao Transformer Station	35
90.27—1284	Chugoku Steam Power Plant	1
90.30— 796	Saka Steam Power Plant	5
90.34—1127	Kokura Steam Power Plant #1	9, 10, 11
91.4 — 82	Jitsugetsutan Power Plant #1	19, 30
91.4 — 83	Jitsugetsutan Power Plant #2	20, 31

SECTION 1—STEAM ELECTRIC STATIONS

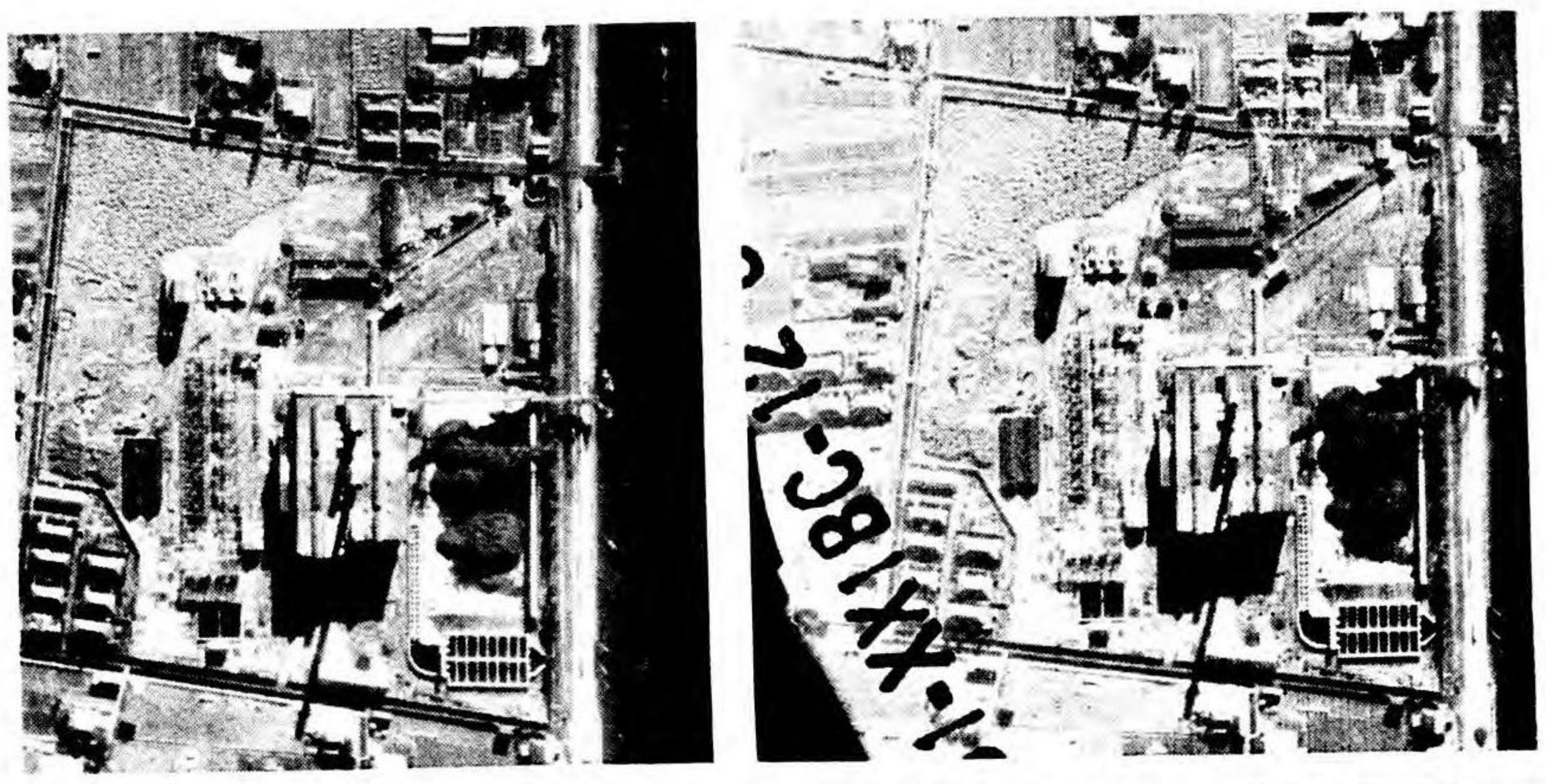
A. RECOGNITION

There are several definite characteristic identifying features which make possible the recognition of Japanese steam electric stations from aerial photography. By looking for a combination of these features, the interpreter can with reasonable certainty establish the identity of most installations. These features are:

(1) Waterfront location
(2) Coal Yard
(3) Station Building
(4) Chimneys
(5) Outdoor Electrical Equipment
(6) Transmission Towers
(7) Cooling Towers
(8) Settling Basin
(9) Reservoir

They are most prominent in the modern large central stations and become progressively less noticeable as the date of construction extends back to earlier years. The location of Japanese electric generating facilities, both steam and hydro, is probably more fully known to us than any other aspect of her war economy and is listed in this as well as numerous other publications. Most comprehensive list is that given in OSS R & A 1,000. The following illustrations show the features of typical plants.

Figs. 1 to 5—Recognition Features of Steam Electric Stations



Target No. 90.27-1284
Photography 8 Dec 44

Annotation refers to features as numbered above.

Fig. 1.

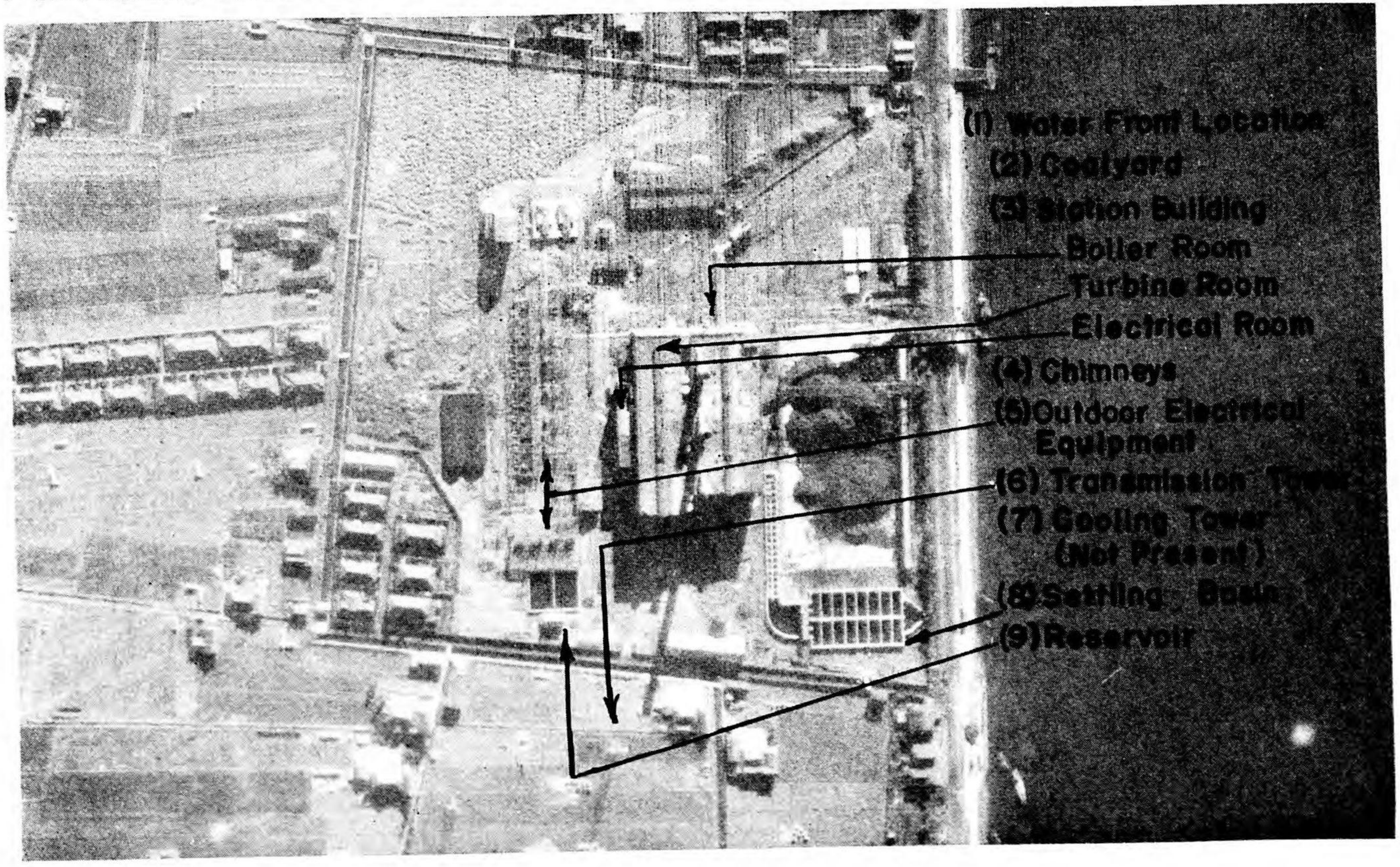
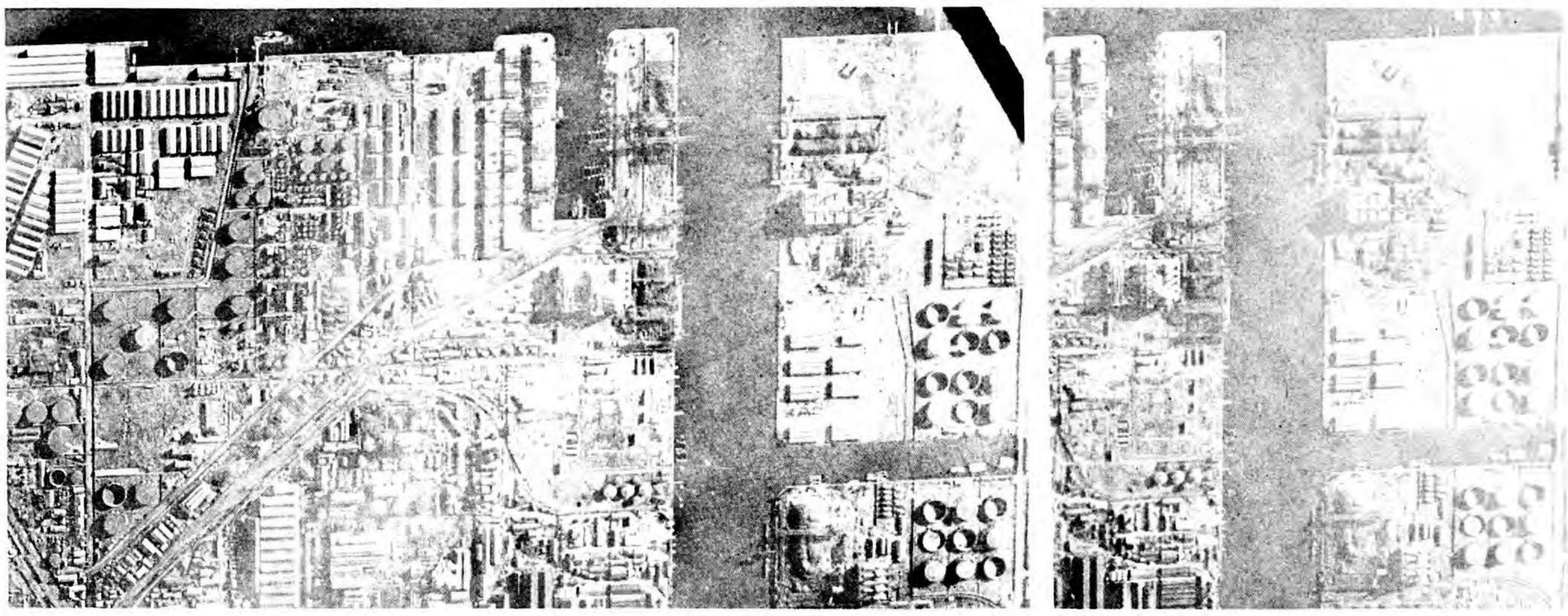


Fig. 2—Photography 13 Dec 44
Target 90.17-110 Top right
111 Left
493 Lower right



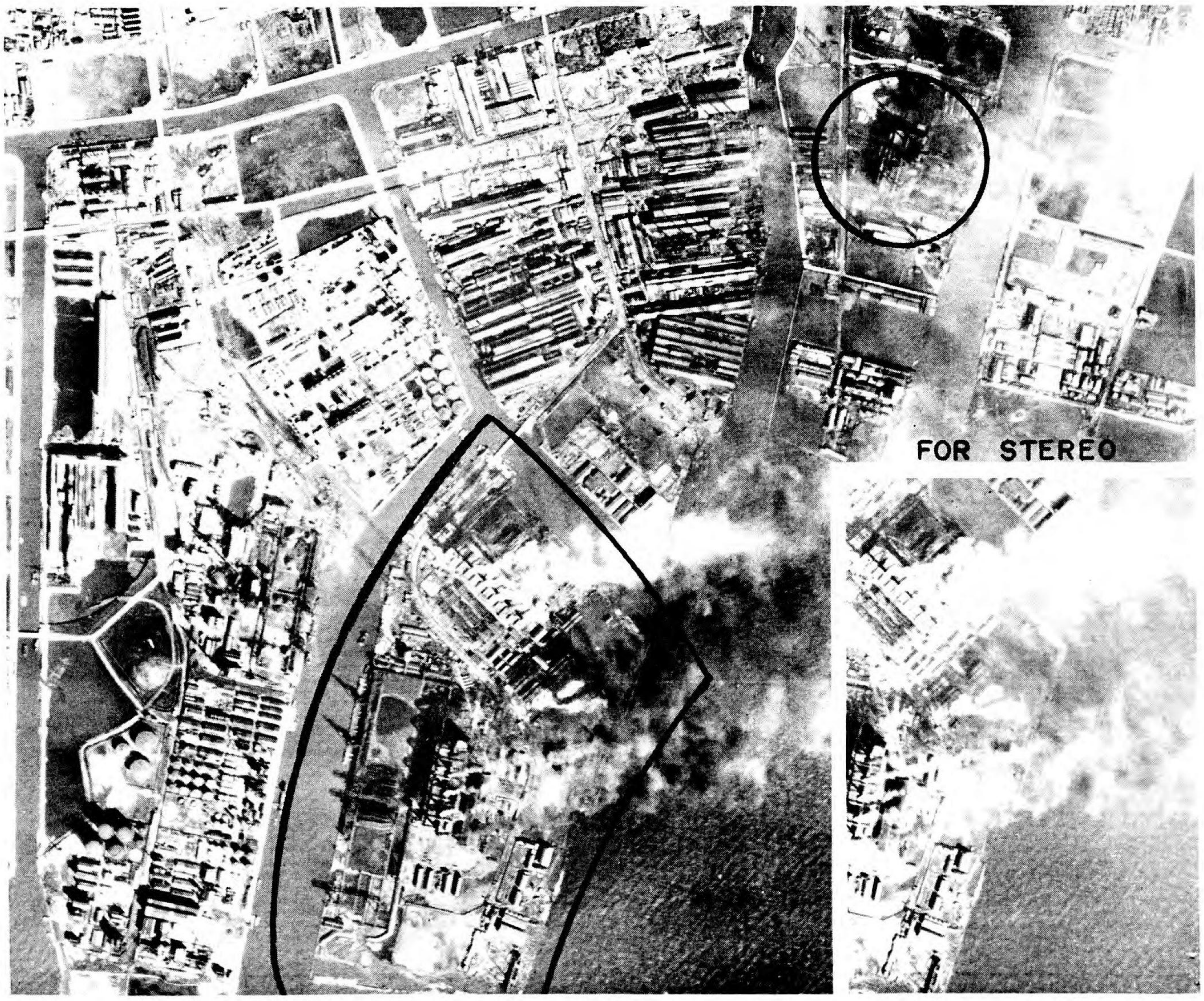


Fig. 3—Photography 18 Jan 45
Target 90.25-536 Top
540A Center
540B Lower

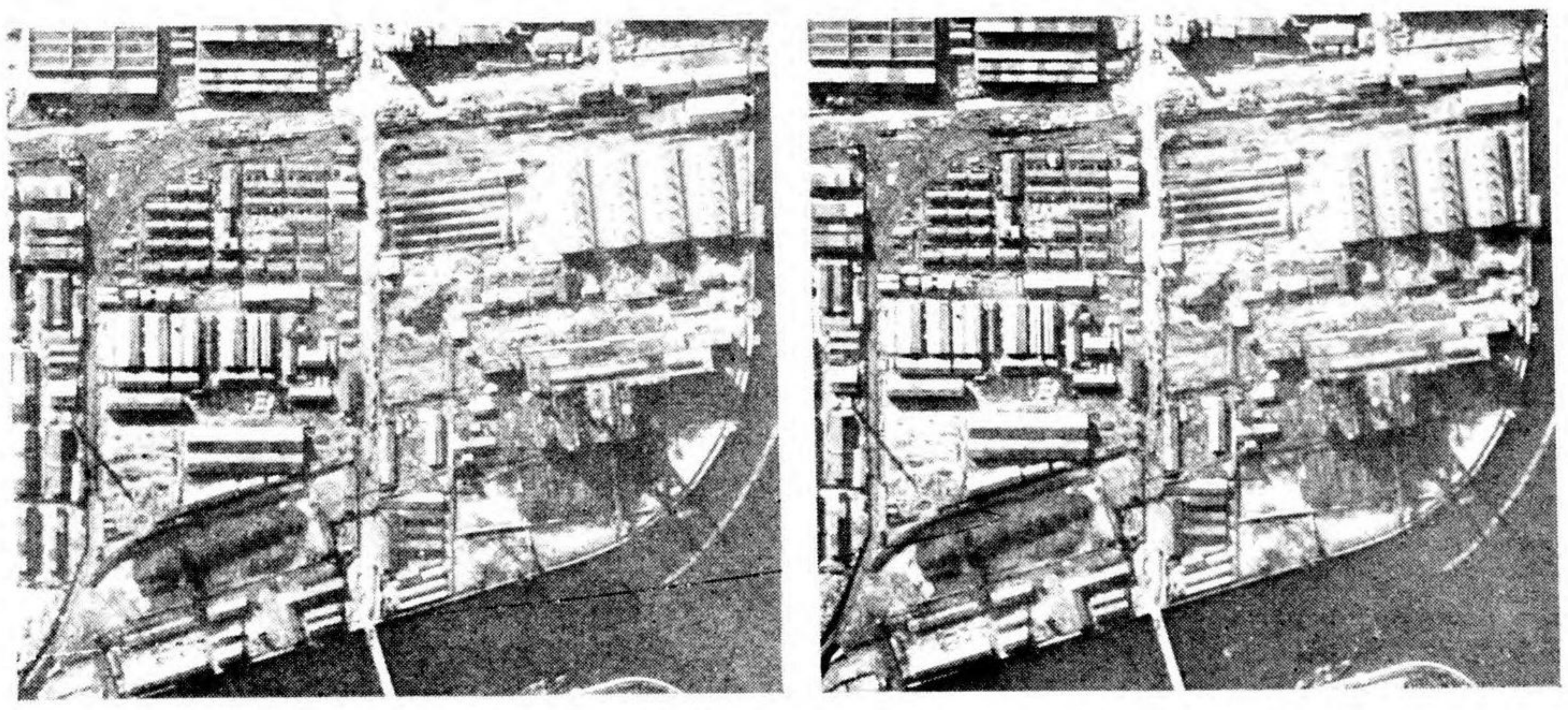


Fig. 4—Target 90.20-195 Photography 19 Jan 45

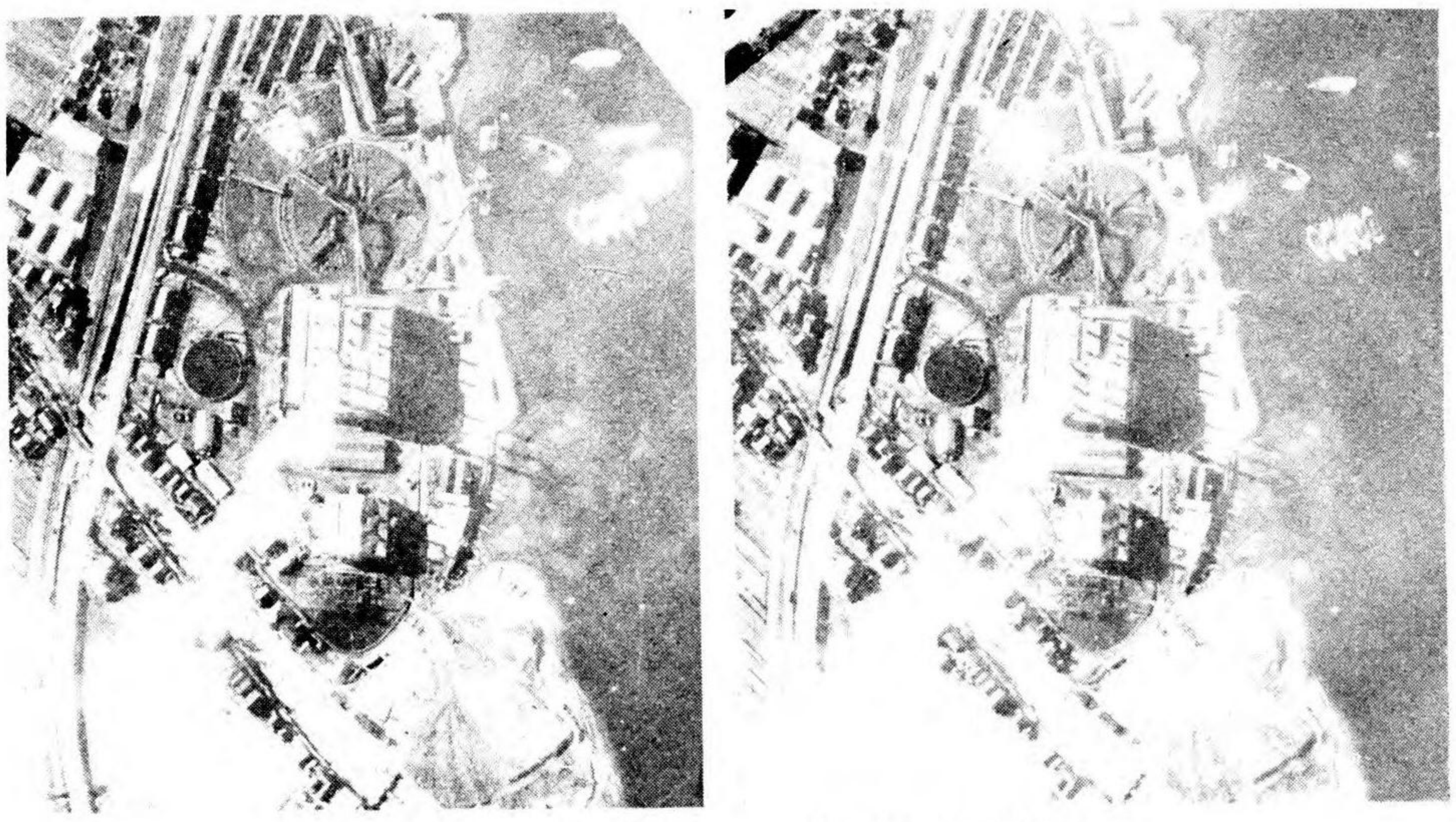


Fig. 5—Target 90.30-796 Photography 8 Dec 44

(1) *Waterfront Location:* The important stations in Japan are located at waterfront sites, either bay or river. They require large volumes of cooling water and in addition take advantage of water transportation for their fuel.

