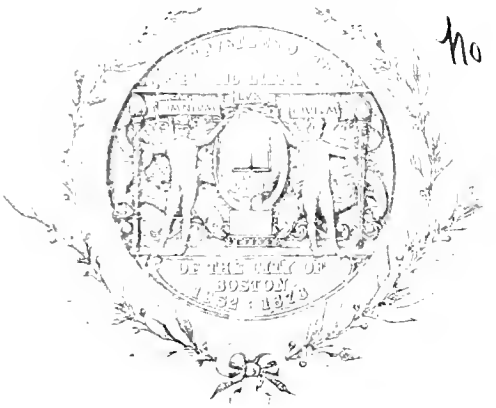

THE UNITED STATES
STRATEGIC BOMBING SURVEY

UNDERGROUND PRODUCTION OF JAPANESE AIRCRAFT

REPORT NO. XX

Aircraft Division
March 1947

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Aircraft Division
Dates of Survey:
23 October-25 November 1945
Date of Publication:
March 1947

This report was written primarily for the use of the United States Strategic Bombing Survey in the preparation of further reports of a more comprehensive nature. Any conclusions or opinions expressed in this report must be considered as limited to the specific material covered and as subject to further interpretation in the light of further studies conducted by the Survey.

FOREWORD

The United States Strategic Bombing Survey as established by the Secretary of War on 3 November 1944, pursuant to a directive from the ate President Roosevelt. Its mission was to conuct an impartial and expert study of the effects f our aerial attack on Germany, to be used in onnection with air attacks on Japan and to stablish a basis for evaluating the importance nd potentialities of air power as an instrument f military strategy for planning the future deelopment of the United States armed forces and or determining future economic policies with espect to the national defense. A summary reort and some 200 supporting reports containing he findings of the Survey in Germany have been ublished.

On 15 August 1945, President Truman requested hat the Survey conduct a similar study of the ffects of all types of air attack in the war against Japan, submitting reports in duplicate to the Secretary of War and to the Secretary of the Navy. The officers of the Survey during its Japanese phase were:

Franklin D'Olier, *Chairman*.
Paul H. Nitze, Henry C. Alexander, *Vice Chairmen*.
Harry L. Bowman,
J. Kenneth Galbraith,
Rensis Likert,
Frank A. McNamee, Jr.,
Fred Searls, Jr.,
Monroe E. Spaght,
Dr. Lewis R. Thompson,
Theodore P. Wright, *Directors*.
Walter Wilds, *Secretary*.

The Survey's complement provided for 300 civilians, 350 officers, and 500 enlisted men. The military segment of the organization was drawn from the Army to the extent of 60 percent, and from the Navy to the extent of 40 percent. Both the Army and the Navy gave the Survey all possible assistance in furnishing men, supplies, transport, and information. The Survey operated from headquarters established in Tokyo early in September 1945, with subheadquarters in Nagoya, Osaka, Hiroshima, and Nagasaki, and with mobile teams operating in other parts of Japan, the islands of the Pacific, and the Asiatic mainland.

It was possible to reconstruct much of wartime Japanese military planning and execution, engagement by engagement, and campaign by campaign, and to secure reasonably accurate statistics on Japan's economy and war production, plant by plant, and industry by industry. In addition, studies were conducted on Japan's over-all strategic plans and the background of her entry into the war, the internal discussions and negotiations leading to her acceptance of unconditional surrender, the course of health and morale among the civilian population, the effectiveness of the Japanese civilian defense organization, and the effects of the atomic bombs. Separate reports will be issued covering each phase of the study.

The Survey interrogated more than 700 Japanese military, government, and industrial officials. It also recovered and translated many documents which not only have been useful to the Survey, but also will furnish data valuable for other studies. Arrangements have been made to turn over the Survey's files to the Central Intelligence Group, through which they will be available for further examination and distribution.

TABLE OF CONTENTS

INTRODUCTION

Because the dispersal of aircraft and engine manufacturing plants to underground locations proved to be far more extensive than had been suspected, a special study of underground plants was undertaken by the Aircraft Division. Lt. Col. J. W. Fredricks was assigned to the task. He made extensive preliminary investigations of Munitions Ministry, Army and Navy, and industrial records, followed up by field investigations at many underground sites throughout Japan. A summary of his findings appears in Section II of the Aircraft Division's report on "The Japanese Aircraft Industry". The follow pages comprise a series of "thumbnail" reports on several sites which he visited.