(2) *Coal Yard:* Coal is burned exclusively and the outdoor storage stands out prominently.

(3) *Station Building:* Height of six or seven stories (100 ft) is characteristic of modern plants. Older plants may be no more than three stories. Division into two distinct sections, boiler room and turbine room, is always apparent in the roof design. A third section, the electrical room, housing transformers and breakers, may be found. It is of less height, narrower than either of the other rooms, and does not extend the full length of the building.

(4) *Chimneys:* These vary in number, arrangement, and height, but are typically fatter and more closely spaced than those of other industries. In modern construction each chimney handles the flue gases from either one or two boilers; in older designs, more than two. In this latter type they usually rise from ground elevation at one side or end of the boiler room instead of from the roof.

(5) *Outdoor Electrical Equipment:* This appears in the yard next to the turbine room of the station building. Transformers, if not inside the building, are in an orderly row on the inboard side of the substation; oil circuit breakers are next.

(6) *Transmission Towers:* Found on or near the station site, they are usually seen only in shadow.

(7) *Cooling Towers:* In Japan Proper stations are located at waterfront sites and do not use cooling towers; in Manchuria, stations are inland, and with river water insufficient, must use cooling towers.

(8) *Settling Basin:* This is found in the intake section of the cooling water duct.

(9) *Reservoir:* One is usually located near the outdoor electrical equipment.

REPRINT

B. FUNCTIONAL ANALYSIS

To select primary and secondary objectives, to determine the probable occupancy of buildings, and to make damage assessments, the interpreter must identify parts of the target with the various operations conducted therein. This is called a functional analysis and is usually done on an annotated photograph showing the function of buildings and their relative importance as objectives. Preparation of a functional analysis requires that one have a knowledge of the process, be familiar with the general layout of buildings on the plant site, and know the location of important pieces of equipment used in the process.

1 The Process: In steam electric stations this breaks down into three cycles consisting of (A) coal, (B) water/steam, and (C) electricity. Fig. 6 below shows how they tie together. In cycle (A), coal is unloaded and stored, then conveyed as needed to the boiler room where it is burned in furnaces for the generation of steam. Gases pass out of the chimney, and unburned matter drops out through disposal gates at the bottom of the furnace. In cycle (B), steam generated in the boiler is led to a turbine, expanded, and finally converted to water by a condenser. Condensate collected in the condenser is pumped back into the boilers as feedwater. In cycle (C), an electric generator is rotated by the steam turbine, producing electricity.

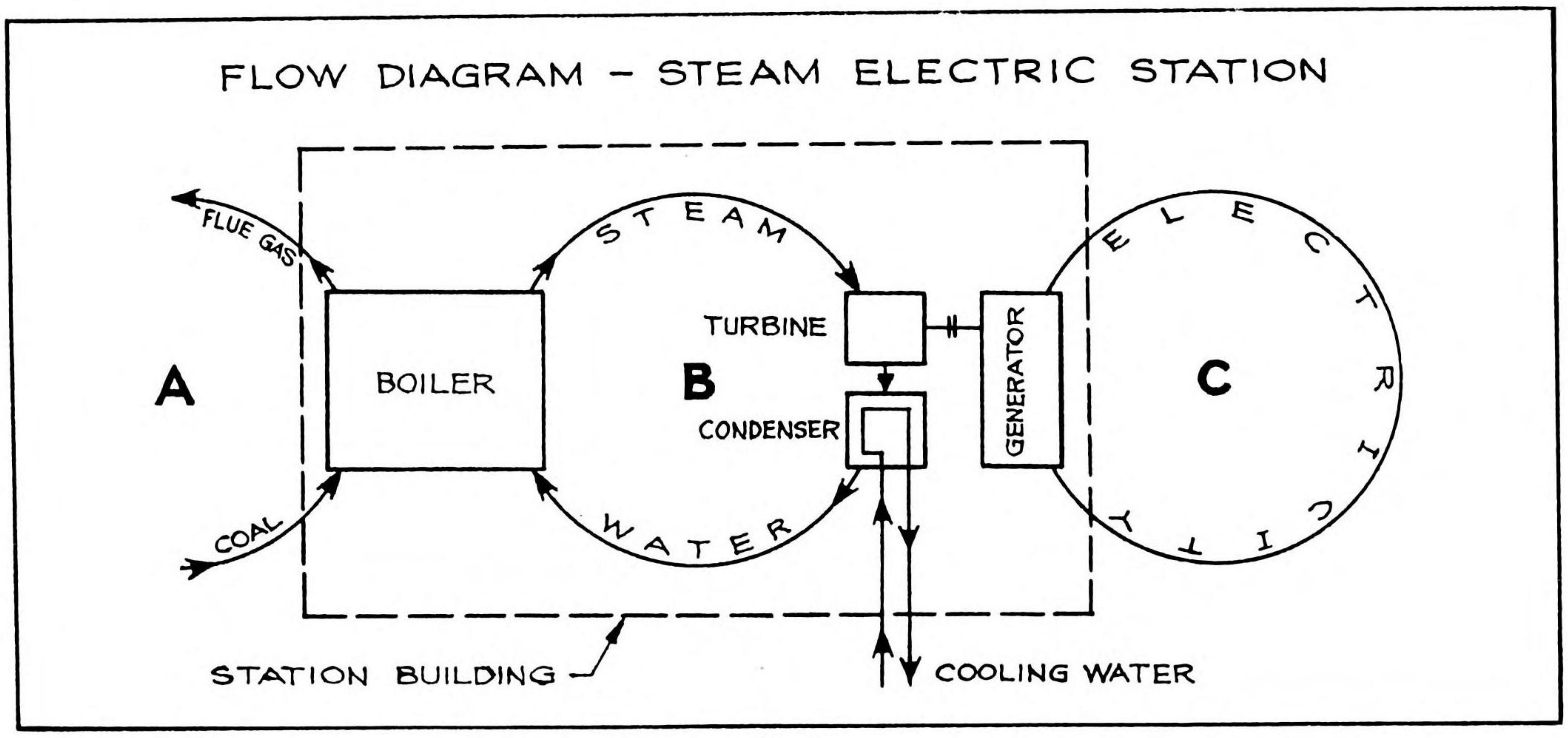
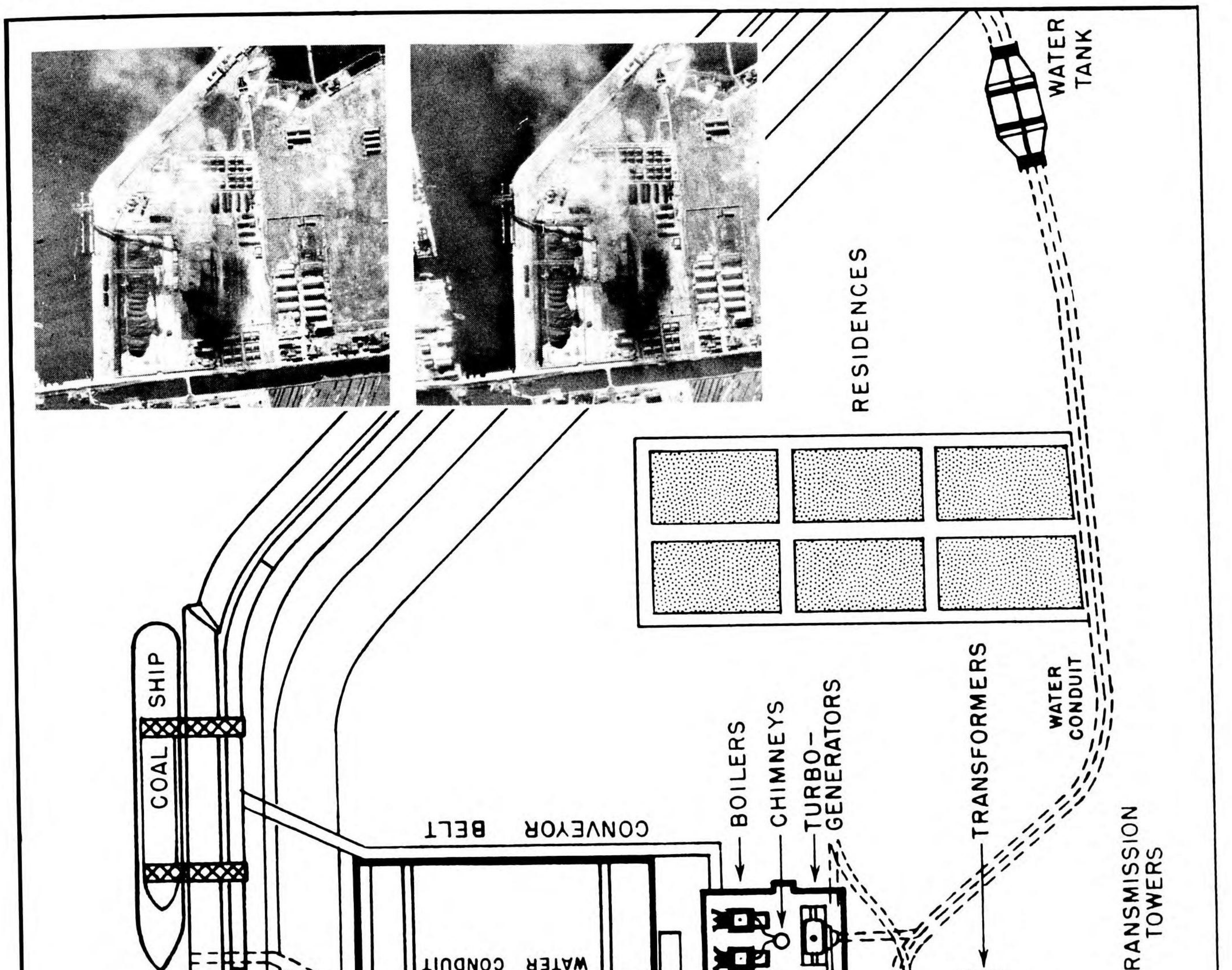


Fig. 6.

2 General Layout: The same features used for recognition of these plants, when followed with reference to the various successive steps required in the process, say from coal wharf to transmission towers, make possible the determination of the function of all buildings and structures. With the coal yard spotted, one can usually follow the flow of fuel from wharf to the boiler room bunkers. The boiler room is adjacent to the coal storage and is seen separated from the next or turbine room by a break in the roof design or the arrangement of chimneys. Outdoor electrical equipment is next to the turbine room, and last are the transmission towers. General layout of a typical plant is given in Fig. 8. Listed in order of importance as objectives, the several parts are station building, outdoor electrical equipment, cooling towers (if present), coal handling facilities (less storage), and miscellaneous yard buildings.

Fig. 7—*General Layout of a Typical Steam Electric Station*

Target No. 90.20-1598 Photography 19 Jan 45



3 Important Equipment: This consists of turbo-generators, condensers, boilers, and transformers. The photographs following show such equipment and where it is installed in the plant.

Figs. 8 to 12—*Important Equipment in Steam Electric Stations*

Target No. 90.25-540A

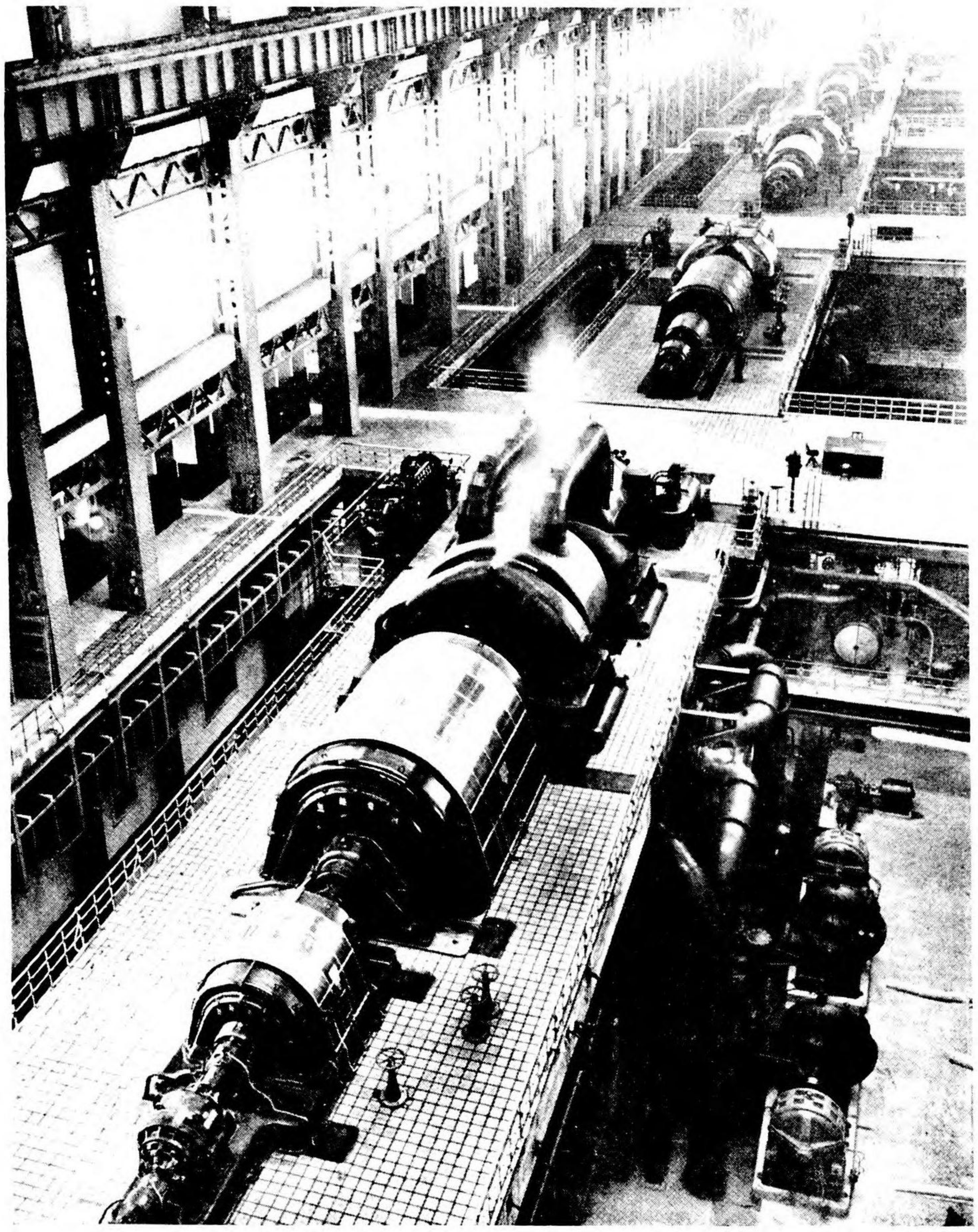


Fig. 8.

Turbo-generators in the turbine room of the Kansai Kyodo Steam Power Plant No. 1, Amagasaki. Each unit consists of turbine, main generator, house generator, and exciter, all mounted on a single shaft. It is rated at 53,000 kilowatts; manufacturer, Shibaura. Overall length is about 75 ft.

Target No. 90.34-1127

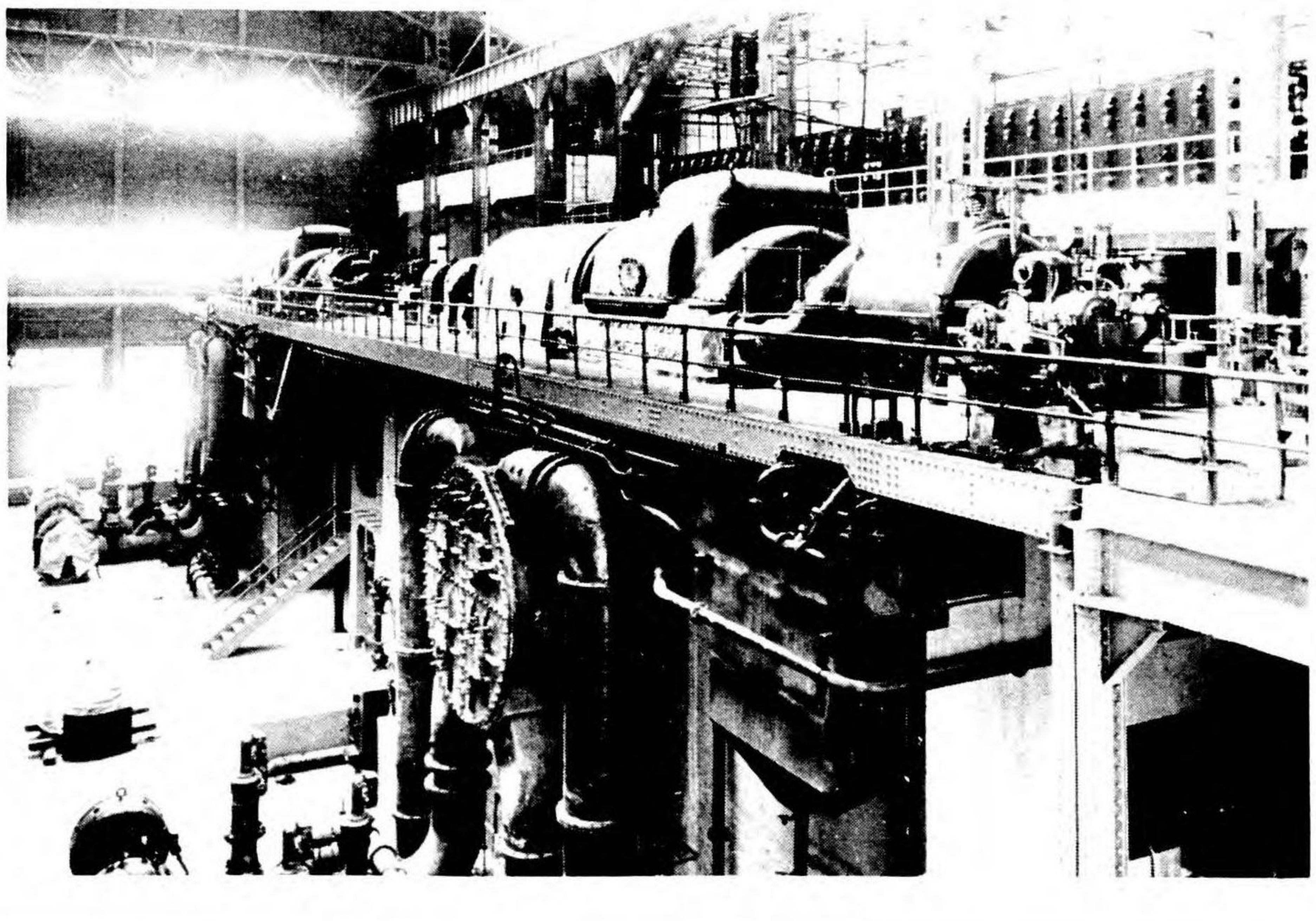


Fig. 9.

Two of four turbo-generators in the turbine room of Kokura Steam Power Plant No. 1, Kyushu. End cover plate and water connections for the condensers show underneath the turbo-generators.

(303)

Target No. 90.34-1127

Fig. 10.
Transformers in the electrical room of Kokura Steam Power Plant No. 1, Kyushu.

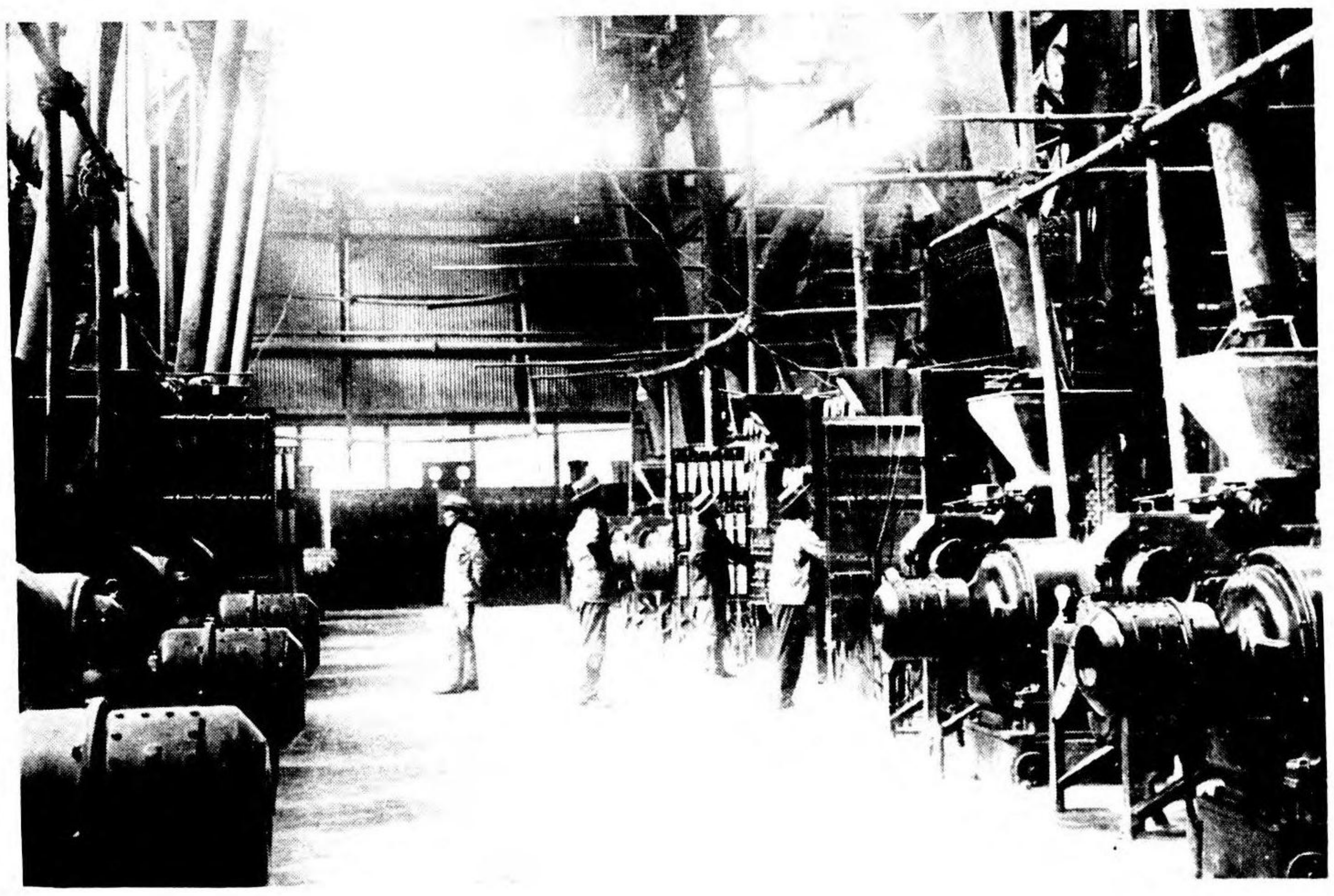


Fig. 11.
Boilers and firing aisle of the boiler room, same plant as above.

Target No. 90.25-540A

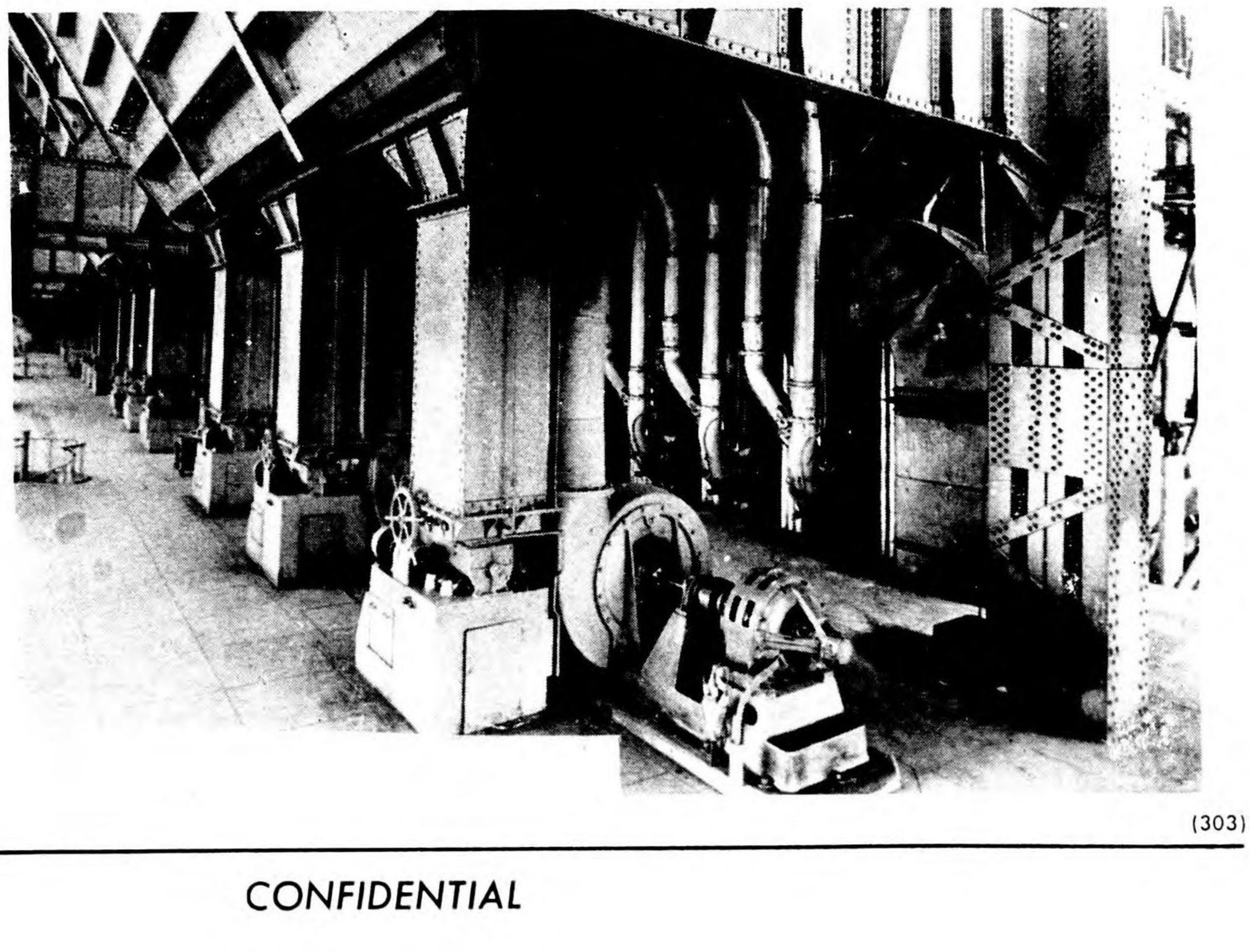


Fig. 12.
Coal pulverizers and lower section of bunkers, boiler room, Kansai Kyodo Steam Power Plant No. 1.

REPRINT

C. STRUCTURAL ANALYSIS

Structural characteristics of the target which determine the choice of weapons are given in a structural analysis. This consists of a description of materials used in construction, spacing of the structural elements, size of buildings, and built-upness of the site. It is discussed here under the headings of (1) Site, (2) Primary Objective, and (3) Other Objectives.

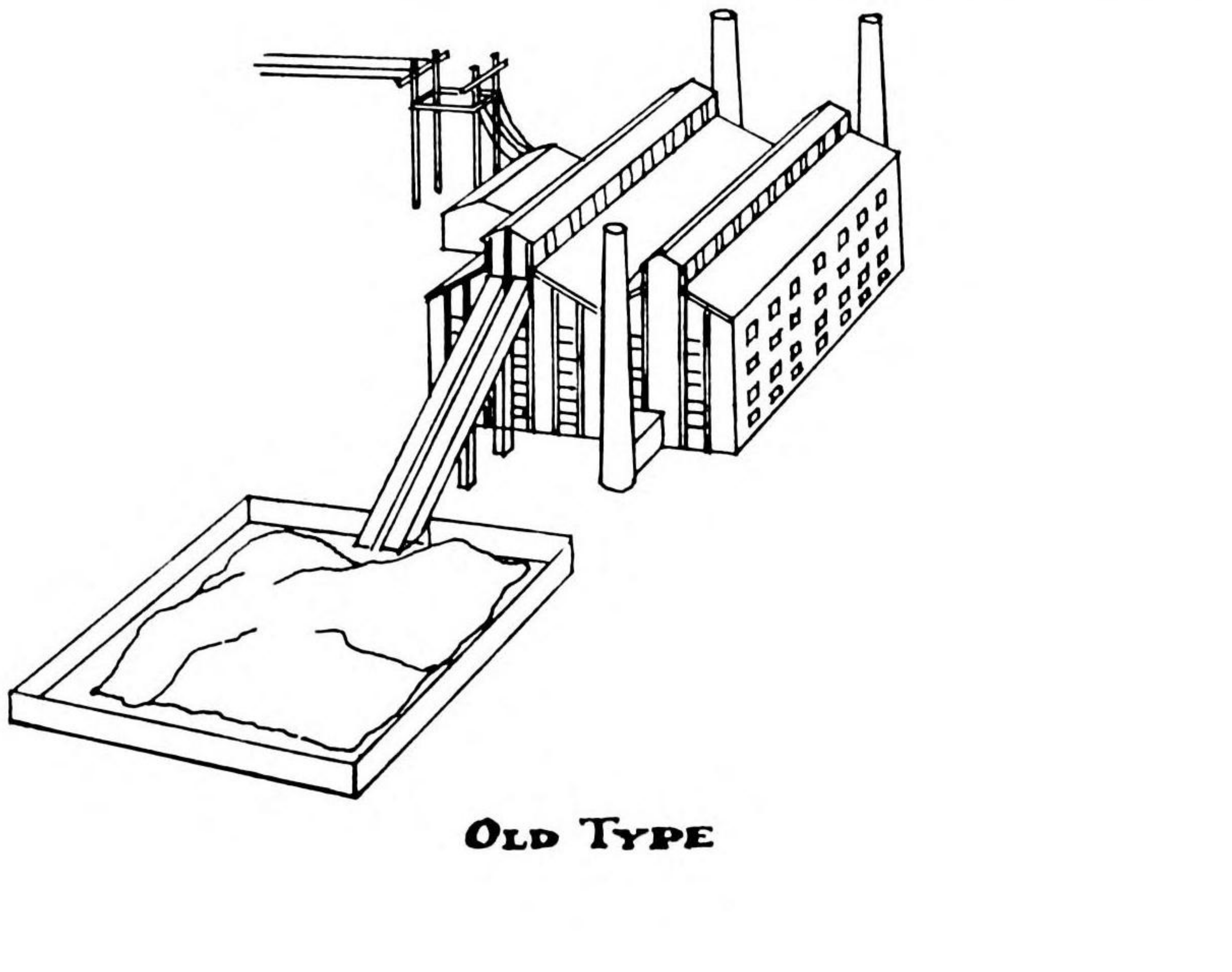
1 Site: This is generally rectangular in shape with sides ranging from 500 to 1,500 ft. One or two of the property boundaries may conform with a railroad siding or the bank of a river. Built-upness is low. A circle of 500 ft. radius will contain the station building and all of the important yard installations.

2 Primary Objective: The station building is always the primary objective and typically in modern plants is a six or seven story steel frame structure, of reinforced concrete walls, built on reclaimed land. The foundation is a five or six foot thick concrete mat laid over concrete caissons or wooden piling. The roof is a flat five inch concrete slab, supported by beams or trusses extending across the boiler room and the turbine room. An overhead traveling crane is always located in the turbine room. Turbo-generators are at the third floor level, whereas boilers extend from the second floor to the trusses of the roof.

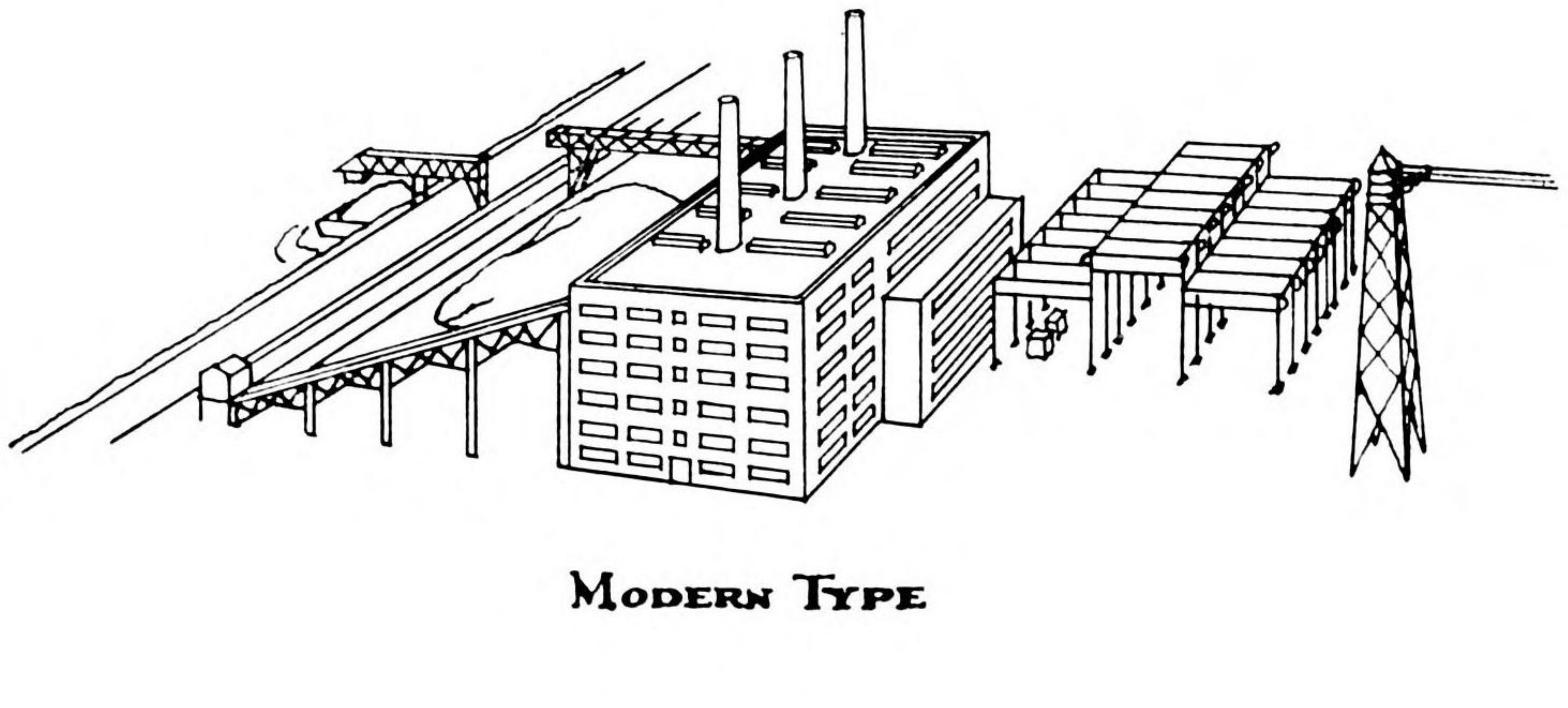
Older stations, built more than twenty years ago, are housed in structures of three or four stories with walls of steel frame and reinforced concrete or of brick. Roofs are pitched and constructed of sheet metal or asbestos. A sketch of the two types is given below. A cross section and ground photographs follow on the next sheets.

3 Other Objectives: These are the yard installations consisting of outdoor electrical equipment, a number of one story wooden buildings used as shops, warehouses, and residences, and coal handling facilities.

Fig. 13—*Types of Station Buildings*



Old Type



Modern Type

Figs. 14, 15—*Ground Photographs of Station Buildings*

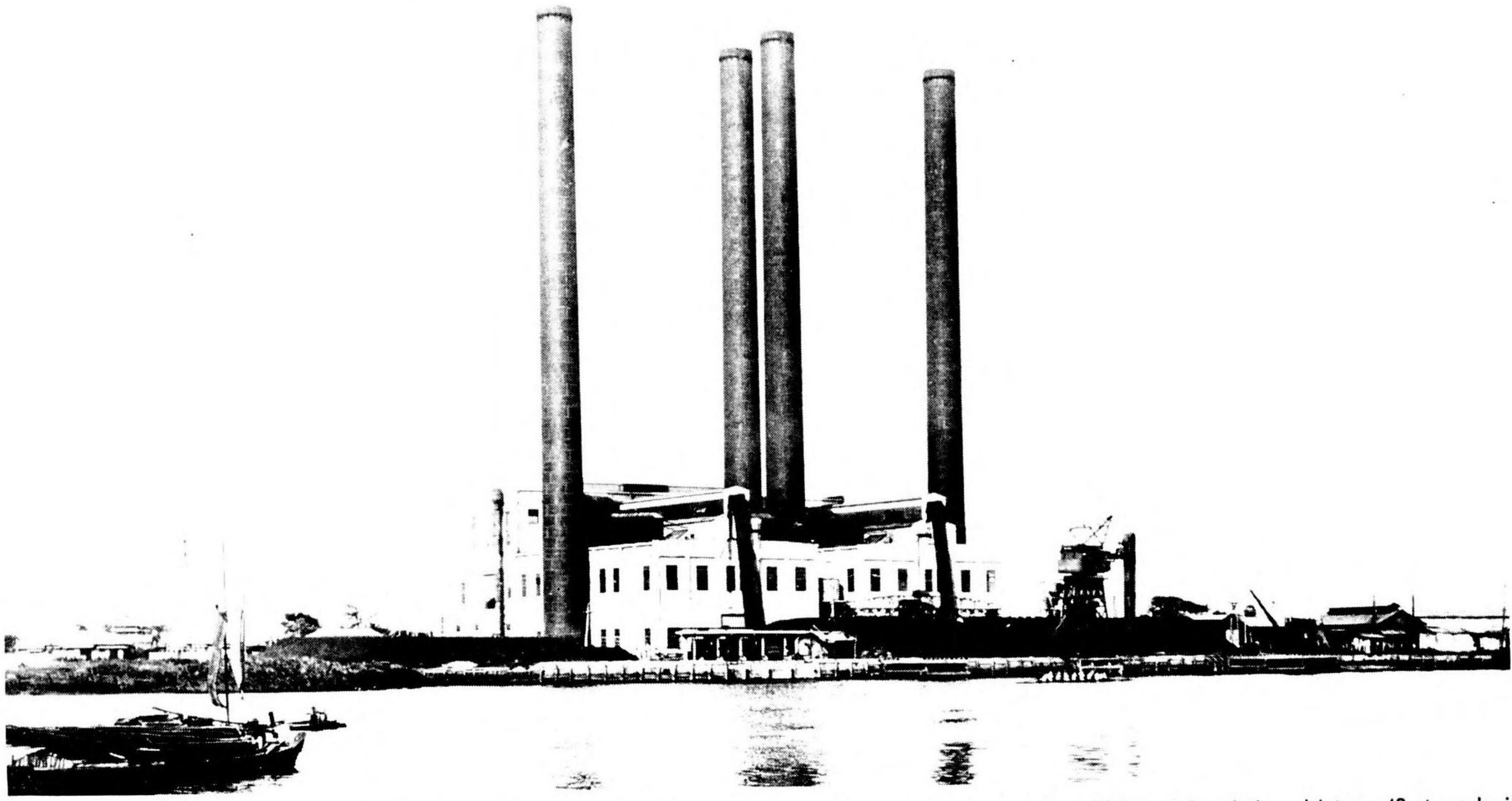


Fig. 14—Target No. 90.17-230 Senju Steam Power Station, Tokyo. This plant was constructed in 1925 and is of the old type (3-story boiler room with low pressure boilers) though it has a 5-story turbine room and flat roof which are characteristics of the modern plants.