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PART I

UNDERGROUND PLANTS OF NAKAJIMA AIRCRAFT CO.

OYA

When Allied air attacks toward the end of 1944 made it evident to the Nakajima Aircraft Co. that their plants were vulnerable, plans were drawn to disperse them and, insofar as possible, place them underground. Oya and Shiroyama in Tawanchi Gun, Tochigi prefecture, four miles northwest of Utsunomiya were selected for the dispersal of part of the airplane engine manufacturing facilities of the Musashi plant near Tokyo, and later for the dispersal of most of the airframe manufacturing and assembling facilities at Utsunomiya. This works, both engine and airframe, was the best developed and most extensive of all the Japanese underground plants.

The area was selected largely because many of the surrounding hills were already honeycombed with stone quarries that provided large unde ground areas already dug. The stone was rel tively soft and would therefore readily lend itse to changes or expansion of the existing caves.

Plans called for the utilization of two separa underground areas and three surface areas f the manufacture of one engine type, the Japane Army designated Ha 45, Model 12 (1793 hp This engine was the type used in the Frank Arm fighter (Japanese Ki 84) which was being asse bled at nearby Utsunomiya, and later was to assembled in other underground works in t Oya area. The following table gives details the engine works, and compares plan with acco plishment:

Location	Utilization	Area in square feet		Equipment[1]	
		Planned	Completed	Planned	Installed
Tomoro Mountain (underground)	Machine shop and heat treatment	177,000	111,000	991 MT and 11 Fur	347 MT and 4 Fu
Benten Mountain (underground)	Machine shop and assembly shop	212,000	118,000	116 MT and 3 Fur	238 MT and 3 Fu
Yoka Mountain (surface)	Heat treatment	3,510	2,120	36 Fur	7 Fur
Tage Mountain (surface)	Machine shop	16,500	1,580	14 MT	4 MT
Kamuma (surface)	Assembly shop	21,200	21,200	3 MT	1 MT
Total		430,210	313,900	1,454 MT and 50 Fur	590 MT and 11 F

[1] MT Machine tool Fur furnace

In addition, there were five surface buildings with a total floor area of 24,200 square feet intended for use as warehouses and offices, and seven separate groups of buildings with a total floor area of 342,000 square feet intended for use as dormitories, dining rooms, etc. The Kamuma factory was an old rope factory about 4 miles away from the other sites.

Excavation was begun in January 1945 to adapt the quarries to their new use, and in March 1945 some of the machinery was put in operation. The first engine was completed in June 1945, but the overall plans were not completed. Before the war ended approximately one-third of the planned area was in production.

Five shafts had been sunk for quarrying. Coverings were put over them to keep out the rain, and also to camouflage the position. One slanting tunnel was excavated for communication between the various levels. Labor for digging w provided by a naval maintenance unit which rather unusual because, in general, there appea to have been a lack of cooperation between t Army and the Navy, and this plant was intend to produce only Army engines.

Organization and Operation

The factory was under the general manag ment of Y. Nagasawa.

The Tommo plant was intended to machi cylinders, cylinder heads and barrels, crankshaf crankcases, propeller shafts, reduction gear co ers, and to do heat treatment. Figure 1 is a la out sheet showing space utilization and numb of machines planned and installed. Photograp 1 6 on the following pages present various viev of the machinery and interior. The positions fro

w ch the photographs were taken are indicated o the drawing.

he Benten plant was intended to produce ar- ti lating rods, master rods, gears, jigs, and mis- cc aneous small parts. Figure 2 is the space and n ization lay-out of the Benten plant, also show in the number of machines planned and installed. P tographs 7-10 on the following pages show so e of the machinery. The photographer's po- si n in each case is shown on the drawing.

he Kannma plant, above ground, was the site of ll assembly, although it had originally been pl ned that assembly would be done under- gr nd. The Yuba and Tage works were rela- ti ly small and only a few pieces of equipment w e installed.

total of 1075 machine tools were acquired fo the varions works—765 from Musashi, 76 fr a Omiya, 88 from Yokkaichi, and 146 from a mbine known as Nippon Nainenki. Of these, on 604 were installed.

lans called for 14 test cells, but only 2 were co pleted. They were above ground, so ventila- a n was not a problem.

mployment reached a maximum early in A ust, 1945. The total for all the works was as fo ows:

Direct Employees:		
Regular	2,497	
Soldier	876	
Student	300	
		3,673
Indirect employees:		
Regular	1,642	
Soldier	..	
Student	387	
		2,029
Total		5,702

hirteen per cent of the regular and soldier en loyees worked on two shifts of ten hours ea , and the remainder worked on one ten hour sh t.