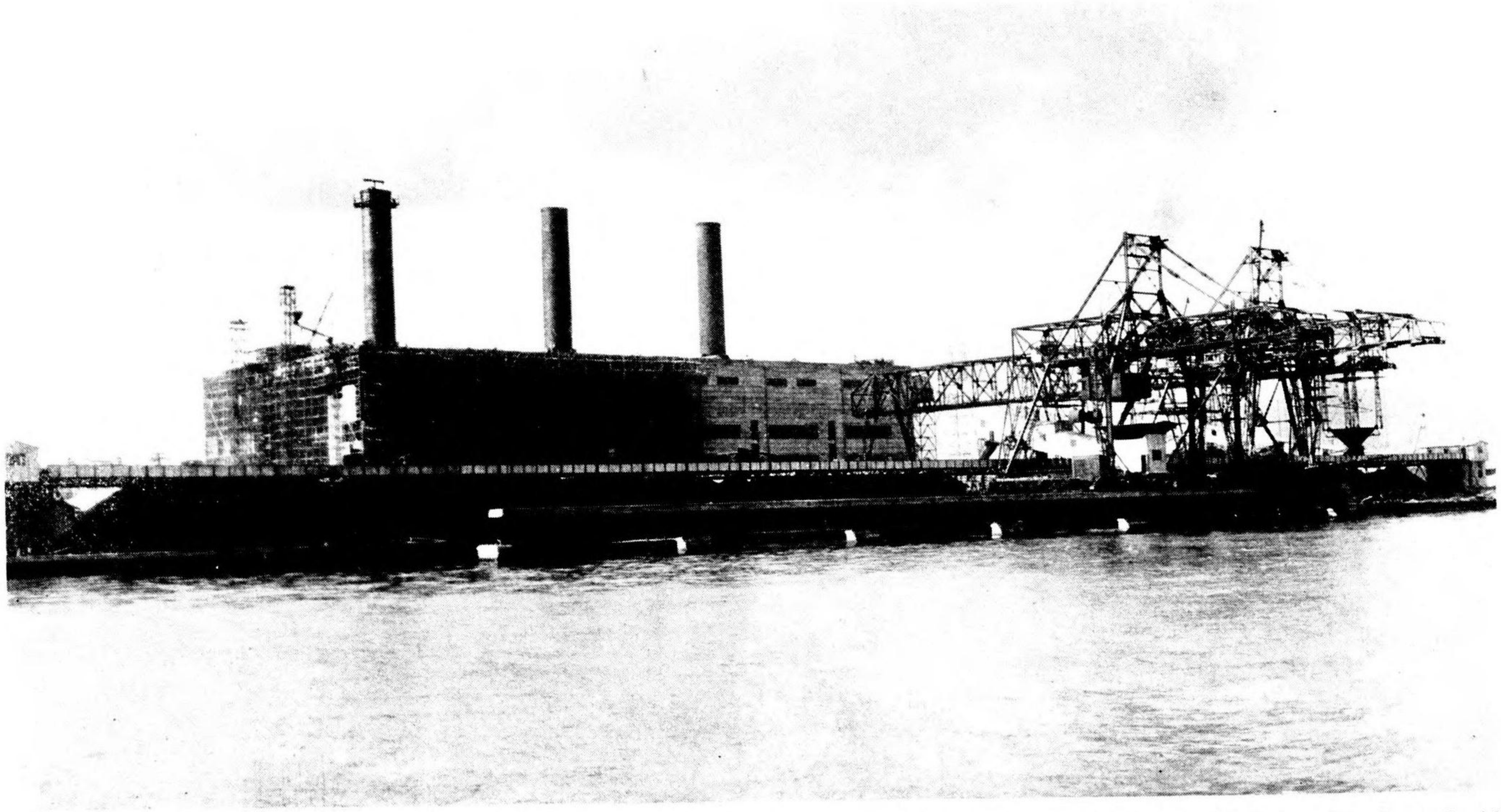
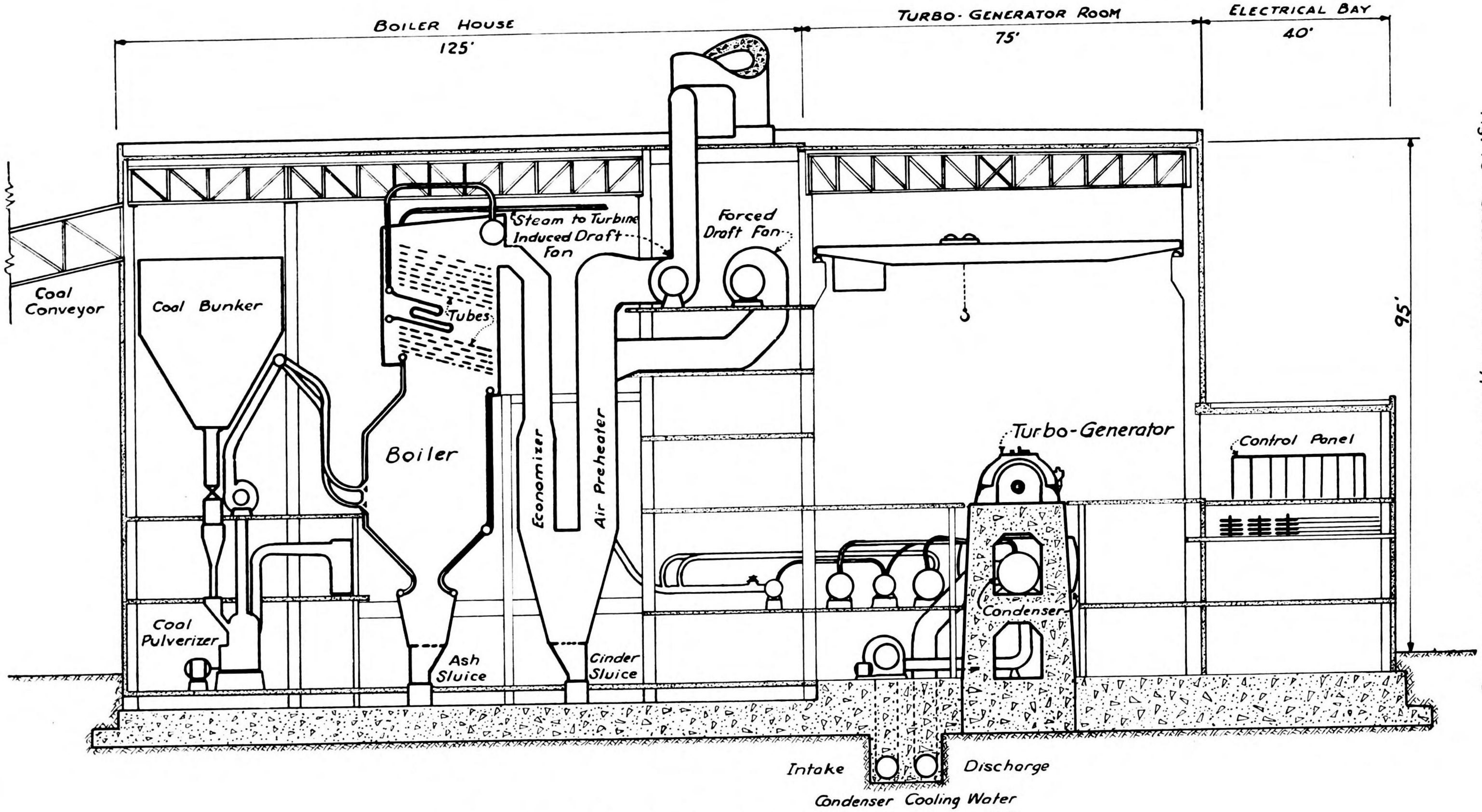


Fig. 15—Target No. 90.25-540A Kansai Kyodo Steam Power Plant No. 1, Amagasaki, during construction in 1933. It has since been doubled in size. See Fig. 3 for recent aerial photography.

REPRINT

Fig. 16—Cross Section of a Typical Steam Electric Station Building



Cross Section of a Typical Steam Electric Station Building

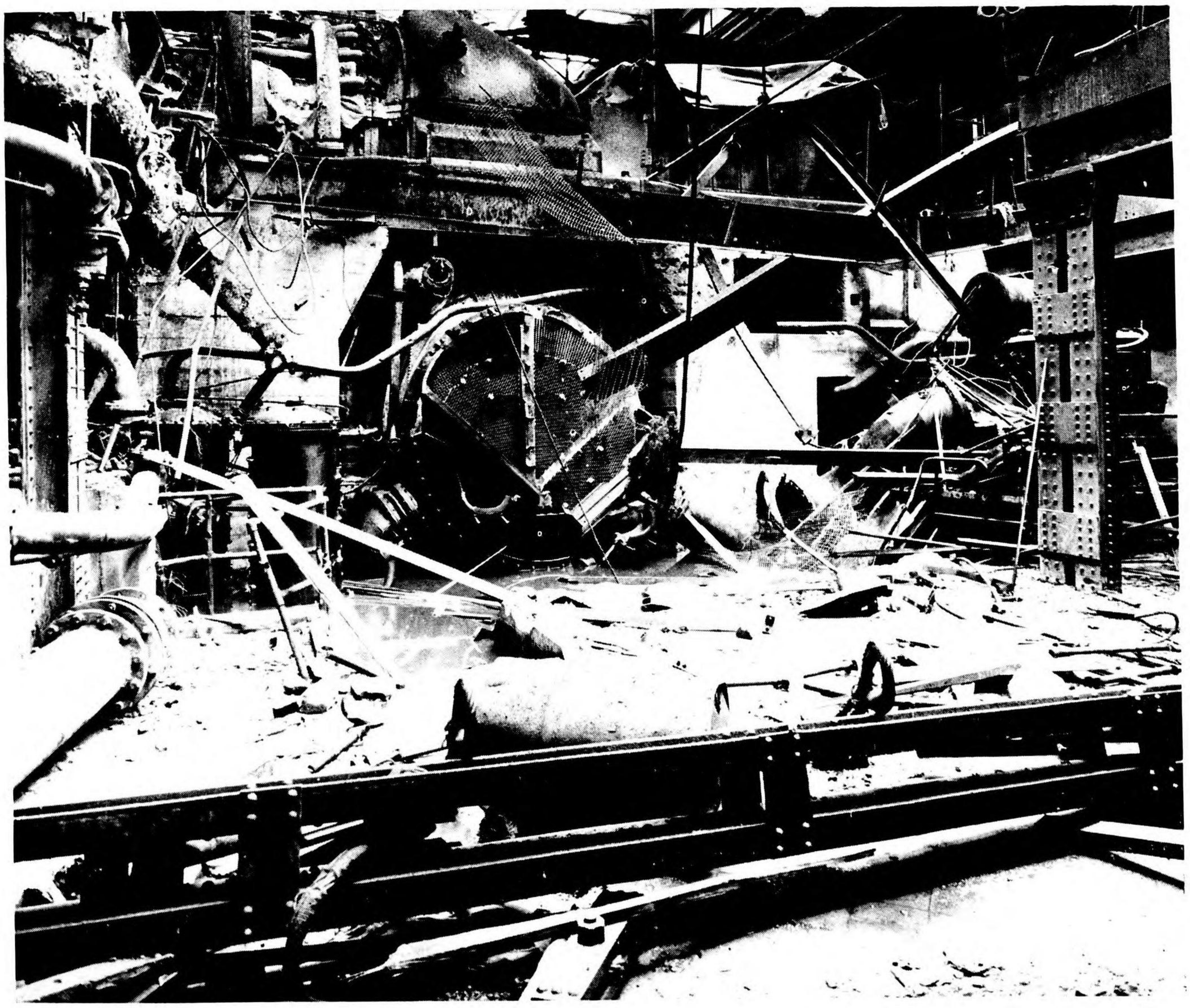
D. DAMAGE ASSESSMENT

Important damage is to the equipment inside of the station building. There seems to be no entirely satisfactory method of estimating this damage from aerial photography, since the customary square foot measure of structural damage to the building is not applicable. Perhaps the most reasonable estimate could be made from a comparison of the location of roof penetrations with the known location of the equipment. MAE's for the various size and fusing of bombs against either boiler or turbo-generator units might then be used as the basis for the estimate.

It may or may not be possible to see in aerial photography smoke rising from the chimneys of power stations. During normal operation all chimneys are seldom used at the same time, and with proper firing, the smoke may be very difficult to see. Cottrell precipitators for elimination of smoke are commonly installed. Thus the absence of smoke or apparent absence is inconclusive as to possible damage.

The photograph below shows a turbo-generator and condenser of a British station hit 4 Oct 1940 by a medium size HE bomb. It exploded four ft below the main floor level about six ft away from the end of the condenser, which received the major portion of the impact of the explosion. New castings were required, and the outage of the particular set lasted for six months.

Fig. 17—*Damage to Turbo-generator Unit*



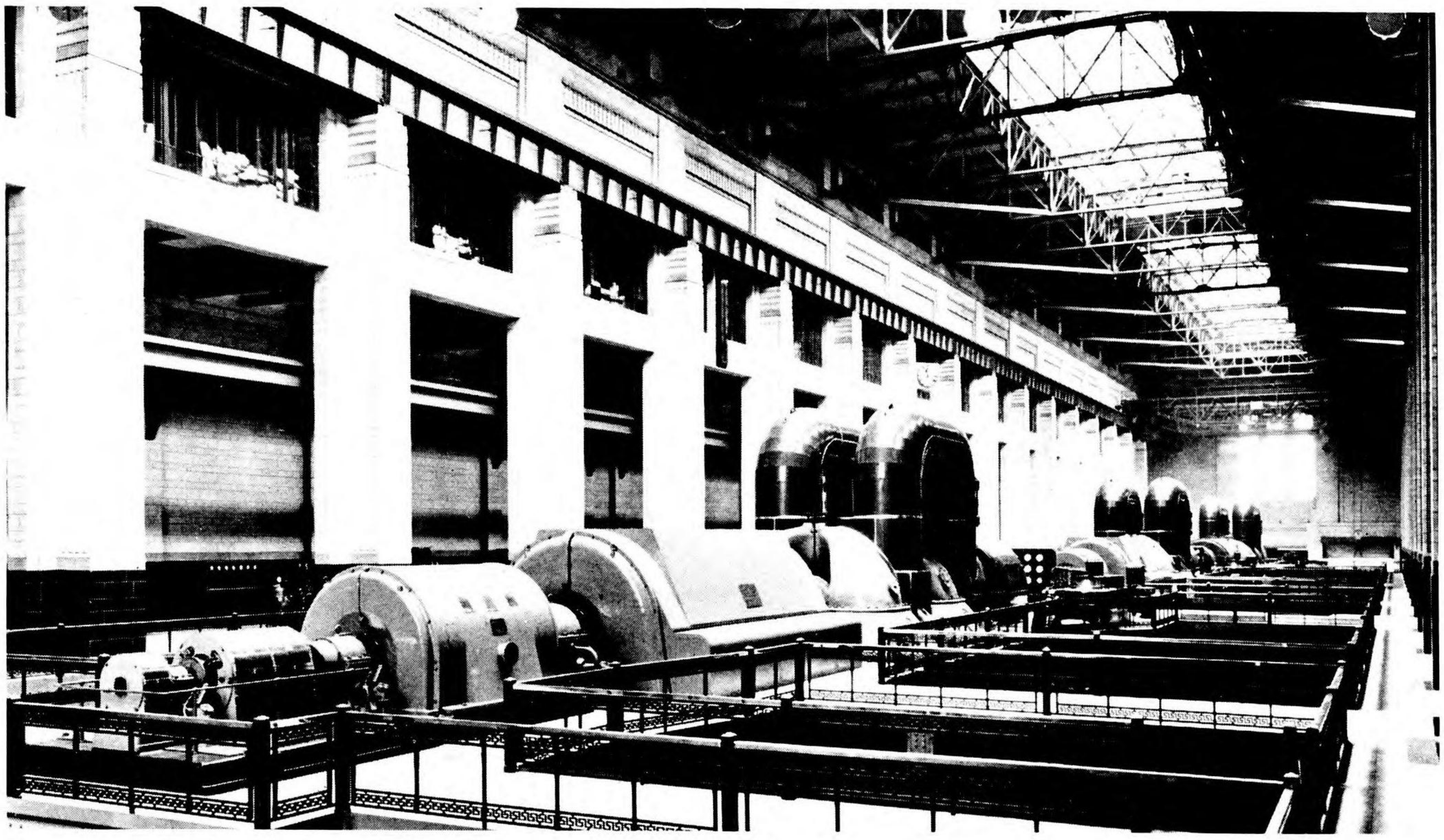
E. PROTECTIVE MEASURES

Protection against direct hits is entirely impracticable, but protection against blast and fragments of near misses has undoubtedly been provided for certain pieces of equipment inside of the station building. Isolating and blast walls are used outside of the building in outdoor electrical equipment in which fire damage is a hazard even in peace-time operation. Personnel shelters of concrete or sand bags, each for two or three people, are probably installed at various points throughout the plant.

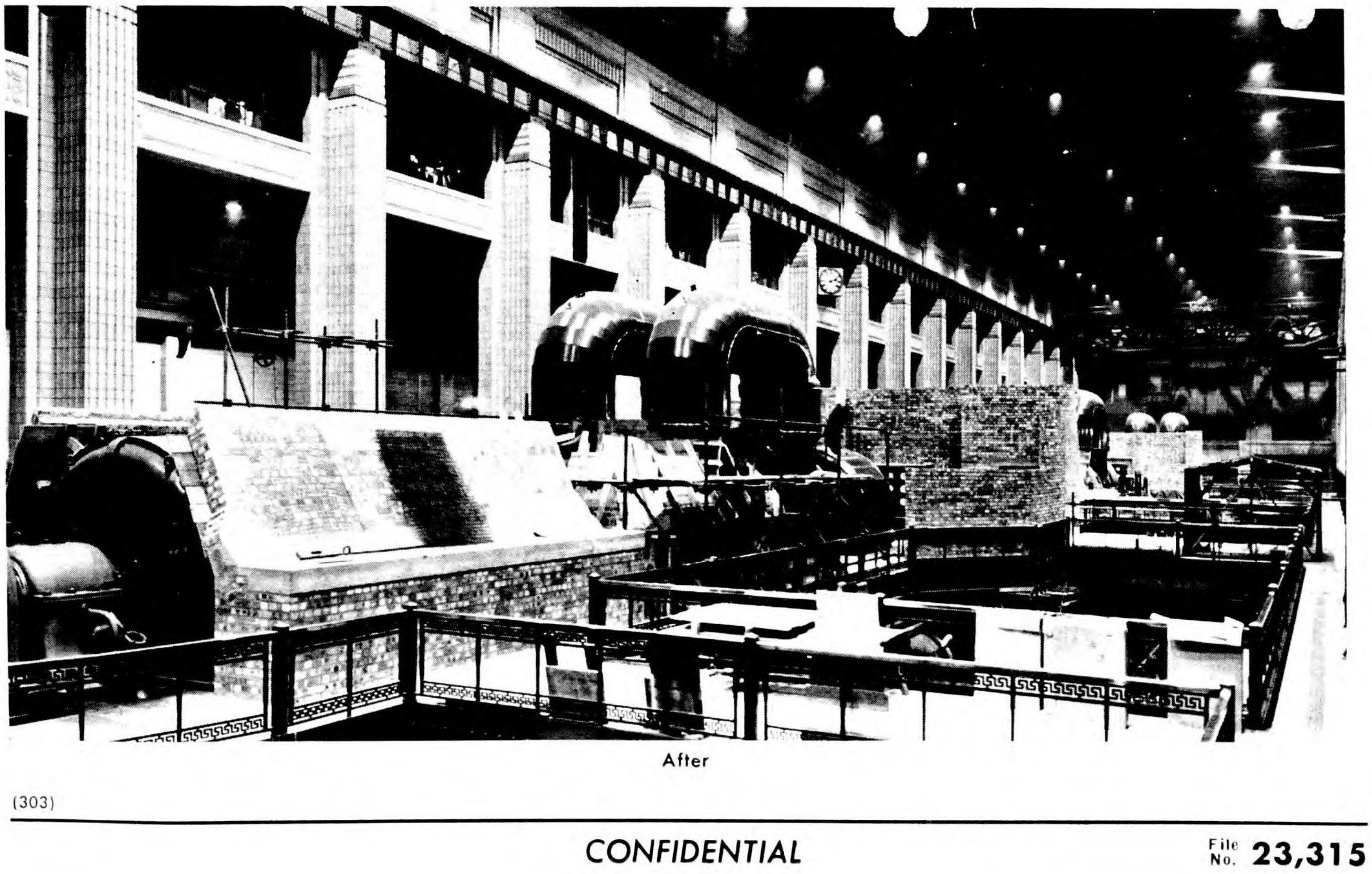
Unquestionably regional and national pools of supplies have been organized from which critical material can be drawn to effect immediate repairs. Some equipment, individually designed, of course, cannot be pooled. Construction personnel is likely to be organized into repair teams to assist on jobs not readily handled by an individual station's normal crews.

The before and after photographs below show protection installed for turbogenerators at a British station.

Fig. 18—*Protection of Turbo-generators*



Before



After

SECTION 2—HYDRO ELECTRIC STATIONS

A. RECOGNITION

Outstanding identifying feature of these stations is the penstocks, though some plants installed directly at the base of dams may have none visible. Due to their remote and isolated locations, hydro electric stations are not likely to be confused with other industries. The following are the most important recognition features of a typical plant:

Figs. 19 to 22—*Recognition Features of Hydro Electric Stations*

(1) Penstocks
(2) Riverbank Location
(3) Dam
(4) Station Building
(5) Outdoor Electric Equipment
(6) Tail Race
(7) Transmission Towers

Fig. 19—Target No. 91.4-82 Photography 13 Oct 44

Annotation refers to features as numbered above

See Fig. 30 for results of an attack against this target on 23 March 1945.

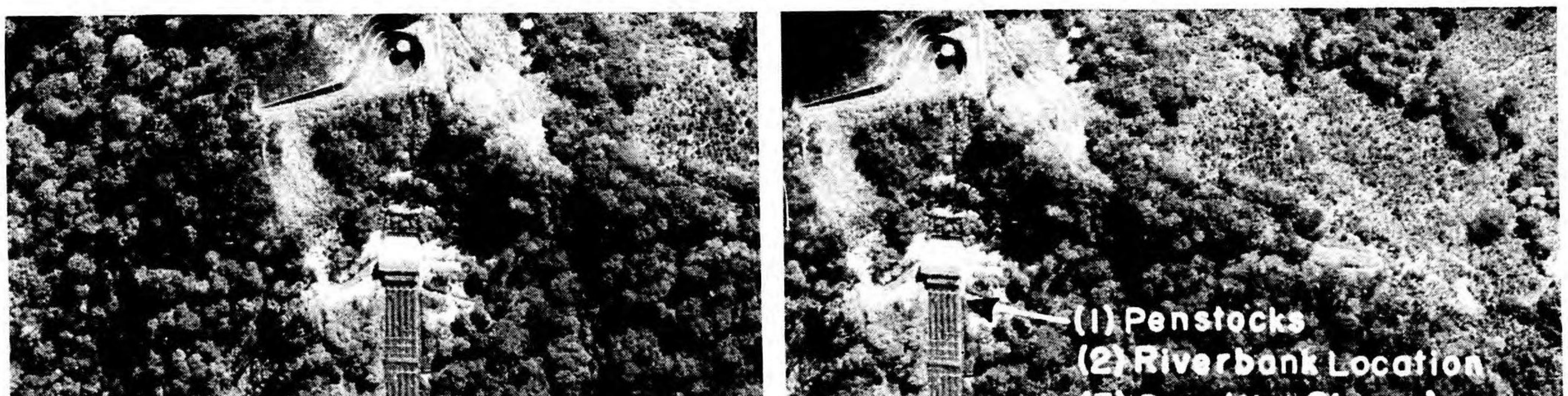


Fig. 20—Target 91.4-83 Photography 13 Oct 44
Jitsugetsutan (Formosa) Power Plant No. 2
Penstock type
See Fig. 31 for results of an attack against this target on 23 March 1945.

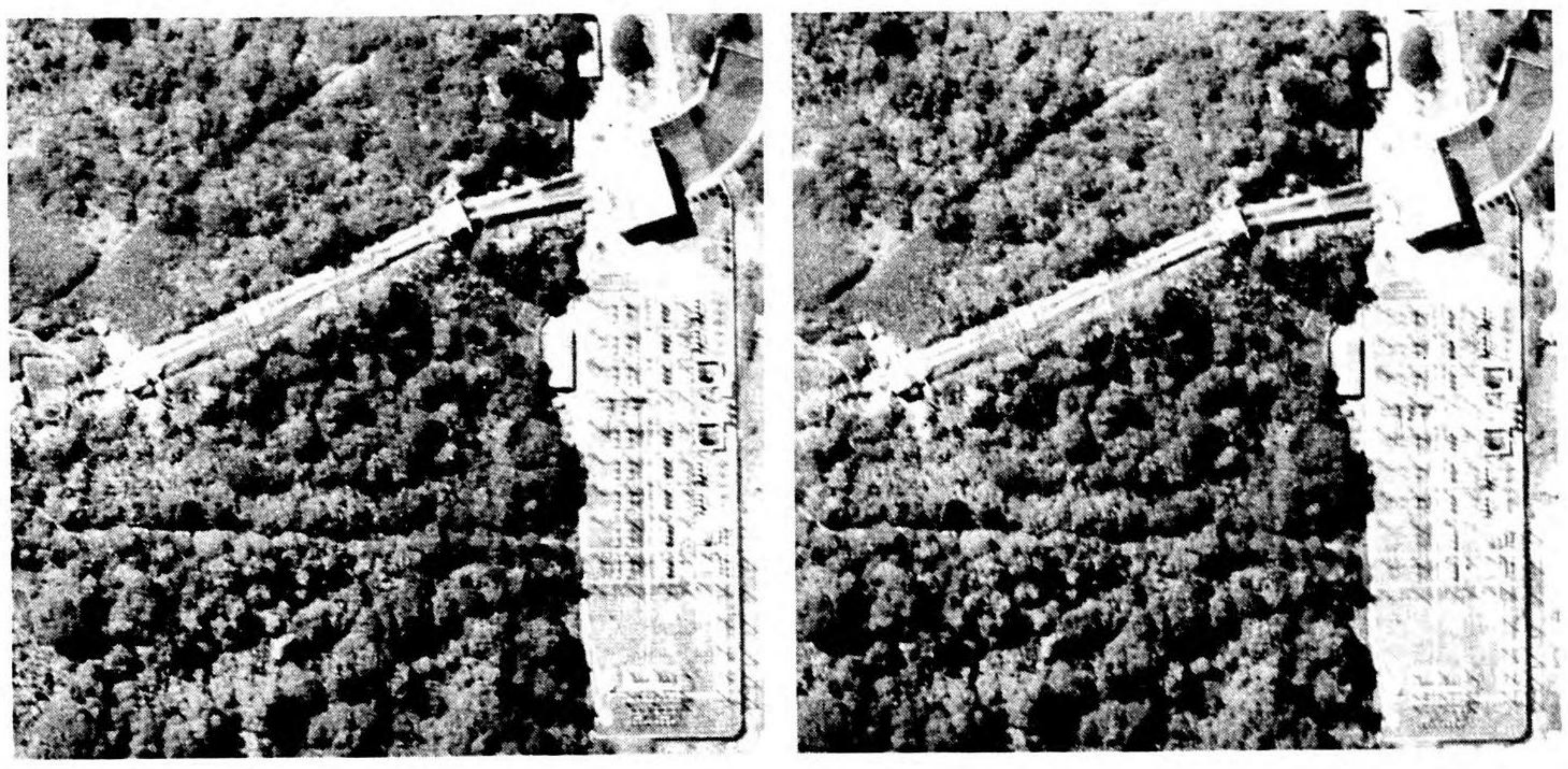


Fig. 21—Target No. 90.20-1614
Kaneyama Hydro Electric Station near Nagoya
Photography 12 March 45. Installed capacity 37,000 kw.
Dam-type, no exposed penstocks.

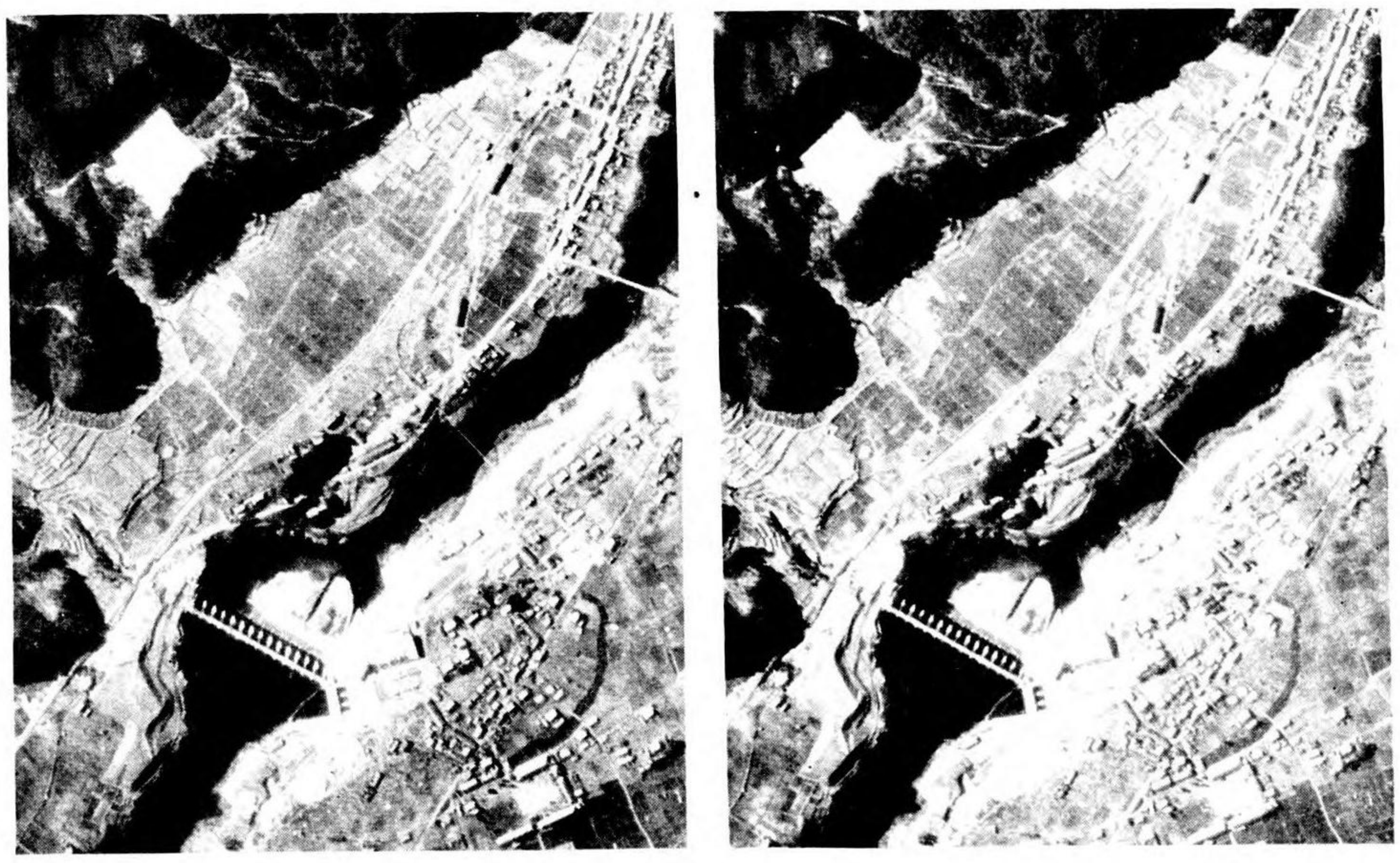
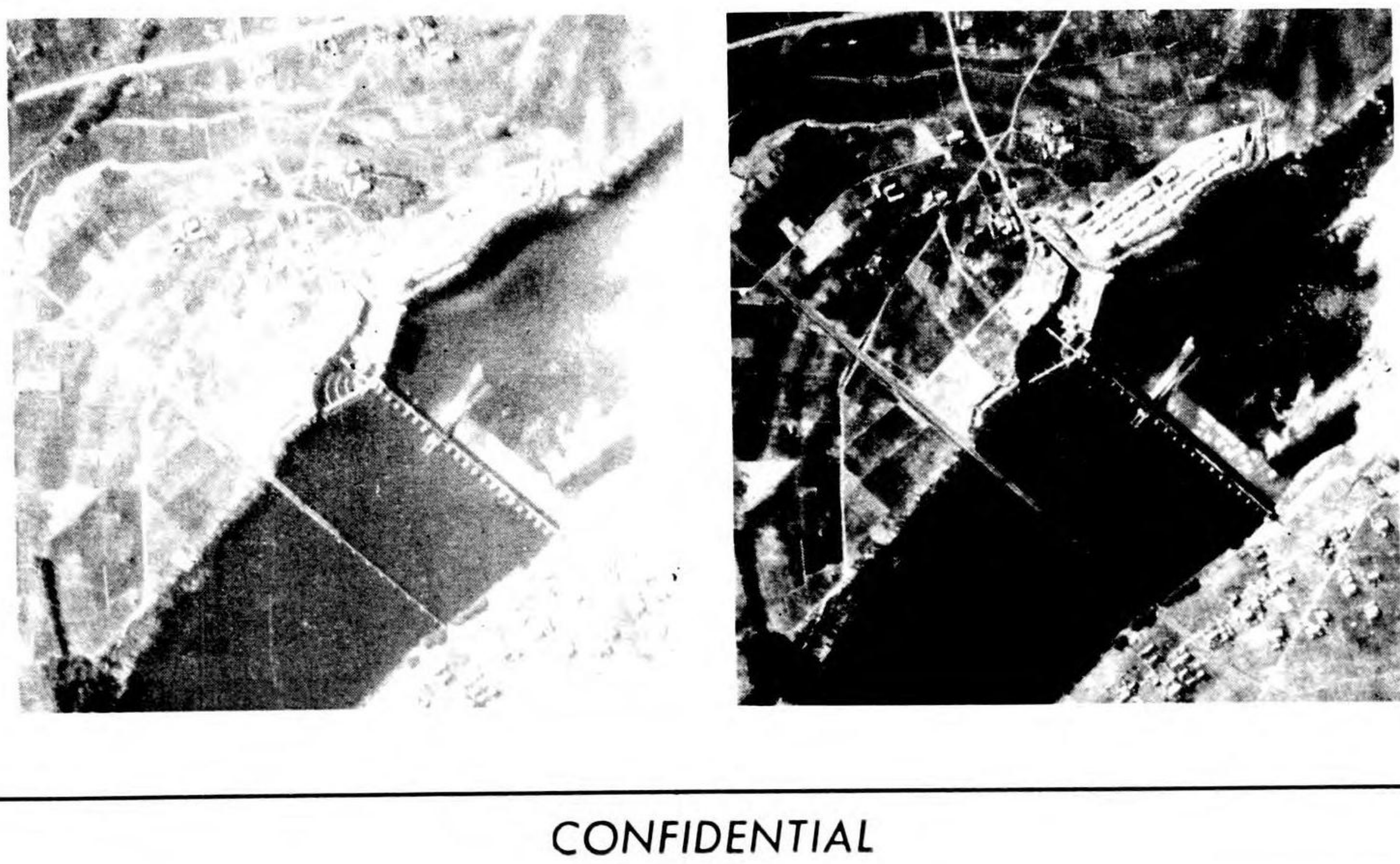


Fig. 22—Target No. 90.20-2076
Imawatari Hydro Electric Station near Nagoya
Photography 12 March 45. Installed capacity 20,000 kw.
Dam-type, no exposed penstocks.

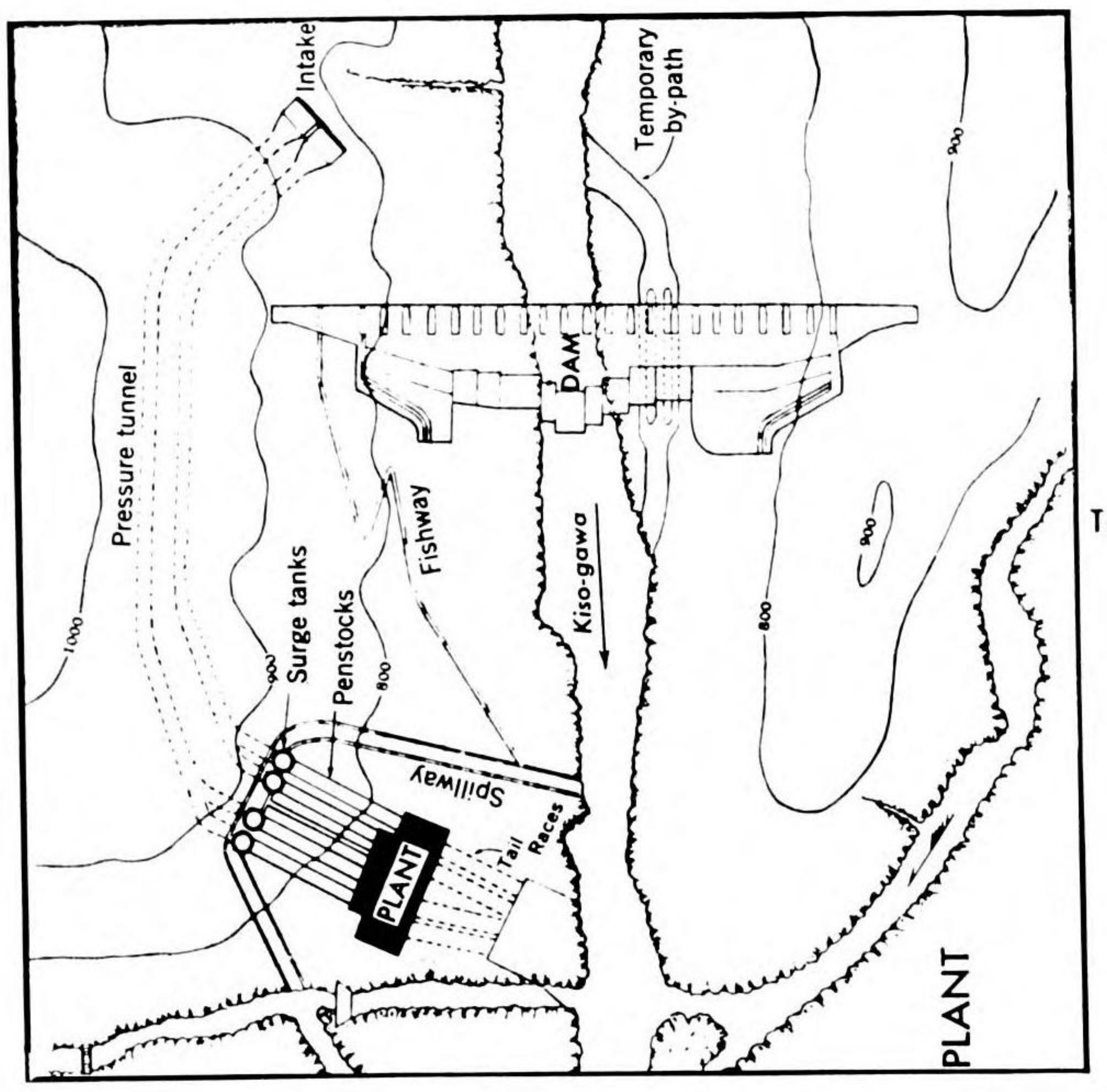


B. FUNCTIONAL ANALYSIS

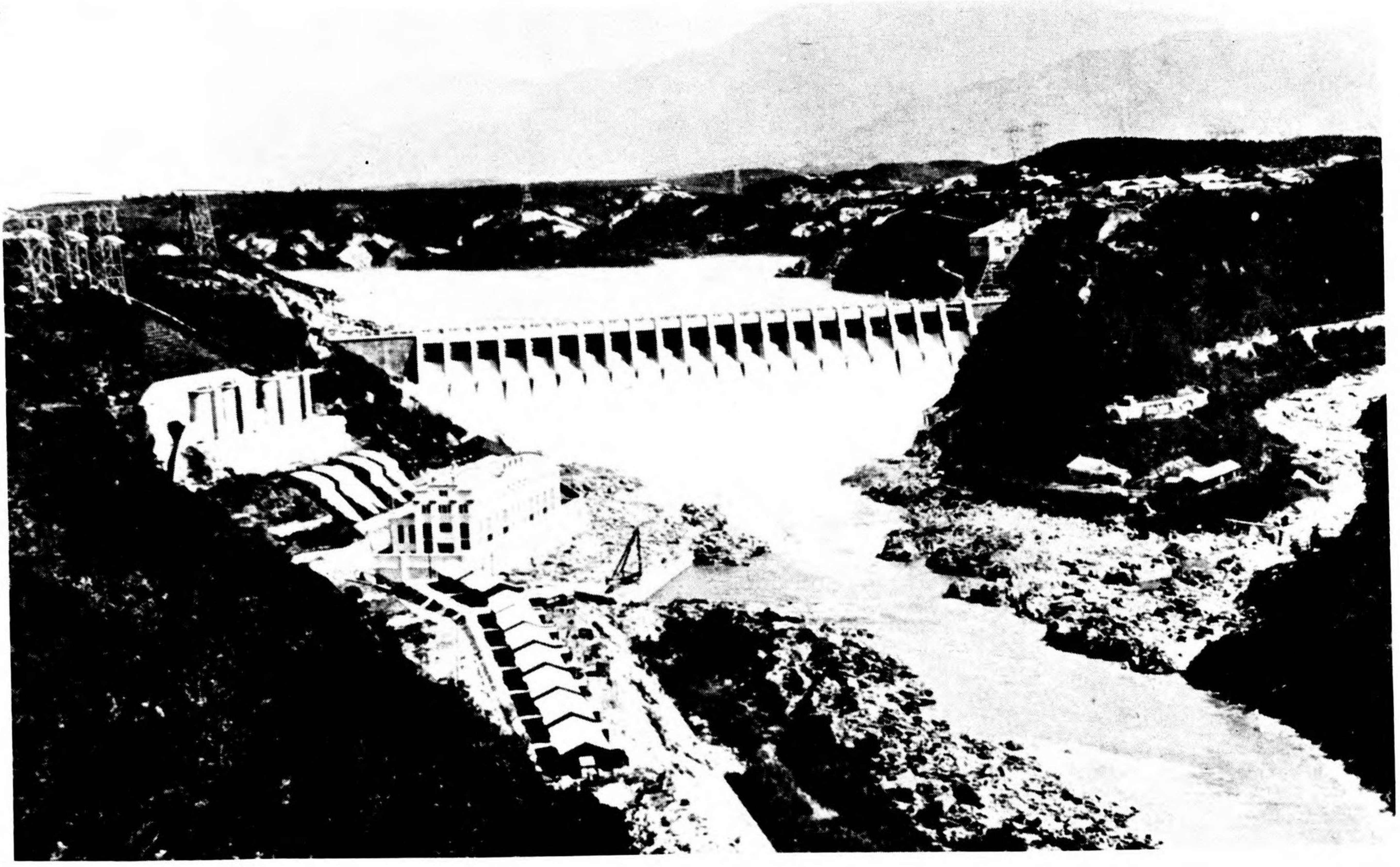
1 The Process: Water under pressure is directed against vanes of a runner which rotates an electric generator. Variation in the type of plants relates (a) to the head of water under which the plants operate and (b) to the size of facilities for storing water behind the dam. High head plants are usually of the exposed penstock type, whereas low head stations, located directly at the base of dams, may or may not have exposed penstocks. Without storage, they are called run-of-stream type and are thus unable to operate except in conformance with the natural flow of water. Japanese plants are of both high head and low head types but generally have only limited storage facilities.

2 General Layout: The illustration below gives the general layout of a Japanese hydro electric installation including both dam and plant.

Fig. 23—*General Layout of a Typical Hydro Electric Station*



Target 90.16-1505

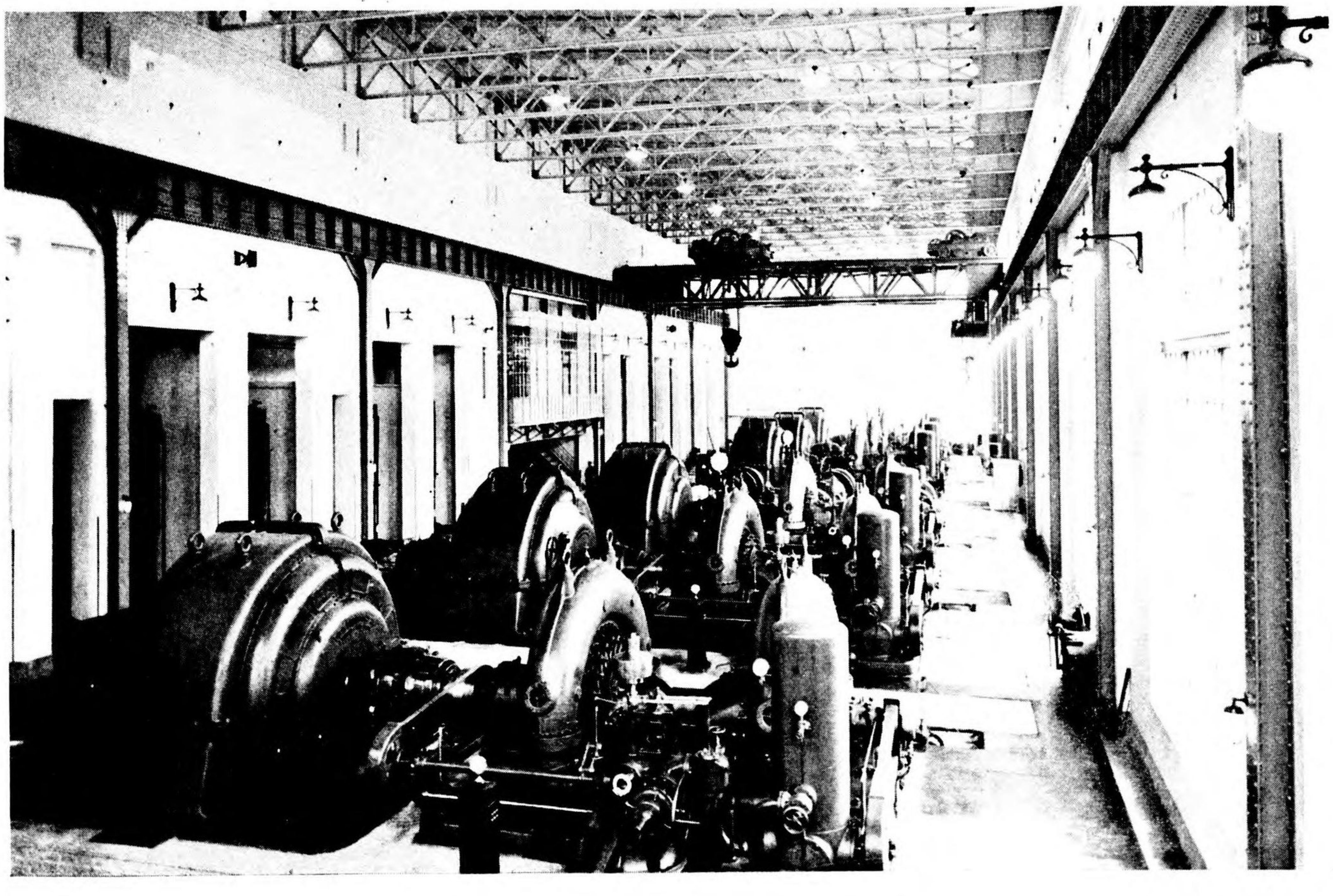


3 Important Equipment: This consists of the dam, penstocks, and generator units inside the station building. Photographs of this equipment are given below and on the following sheets.