P duction

nly part of the engine components were pro- du d at this plant. These included crankshafts, cr nkcases, reduction gear housings, certain rods an gears, cylinders, cylinder barrels and heads, vo te casings, etc. The parts produced by this pl t for other plants, including the Hamamatsu and Omiya plants, were crankshafts, crankcases, reduction gear housings, and volute casings.

Production of other parts was planned but not accomplished.

The plans also called for production of 300 engines per month. Actually, both new and re paired engines turned out in 1945 were as fol lows:

	June	July	August	Total
New engines	1	4	6	11
Repaired engines	18	25	12	55
				66

Repairs were made on engines that had been improperly assembled by unskilled workers at other plants, and on engines that had been damaged in bombing attacks at other places.

No research or experimentation was carried on at this plant.

Effect of Attack

There were no direct attacks on the subject plant, and officials felt no concern over the possibility of raids. That part of the underground works with the shallowest protection from above was 180 feet below ground.

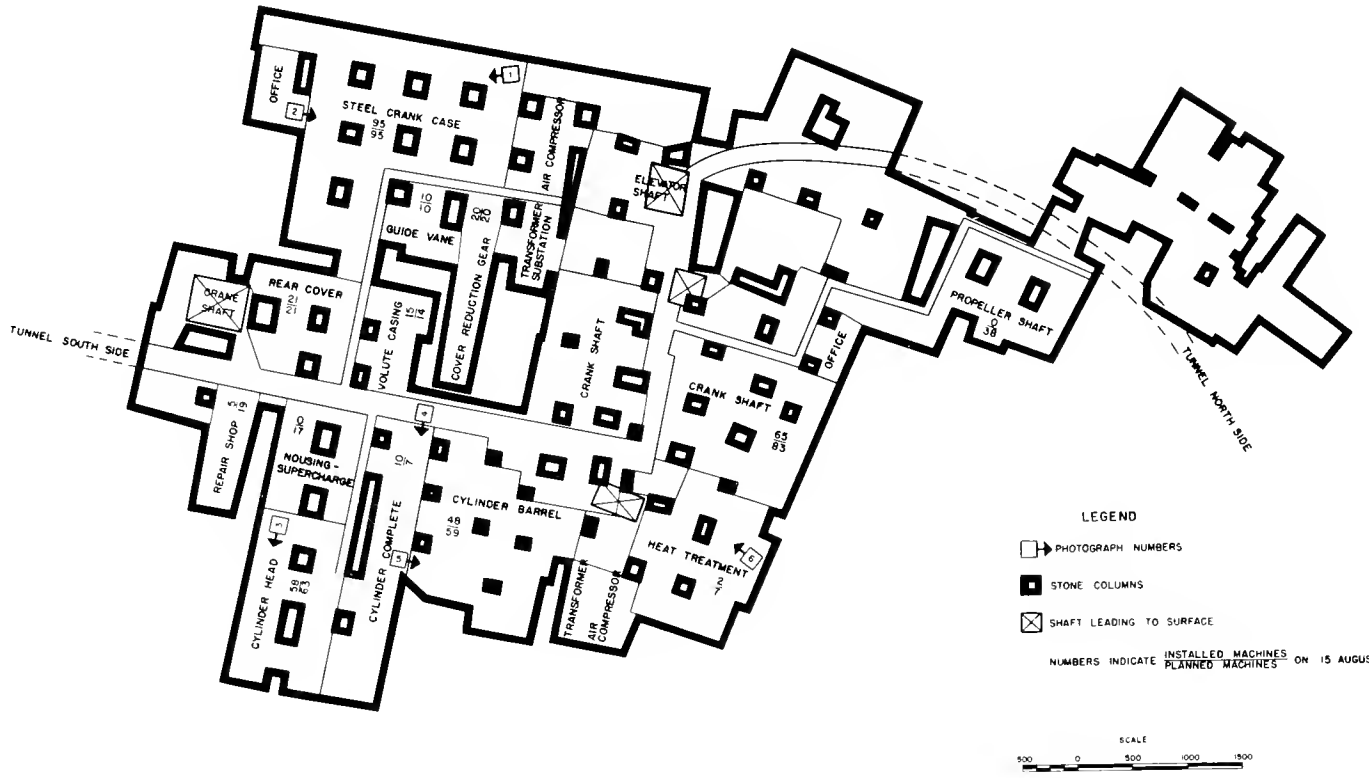
Area attacks, however, had an adverse effect on production. For one week after the area attack on Utsunomiya City, worker attendance fell off about 20 per cent. There was no serious power interruption resulting from area attacks.