Figs. 24 to 27—*Important Equipment at Hydro Electric Stations*

Fig. 24.
Right: Target No. 90.20-1144 Vertical generators in the turbine room of the Seto Hydro Electric Station.

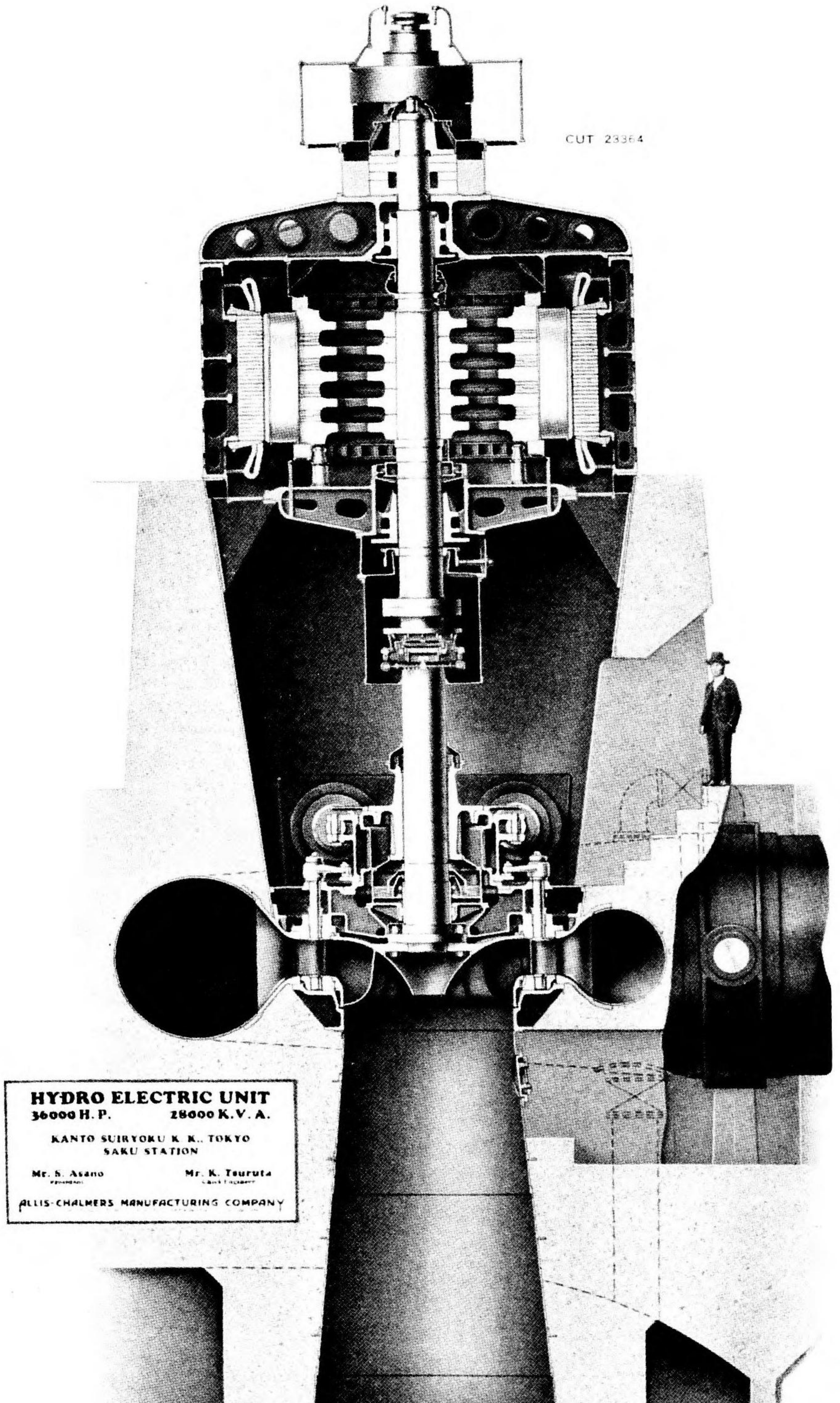
Fig. 25.
Below: Target No. 90.10-881 Horizontal generators at Inawashiro Hydro Plant No. 1.



REPRINT

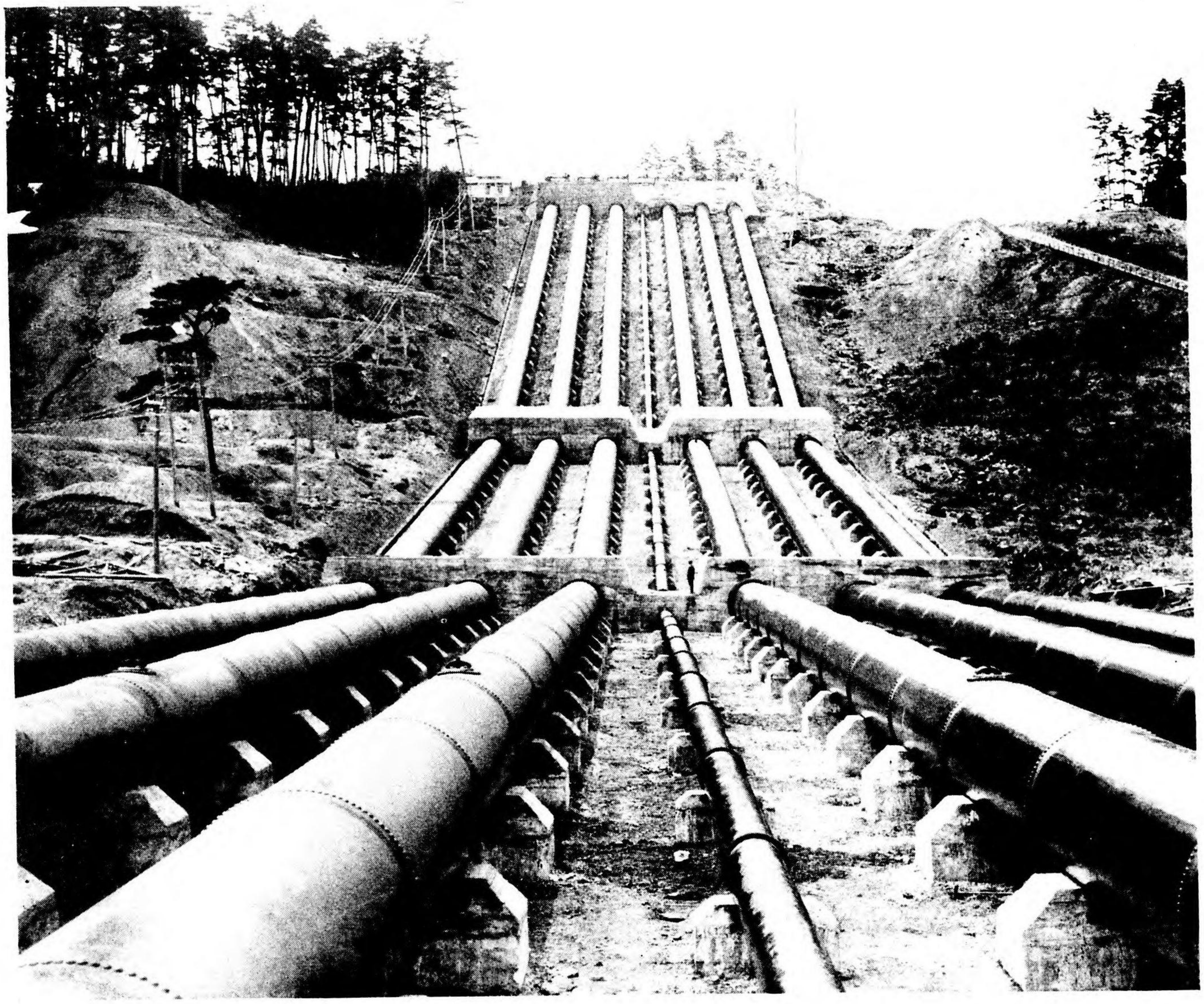
Fig. 26—Cross Section of a Vertical Generator

Target No. 90.13-1059



REPRINT

Fig. 27—*Penstocks.* Target No. 90.10-881. Those of more recent construction are welded at the joints instead of riveted. The small pipe line is for operation of pressure governors.



C. STRUCTURAL ANALYSIS

1 Site: Although located away from the cities, Japanese hydro electric stations are found on the banks of streams and thus frequently are crowded due to the mountainous topography through which the rivers flow. Shape and boundaries of the site have no particular significance. The dam and plant may be separated by as much as seven miles.

2 Primary Objective: This may be either the dam, penstocks, or station building. The relative importance and vulnerability of each vary widely for different installations, and the one selected as the primary objective must be determined separately in each case.

The station building is typically a three or four story steel frame structure of reinforced concrete walls and a five inch concrete slab roof. A massive concrete substructure rises from solid foundation to the level of the basement floor. For vertically mounted generators, the runner is placed below low water level of the tail race, and the generator is set above high water level which is usually the second floor of the building.

3 Other Objectives: The part of an installation not usually included as a primary objective is the outdoor electrical equipment, which is principally oil circuit breakers and transformers. The latter are sometimes located inside the station building instead of in the yard.

Fig. 28—*Primary Objective.* Target No. 90.20-1144

(Station building and adjoining section of penstocks)

Fig. 29—*Other Objective.* Same target (Outdoor electrical equipment)

REPRINT

D. DAMAGE ASSESSMENT

The following two strike photographs, taken 23 March 1945 of hydro electric plants at Lake Jitsugetsutan, Formosa, show the type of damage that results from air attack of these installations.

Figs. 30 and 31. *Damage of Hydro Electric Stations*

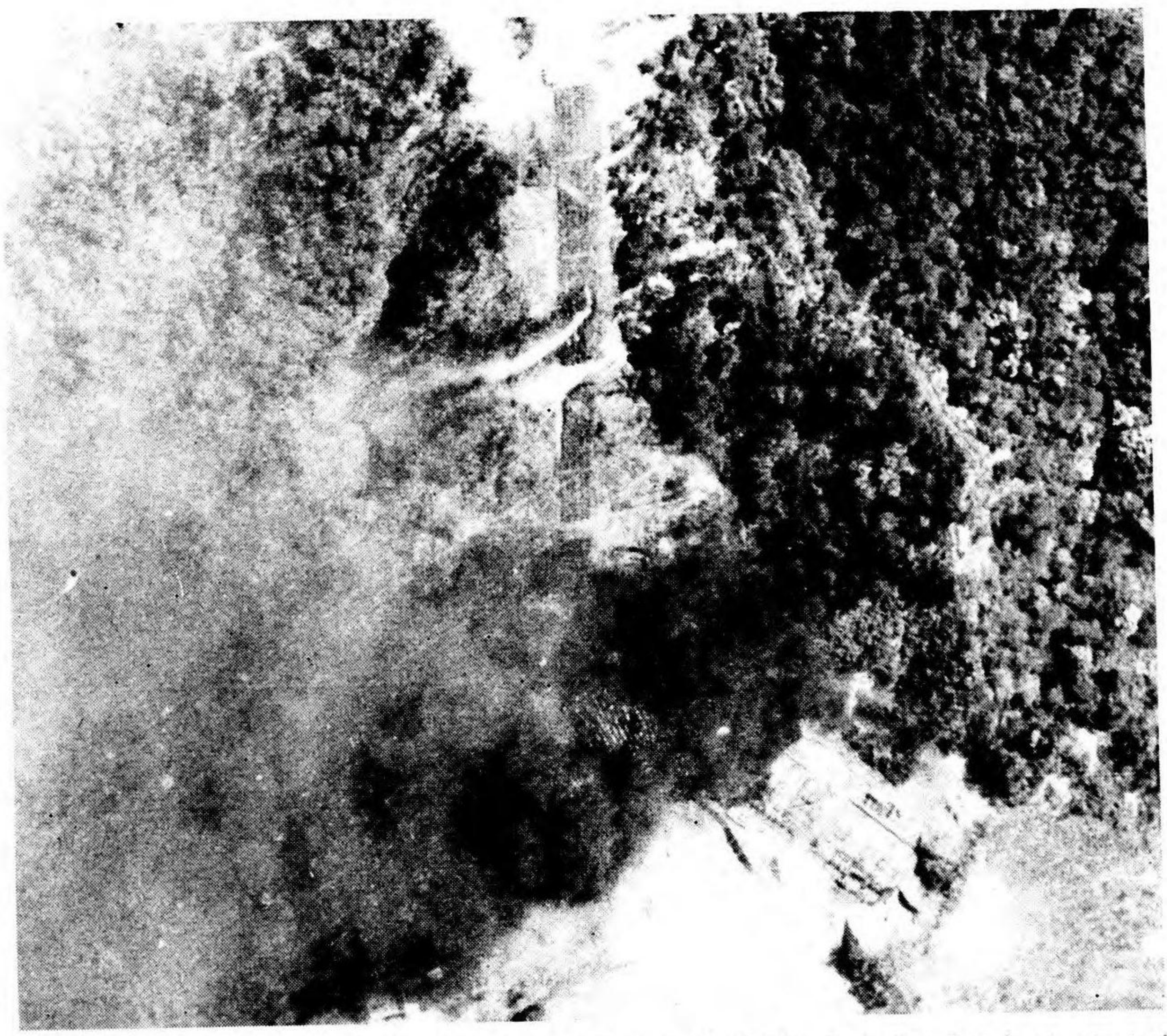


Fig. 30—Target No. 91.4-82 Jitsugetsutan Power Plant No. 1. A fire has been started in one end of the transformer yard and two geysers of water are spouting from ruptured penstocks.

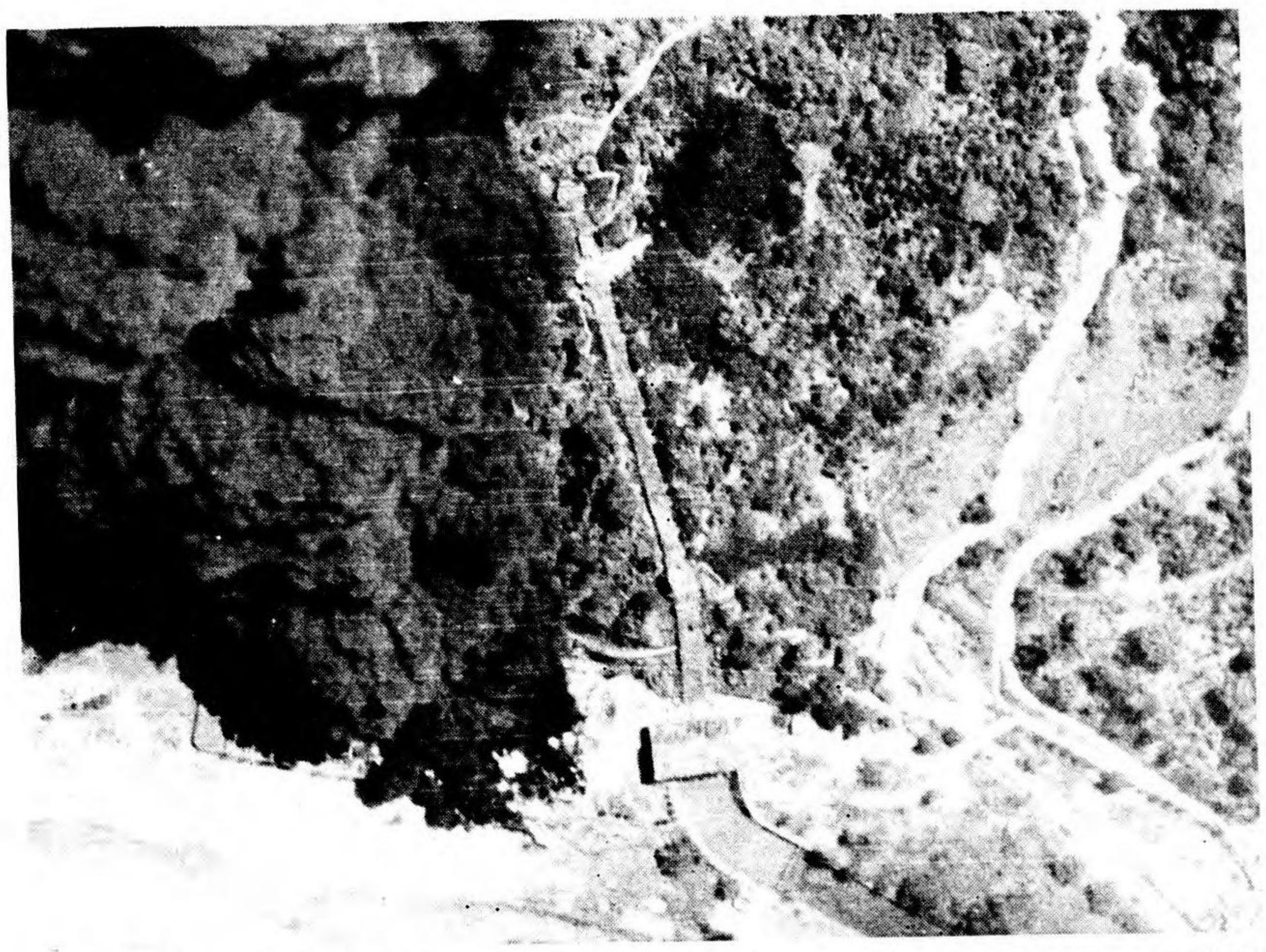


Fig. 31—Target No. 91.4-83 Jitsugetsutan Power Plant No. 2. An oil fire has engulfed the entire transformer yard and the lower section of a penstock has been ruptured.

SECTION 3—SUBSTATIONS

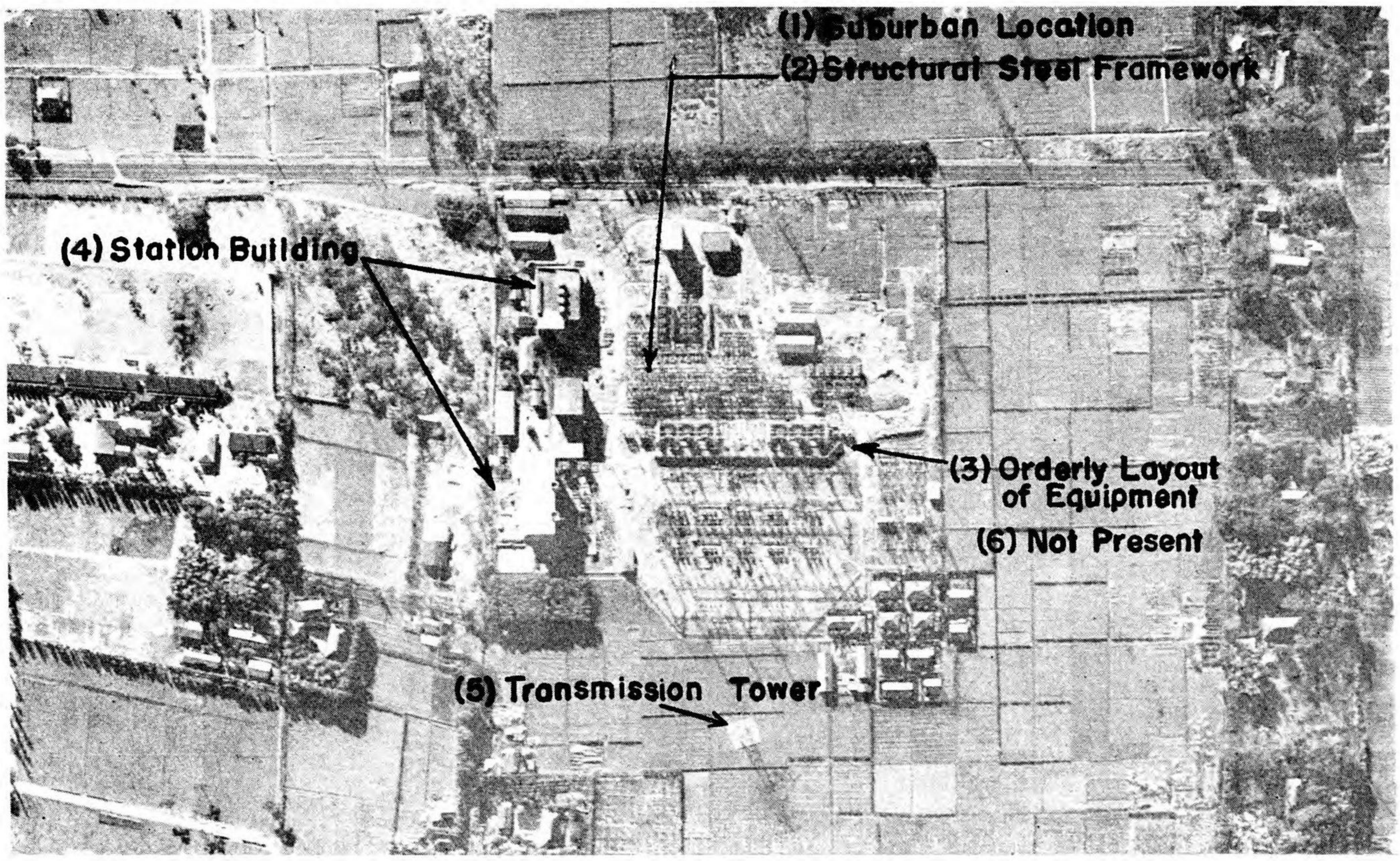
A. RECOGNITION

Principal features by which substations may be recognized in aerial photography are as follow:

(1) Suburban Location
(2) Structural Steel Framework
(3) Orderly Layout of Equipment
(4) Station Building
(5) Transmission Towers
(6) Reservoir

Figs. 32, 33, 34—*Recognition Features of Substations*

Fig. 32—Musashino Substation   Tokyo Area
Photography 16 Jan 45   Annotation refers to features as numbered above



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

Fig. 33—Target 90.25-1629 Photography 4 Feb 1945

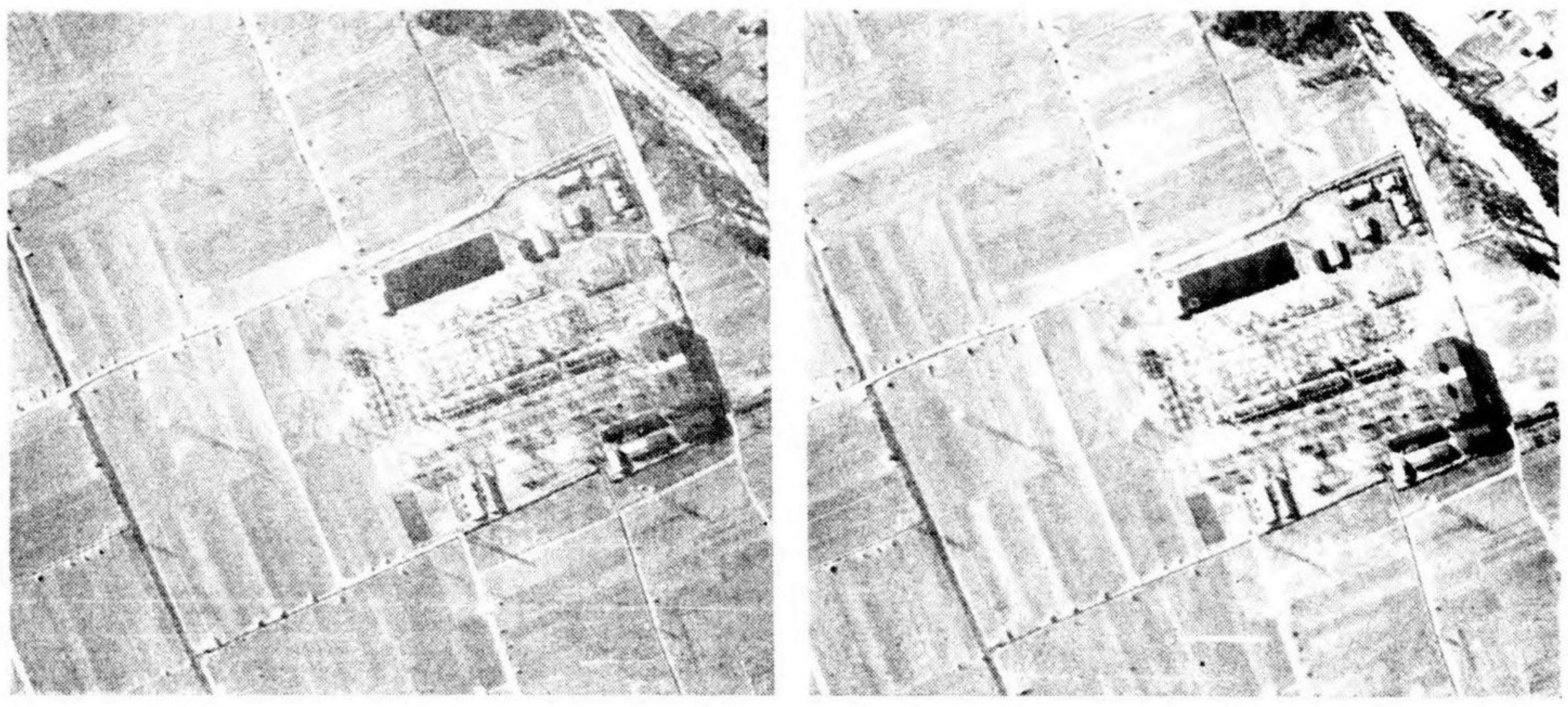
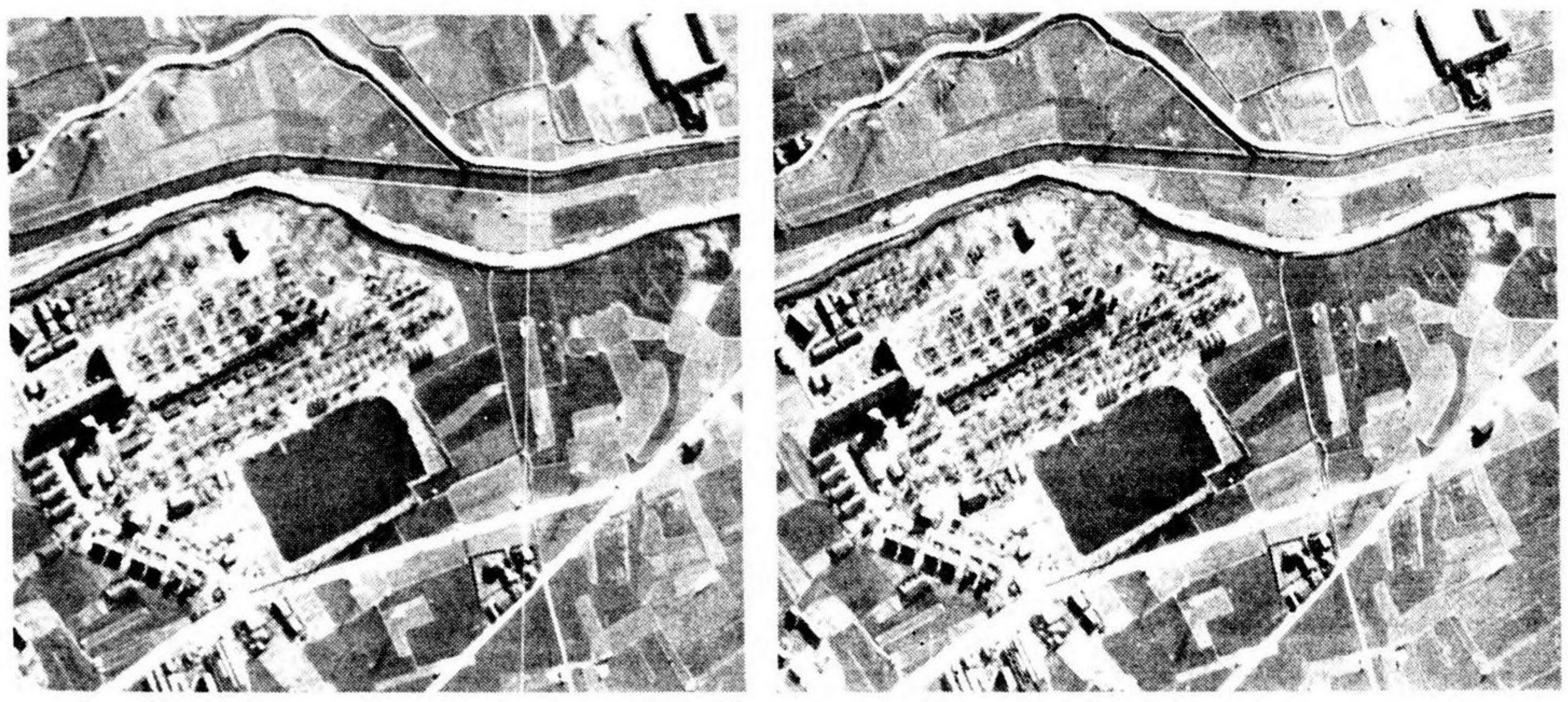


Fig. 34—Target 90.25-1630 Photography 4 Feb 1945



(1) *Suburban Location:* The large step-down substations, which are the most important of the various types of substations, are located in rings of six to twelve stations around Tokyo, Nagoya, and Osaka. Tokyo has an inner and outer ring. They are not generally found in the congested districts.

(2) *Structural Steel Framework:* The exposed steel supporting structures, seen in their square bay arrangement, give a characteristic checkerboard effect.

(3) *Orderly Layout of Equipment:* Even though individual units may not be seen, the orderly arrangement of transformers and circuit breakers in parallel rows is always apparent. Circuit breakers appear in groups of three per bay; transformers, as one or three per bay. Large stations frequently have one spare transformer.

(4) *Station Building:* A two or three story building houses controls and the panel board for the operators. Synchronous condensers may also be inside the building.

(5) *Transmission Towers:* These are usually seen in shadow leading to and away from the substation. They are of two or more different heights. A white square at the base of towers is a concrete foundation.

(6) *Reservoir:* These are seen frequently, and except for water cooling of transformers, their use is not definitely determined.

B. FUNCTIONAL ANALYSIS

1 The Process: Substations are used to step-up or step-down the voltage of current carried by transmission lines. All of them provide facilities for a certain amount of switching, and in some instances may contain nothing but switches (circuit-breakers).

2 General Layout: Transformers are located in a row down the center of the yard. High voltage breakers are in one or two parallel rows on the incoming side; low voltage breakers are on the other side.

3 Important Equipment: This consists of the two pieces of equipment mentioned above, illustrations for which follow.

Figs. 35, 36, 37—*Important Equipment at Substations*

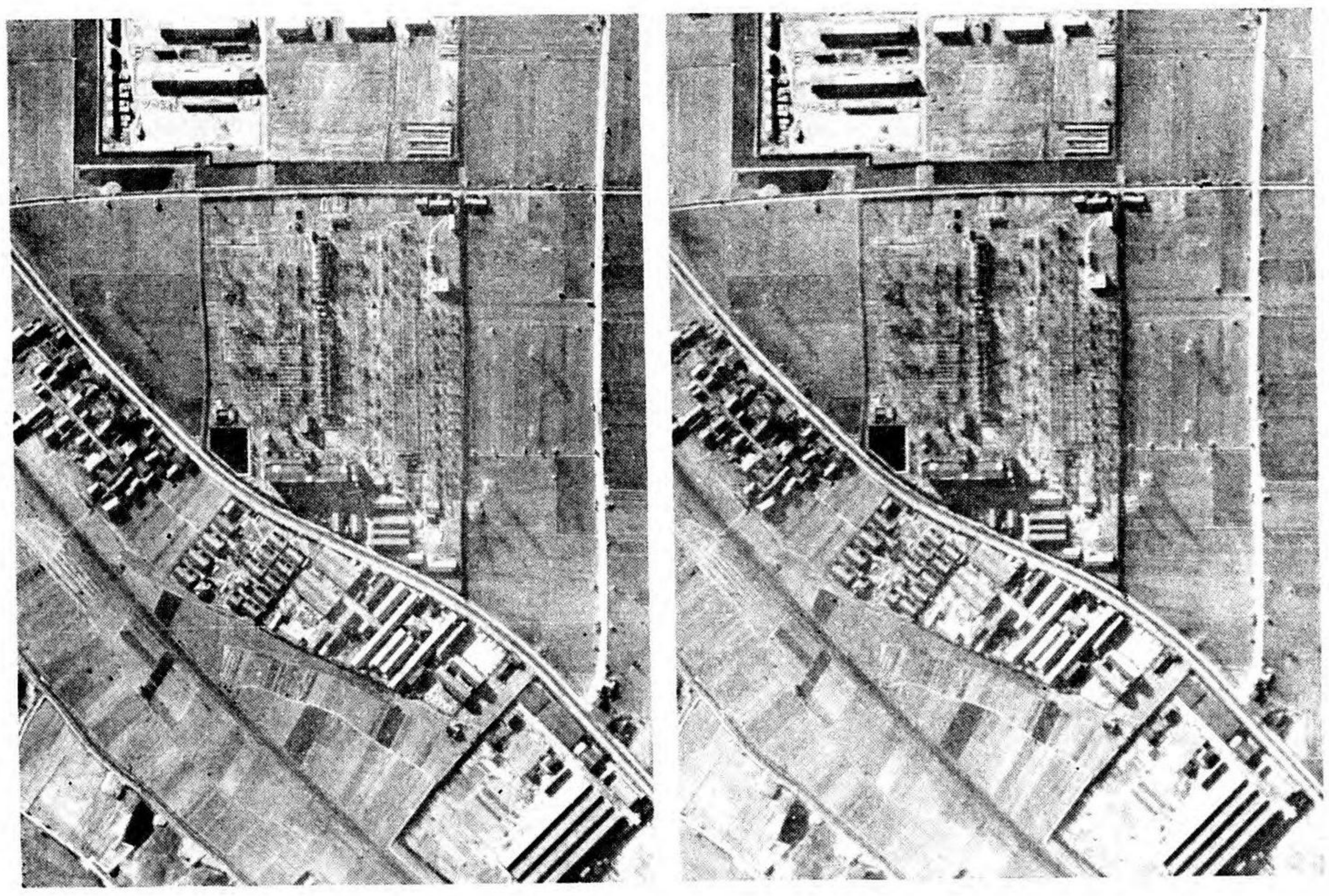


Fig. 35
Target 90.25-1631
Aerial Photography of 19 Jan 45
Two rows of breakers are shown to the left of the transformers.

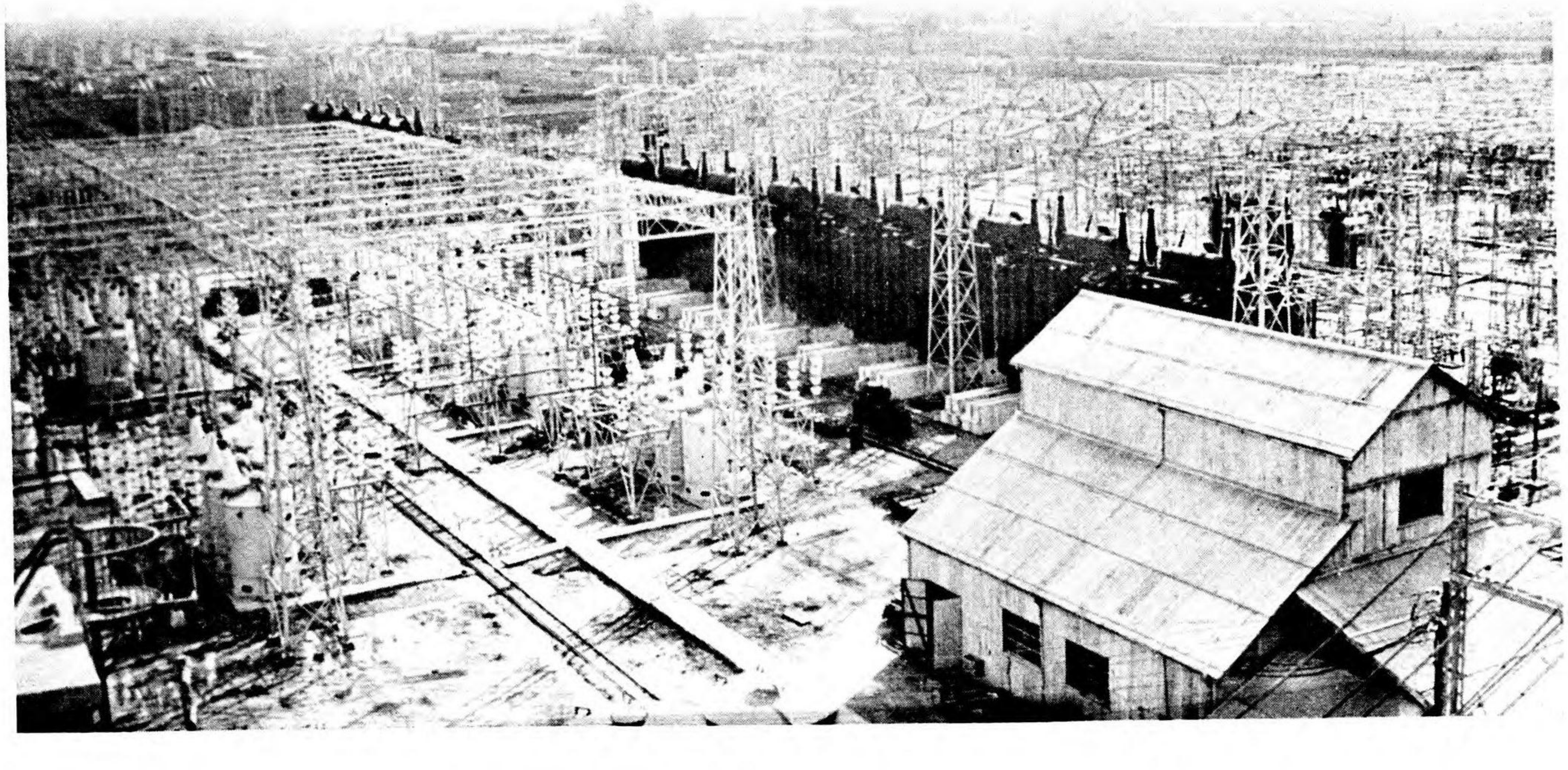


Fig. 36—Amagasaki Substation, Target No. 90.25-1629

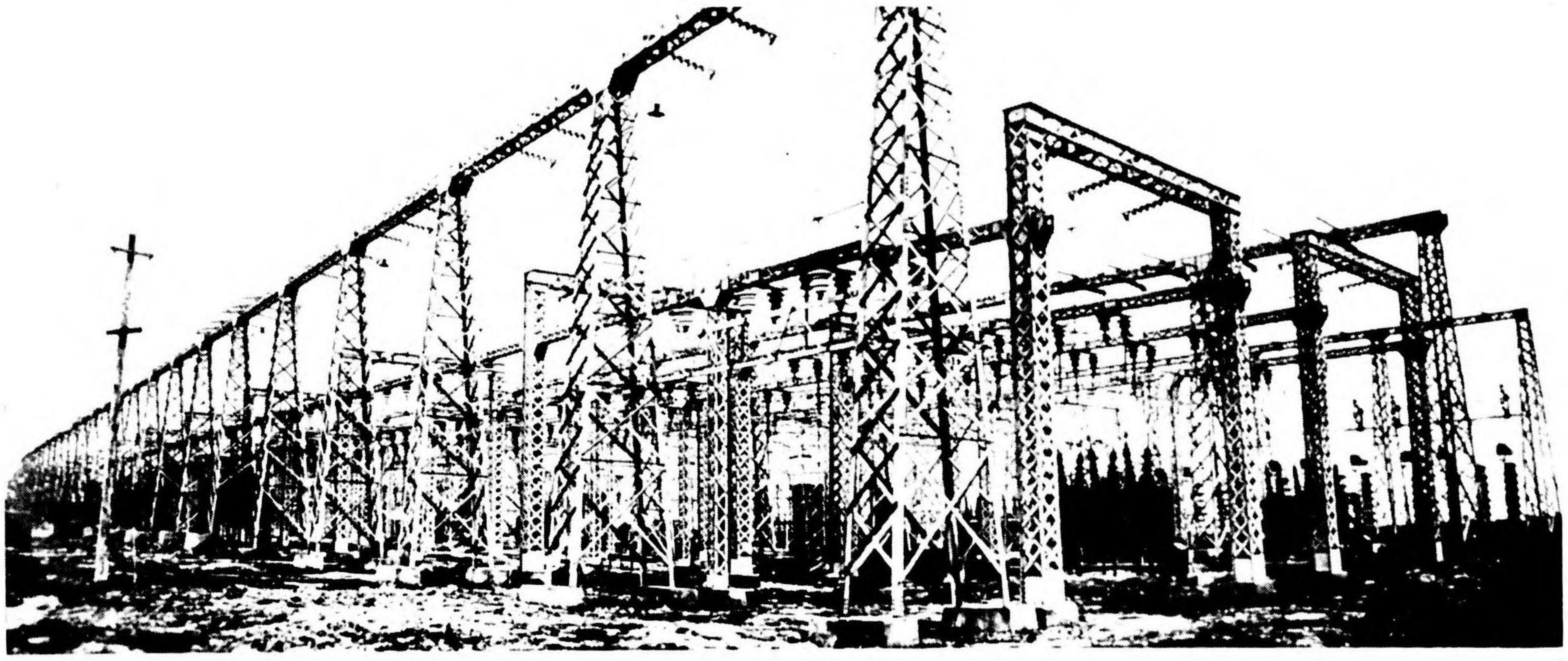
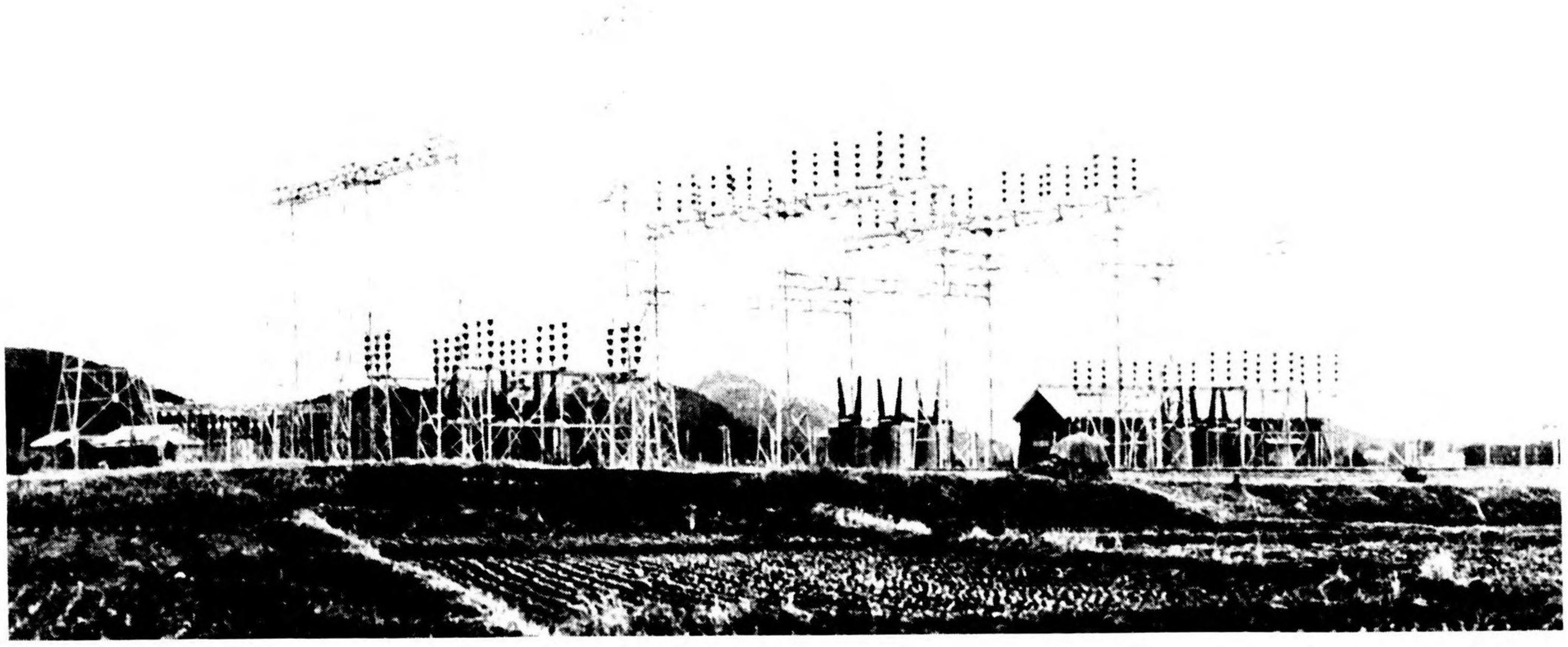


Fig. 37—Azushi Switching Station, north of Tokyo. There are no transformers at this station.