Plant officials said that difficulty in obtaining parts, due to attacks on other plants and to poor transportation, caused a slowing-down of production schedules.

Operational Difficulties

The plant manager complained of very serious operational difficulties that had not been overcome: underground areas were cold and damp, causing extreme discomfort to the employees; the atmosphere was foggy from the dampness, making visibility very poor; all machinery was constantly subject to corrosion unless the greatest precautions against it were taken. One difficulty that was not encountered during the war was cave-ins, although there have been several since the war ended.

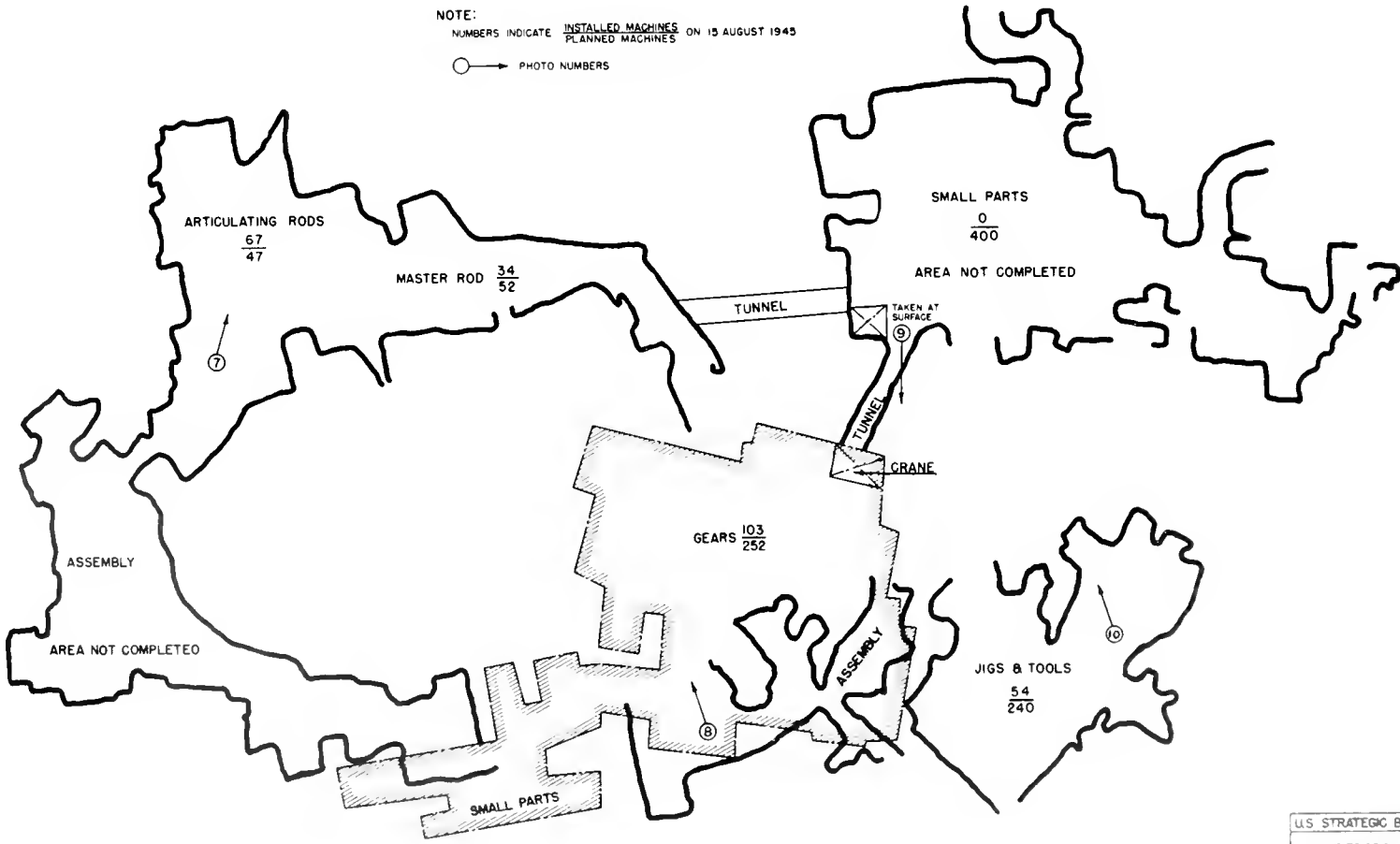
THE ARRANGEMENT OF THE TOMURA FACTORY



U.S STRATEGIC BOMBING SURVEY

UNDERGROUND PLANTS
TOMURA FACTORY
FIGURE 1

LAYOUT OF THE BENTEN FACTORY



U.S. STRATEGIC BOMBING SURVEY

UNDERGROUND PLANTS
BENTEN FACTORY

FIGURE 8

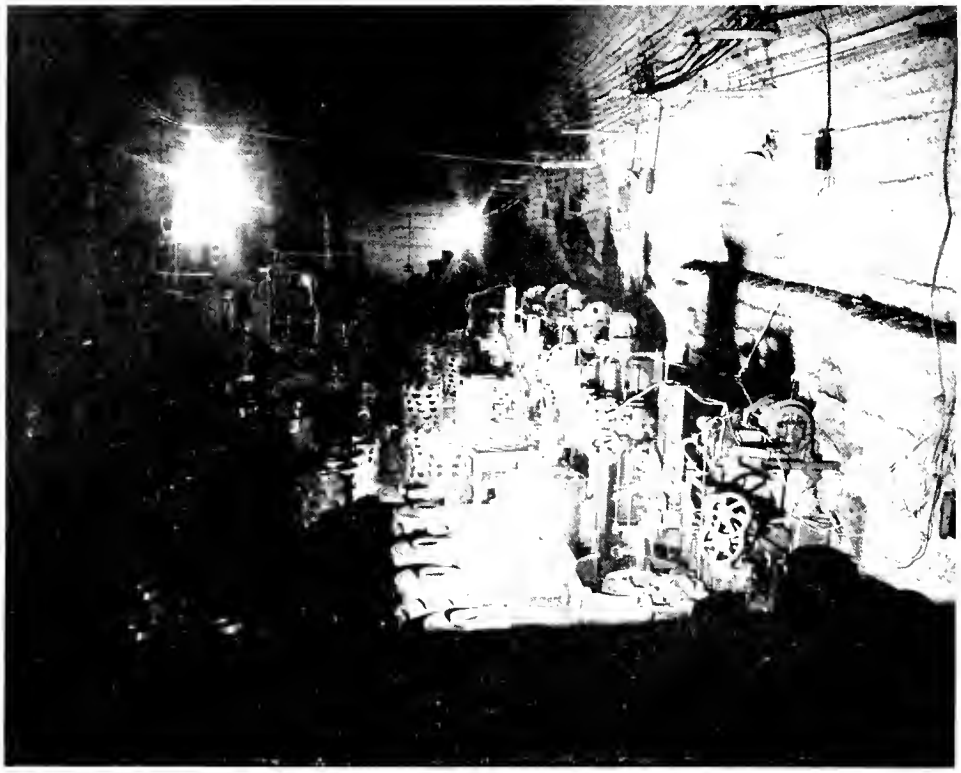


Photo No. 1. Crankcase shops, Tomura plant at Oya Works.