REPRINT



C. STRUCTURAL ANALYSIS

1 The Site: Rectangular in shape, the yard may have sides up to 1,000 ft in the case of large substations. The location is suburban where ample space is available.

2 Primary Objective: The transformers and breakers located in a narrow strip through the center of the yard are the primary objective. Each unit is constructed of a tank, ¼ inch steel plate, filled with insulating oil in which is immersed the core and windings of the transformer or contacts of the breaker. Blast walls may be built around three sides of each bank for protection against blast, splinters, and fire spread. See PART III, Figs. 30 and 31 for photographs of oil fires resulting from attack of this equipment.

3 Other Objectives: These are (a) miscellaneous electrical equipment lying on either side of the primary objective, (b) the substation building, and (c) synchronous condensers which may be located either outdoors or inside the station building.

BSU—EP

BSU—EP
MAPS & TABLES

File No. 23,900

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

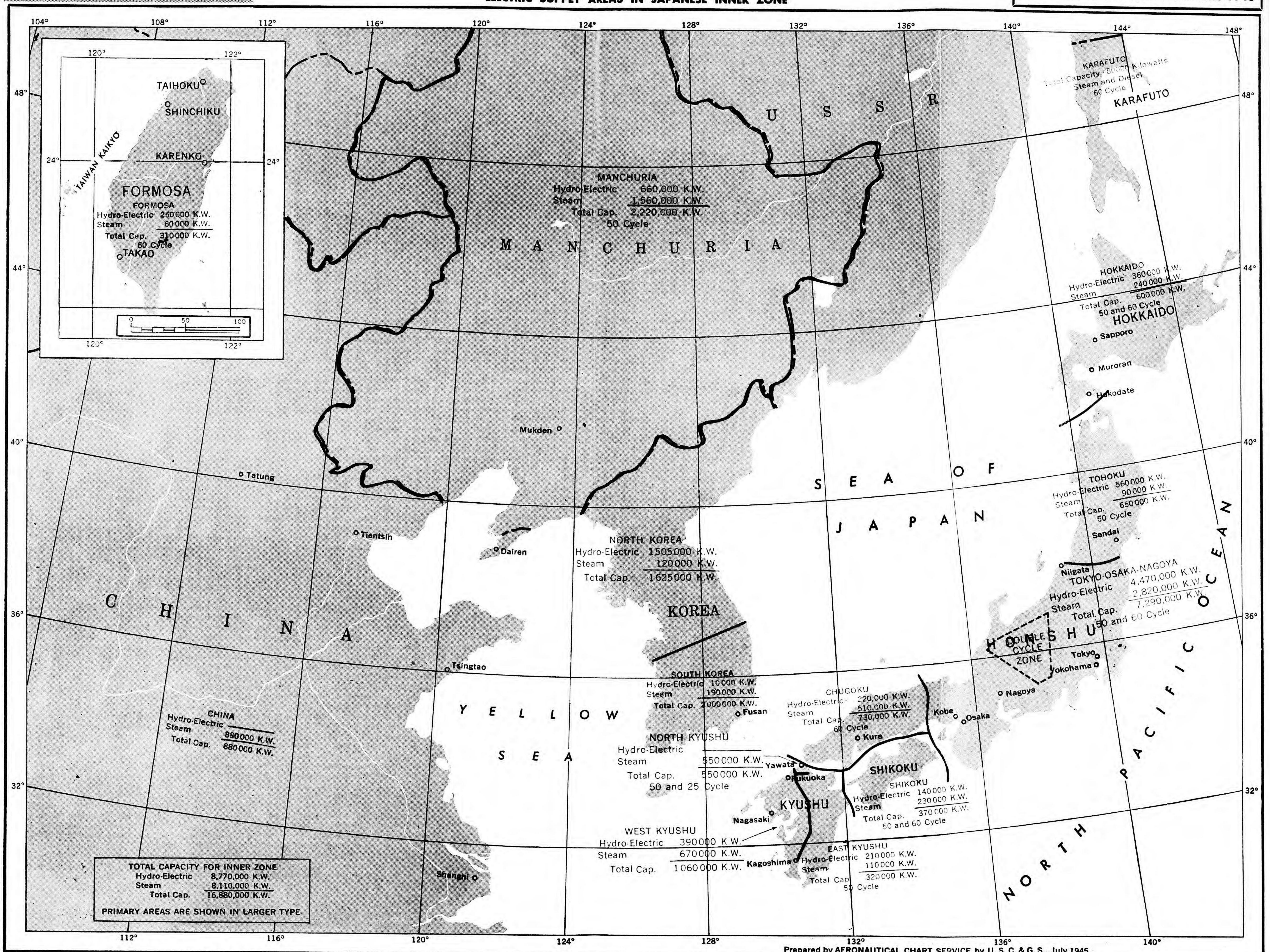
BASIC SERVICES AND UTILITIES

ELECTRIC POWER

ELECTRIC SUPPLY AREAS IN JAPANESE INNER ZONE

CONFIDENTIAL

SHEET........................EP–M1
DATE......................29 June 1945



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

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

STATUTE MILES
100 0 100 200 300 400 500

CONFIDENTIAL

File No. 23,911

BPI

BASIC PROCESSING INDUSTRIES

File No. 25,000

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

NFM
ALUMINUM
11 JUNE 1945

BASIC PROCESSING INDUSTRIES

NON-FERROUS METALS

ALUMINUM INDUSTRY

SECRET
By Authority of
The Commanding General
Army Air Forces
11 June 1945
(Date) (Initials)

(193)

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

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

SHEET ....**NFM (A)**
DATE.....**11 June 1945**
PAGE **1**

BASIC PROCESSING INDUSTRIES: NON-FERROUS METALS
ALUMINUM INDUSTRY

INDEX

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

SHEET........NFM (A)—I
DATE.....11 June 1945
PAGE................1

I. CURRENT DEVELOPMENTS AND STATUS

(June 1945)

A. PRESENT POSITION

Japan's aluminum position, never a serious limiting factor on aircraft output, has been rendered easier in recent months by the decline in aircraft production. Capacity at all stages of the aluminum industry (i.e. alumina, aluminum reduction, and fabrication) is adequate to support aircraft production of more than 2000 aircraft per month. The main limitation on aluminum output in the future is likely to be the availability of shipping to supply raw materials from the Asiatic Mainland. To date, however, there is no evidence that aluminum production has suffered from lack of imports.

The Japanese currently may be stockpiling aluminum at a significant rate in view of the decline in aluminum requirements for aircraft production.

B. EFFECTS OF AIR ATTACKS TO DATE

No significant bomb damage has been suffered by the aluminum industry to date, except at the fabrication stage. Urban area attacks, especially in Osaka and Nagoya, are believed to have done extensive damage to a number of aluminum foundries and rolling mills, although these have not yet been assessed in detail. Attacks on airframe factories have also affected considerably the aluminum fabrication facilities located there. There is no basis at present for evaluating the significance of damage done to aluminum fabrication capacity.

C. CURRENT PRINCIPAL TARGETS

These may be determined on the basis of data presented in Summary Tables II and III. (Table I is not provided in the study at present but will be introduced at a later date when necessary to summarize the current status of principal targets after damage or additional intelligence has altered their status as shown in Summary Tables II and III.)

II. RELATION TO MILITARY STRENGTH

A. REQUIREMENTS

Aluminum requirements are determined mainly by the level of aircraft production which absorbs at least 75% of Japan's primary aluminum supply. Estimates of Japan's current aluminum requirements must be very rough due to the rapidly changing conditions in the aircraft industry and the absence of detailed intelligence. Estimates presented below assume aircraft production of 1500 per month and are based on analogy with U. S. experience:

Estimated Japanese Primary Aluminum Ingot Requirements per Year (as of June 1945)

	Metric Tons		Percent of Total	
Direct Military Uses		138,000		89.6
Aircraft Production	116,000		75.3	
Other Army Uses	10,000		6.5	
Other Navy Uses	12,000		7.8	
Industrial & Indirect Military Uses		16,000		10.4
TOTAL REQUIREMENTS		154,000		100.0

Alumina requirements to support 154,000 tons of aluminum production would be 308,000 metric tons. Allowing for miscellaneous uses of alumina for abrasives, ceramics, chemicals, etc., total alumina requirements are estimated at 350,000 metric tons per year.

B. SUPPLY

Japan's supply of aluminum up to June 1945 has been adequate to support full use of the aircraft industry's capacity. However, had the Japanese aircraft expansion program continued uninterrupted, aluminum supply might have become a bottleneck after a certain point.

It is estimated that as of June 1945 the aluminum industry is capable of supplying current requirements of the aircraft industry without full use of capacity. If aircraft production should recover to 2000 per month, the aluminum industry could provide necessary supply unless drastic deterioration of the shipping position curtailed seriously the supply of aluminous raw materials from the Asiatic Mainland.

No direct evidence is available concerning stocks. It is believed, however, that as of January 1945 there existed only working stocks equivalent to about one month's output at each stage of the industry. Since aircraft production declined thereafter, a certain amount of aluminum stockpiling was probably done up to June 1945, although activity in the aluminum industry may have been cut back somewhat. Insofar as production of aluminum is maintained despite a decline in requirements for aircraft production, the Japanese aluminum position will become decreasingly vulnerable.

C. MILITARY EFFECT OF ATTACKS ON PRODUCTION

The major impact of a sharp reduction in aluminum output clearly would fall upon the aircraft industry, although a variety of minor uses of aluminum would be affected. Aircraft production would be curtailed only after aluminum stocks were consumed and only if the cut in aluminum were sufficient to reduce supply below that which remaining capacity in the aircraft industry could absorb. Under conditions prevailing in June 1945, capacity at any stage in the aluminum industry would have to be reduced by more than 50% before any significant effect at all on aircraft output could be assured. A permanent cut of at least 80% would be required to assure a ceiling on aircraft production not exceeding 800 aircraft per month.

At a minimum, assuming stocks only at a normal working level, there would be a time lag between attack on plants and effect on frontline air strength ranging from 3 to 6 months, depending on what stage of the aluminum industry was attacked. The breakdown of this time lag is shown below:

In stock at alumina plants and in transit to aluminum reduction plants	30 days
In stock at aluminum reduction plants and in transit to rolling mills	15 days
From aluminum ingot delivered at rolling mills to finished sheet delivered at aircraft plants	45 days
From sheet delivered at aircraft assembly plants to completed and tested aircraft	60 days
From factory airfield to delivery at the front line	30 days
	180 days

To the extent that additional stocks were on hand, which is probably the case as of June 1945, the above time lags would be extended.

III. STRUCTURE OF THE ALUMINA INDUSTRY

A. CAPACITY AND PRODUCTION

The Japanese aluminum industry, initiated in 1934, was built around the Bayer alumina process which is dependent on high grade bauxite of low silica content. With loss of access to the southern area, particularly the Netherlands East Indies, Japan no longer has a supply of bauxite suitable for the Bayer process. There is evidence as early as 1937, when the development of the Pedersen process was initiated in the plant at Fushun, Manchuria (Target 93:3-32) that the Japanese realized this weakness in their position and began making plans to overcome it. Recently there is considerable evidence that these plans gradually developed into an intensive effort to convert their alumina industry to handle the low grade aluminous raw materials of which they have an adequate supply in Manchuria and North China. It is believed that this conversion of the Japanese alumina industry to non-Bayer plants had been virtually completed by June 1945. Consequently, Bayer process plants no longer have significance in the industry and are excluded from target lists and statistical estimates of capacity contained in this study.*

Total Japanese alumina capacity (Non-Bayer) as of June 1945 is estimated at 444,000 metric tons per annum and total production at 421,600. These estimates are subject to considerable revision in the light of future intelligence.

B. CONCENTRATION

The alumina industry is highly dispersed geographically and fairly concentrated by individual plants.

The geographic distribution is as follows:

	No. of Plants	Est. Capacity in Metric Tons
China	1	50,000
Manchuria	2	72,000
Korea	3	47,000
Honshu	9	255,000
Shikoku	1	20,000
Total	16	444,000

As of June 1945 there was evidence of 16 non-Bayer alumina plants, half of which had been confirmed by photographic cover. It is estimated that the largest 6 account for about 70% of total capacity. It is not unlikely that later intelligence will reveal a few additional plants and perhaps slightly less concentration than indicated above. Table II lists known and reported plants and their estimated capacity and production as of June 1945.

C. INTEGRATION

Nine plants which account for 40% of alumina capacity also contain aluminum reduction facilities representing about 37% of the total reduction capacity.

D. EXPOSURE TO URBAN AREA ATTACK

Alumina capacity is not at risk in attacks against selected urban industrial areas.

E. RESILIENCE

Under optimum conditions the alumina industry has relatively high resilience, limited mainly by the time required to replace vital equipment or to convert cement factories. Production could be recovered within 3 to 6 months under favorable circumstances, based on the following considerations:

(1) *Pedersen Process Plants:* In the Pedersen process, replacement time for the electric furnaces is about six months. All other equipment in this type of plant could be more quickly replaced or repaired. In the event of serious damage to rotary kilns, production could be continued pending replacement or repairs by shipping the aluminum trihydrate to another plant or to a cement plant for calcination. The boiler plant could be replaced temporarily by a portable contractor's boiler pending repairs.

(2) *Soda-Lime-Sinter Process:* The replacement time for rotary kilns is about three months. This is based on the time required to transport the kiln or kilns from another location and set them up. It is known that the Japanese had a considerable excess of cement plants and rotary kilns before the war. If they had to build new kilns from scratch, the replacement time would be longer—4 to 5 months.

Partial production could probably be continued in a lime-sinter plant, in the event of a successful attack, if one or more kilns remained usable.

Of secondary importance in a lime-sinter plant are the hoppers, conveyors, etc., for the handling of raw materials. The bulk of shale and lime required is such that it could not be handled temporarily by manual labor if this equipment were damaged. Damage to or destruction of this equipment would delay production until repairs or replacement could be made.

---

* The principal Bayer plants, now excluded from further consideration as such, include:

91: 6-3	Nippon Aluminum Co., Takao, Formosa
90:18-1176	Japan Light Metals Alumina Plant, Shimizu, Honshu
90:35-1877	Toyo Aluminum Co., Omuta, Kyushu
90:34-1108	Japan Aluminum Co., Kurosaki, Kyushu

IV. STRUCTURE OF ALUMINUM REDUCTION INDUSTRY

A. CAPACITY AND PRODUCTION

Total aluminum reduction capacity is estimated at 245,000 metric tons per annum and production at 182,000 tons as of June 1945. These estimates are subject to substantial revision in the light of later intelligence.

B. CONCENTRATION

Japan's aluminum reduction capacity is rather widely dispersed geographically but quite concentrated by number of plants.

Intelligence available as of June 1945 indicates a total of 18 plants, excluding two in Formosa no longer considered of significance. (See Table II for details.) Nine plants, including the five largest, have been confirmed by photographic cover and the estimates of their capacity may be considered quite reliable. The 6 largest plants account for about two-thirds of total aluminum reduction capacity and well over 90% is in 14 plants.

The geographical distribution of plants and capacity is as follows:

	Number of Plants	Estimated Capacity in Metric Tons
Manchuria	2	36,000
Korea	4	63,000
Honshu	11	127,500
Shikoku	1	20,000
	18	245,000

Because aluminum reduction requires large quantities of electric energy, plants have been built in areas where electric power is most plentiful, such as Formosa, northern Korea, and southern Manchuria, and as far as Japan Proper is concerned, in the Tokyo electric supply area. Aluminum plants (like alumina plants) are genally located on the coast. Five of the Honshu plants plus two of those in Korea, accounting for 23% of total capacity, are on or near the shore of the Japan Sea.

C. INTEGRATION

Nine plants representing 37% of aluminum reduction capacity also contain about 40% of (non-Bayer) alumina capacity. Some of the reduction plants are integrated with fabrication facilities, particularly sheet rolling mills.

D. EXPOSURE TO URBAN AREA ATTACK

No significant amount of aluminum reduction capacity is within the built-up industrial area of major Japanese cities.

E. RESILIENCE

A high degree of damage throughout the Japanese aluminum reduction industry, particularly to rectifiers and rectifier transformers, would hold down production for many months. A single plant subjected to heavy damage might recover fully within six months. Detailed aspects of recuperability are considered below.

In the event of an attack on a single plant resulting in serious damage to 60 percent or more of either the rectifiers or rectifier transformers (in each rectifier building if there are 2), the immediate results would be as follows:

(a) Direct current power to the pot lines would be cut off.

(b) Assuming the damage was severe enough so that the D.C. power could not be restored within 4 hours, the electrolyte in all the pots would cool and solidify. This would necessitate chipping the electrolyte out of all the 250 to 528 pots and relining them with carbon. This is all hand labor with the assistance of compressed air tools if available. This work would require at least 3 months and full production could not be resumed in less time even though D.C. power were restored earlier. If a sufficient number of rectifiers and rectifier transformers were undamaged, partial production could be resumed in about two months.

The above, however, applies only to the potroom phase of restoring production facilities. Actually full production could not be resumed until the destroyed or seriously damaged rectifying equipment had been replaced and this would require a minimum of six months.

In the event of a concerted attack on the rectifying equipment in enemy aluminum plants, the time required to repair or replace would be greater and would increase progressively with the number of units destroyed. It is estimated that a minimum of 150 mercury-arc rectifiers and 150 rectifier transformers, including installed spares, are in use in the enemy aluminum reduction industry. The time required by the enemy to replace any large number of units of this equipment is not known as it involves the time required to construct the equipment by the Japanese heavy electric industry. Rectifying equipment, especially in the large sizes required for the aluminum industry is highly specialized and is all made to order even in the United States.

The companies which produce about 80% of the mercury-arc rectifiers in the United States estimate that under emergency conditions it would require 29 weeks working at full capacity to produce 150-3600 KW rectifiers and 18 weeks to produce 150 rectifier transformers of comparable size. It is reasonable to believe that the Japanese, with a much smaller heavy electric industry, might require at least double this time. If an attack on the industry were only moderately successful, the recuperability problem would not be nearly as severe, since the Japanese heavy electric industry already produces some rectifiers for expansion purposes. In such a case, overall loss of production might be six months.

V. STRUCTURE OF ALUMINUM FABRICATION INDUSTRY

A. INTEGRATION WITH AIRCRAFT INDUSTRY

It is believed that much of Japan's capacity for fabrication of aluminum from ingot form, with the exception of sheet rolling, is integrated physically with airframe production. Theer is evidence that most of the major airframe plants contain facilities for manufacturing their own aluminum castings, forgings, and extrusions.

Available intelligence is not adequate to provide a detailed picture of any type of aluminum fabrication except sheet rolling. It is believed, however, that in addition to capacity located at aircraft plants, considerable castings are made at numerous small foundries, many of them located within major urban areas. There are no known large non-ferrous foundries in Japan. Some of the larger aluminum rolling mills are thought to produce also forgings and extrusions. The remaining discussion in this section deals only with sheet rolling.

B. SHEET ROLLING CAPACITY AND REDUCTION

It is estimated that Japan's aluminum alloy rolling mills possess sufficient capacity to roll 175 million pounds of non-ferrous sheet per year. Virtually all of this is adaptable to rolling aluminum alloy sheet, though in practice only part is required or used for this purpose. Some of the aluminum alloy rolling mills also manufacture other non-ferrous sheet, including copper, brass, and magnesium.

C. CONCENTRATION OF ROLLING CAPACITY

Geographically Japan's rolling capacity is quite dispersed but in terms of the number of plants involved it is highly concentrated. (See Summary Table III for details.)

There are 9 known plants, all of which have been confirmed by photo cover, and the possibility exists that a few additional ones—probably small hand mills—will be identified later. The four largest plants, all located on Honshu, are estimated to account for more than four-fifths of total capacity.

D. EXPOSURE TO URBAN AREA ATTACK

Only two large plants (90:20-2040 and 90:25-263 A) which account jointly for about 40% of total capacity, are located within built-up industrial urban zones. A high degree of damage to these plants, however, would undoubtedly require employment of HE weapons due to their low combustibility.

E. RESILIENCE OF ROLLING CAPACITY

Resilience is high for three main reasons. First, only a portion of total capacity is required presently to produce sufficient aluminum alloy sheet for current aircraft production; thus there is a substantial capacity cushion within the industry. Second, the capacity cushion is greatly enlarged by the enemy's ability to adapt steel rolling mills for making aluminum sheet. Such conversion might be accomplished within a 3-month period. Finally, aluminum rolling mills contain relatively few facilities which are at once vital, highly vulnerable to physical damage, and difficult to replace.