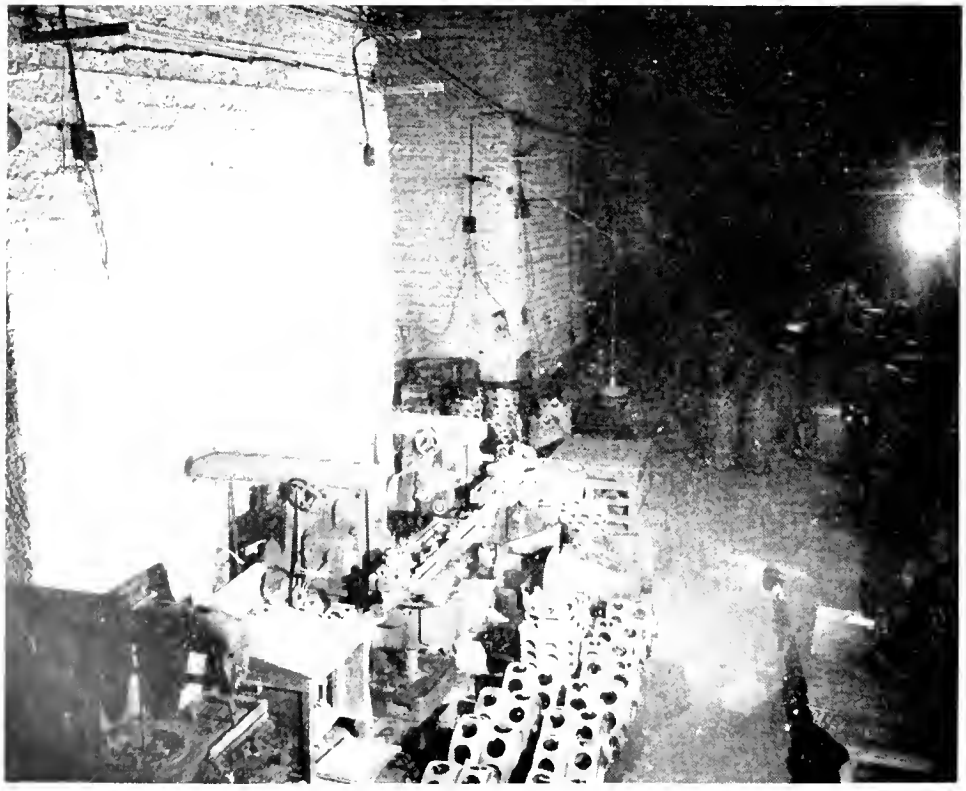


Photo No. 2. Crankcase shop, Tomura plant at Oya Works.

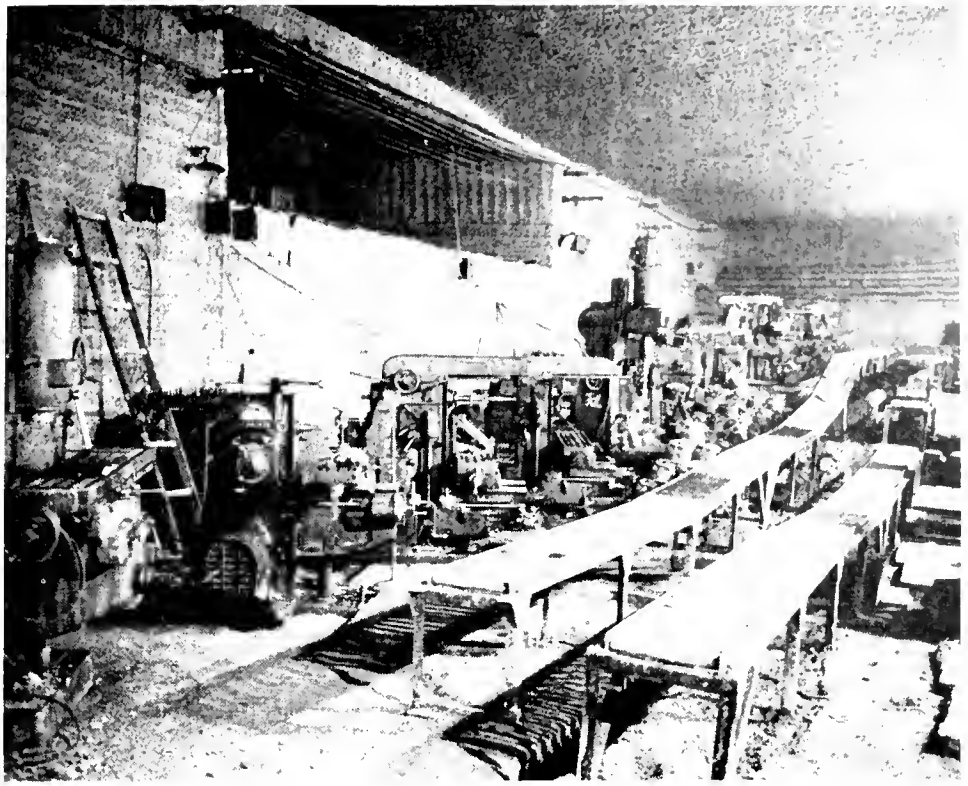


Photo No. 3. Cylinder head shop, Tomura plant at Oya Works.

Photo No. 4. Cylinder assembly shop, Tomura plant at Oya Works.

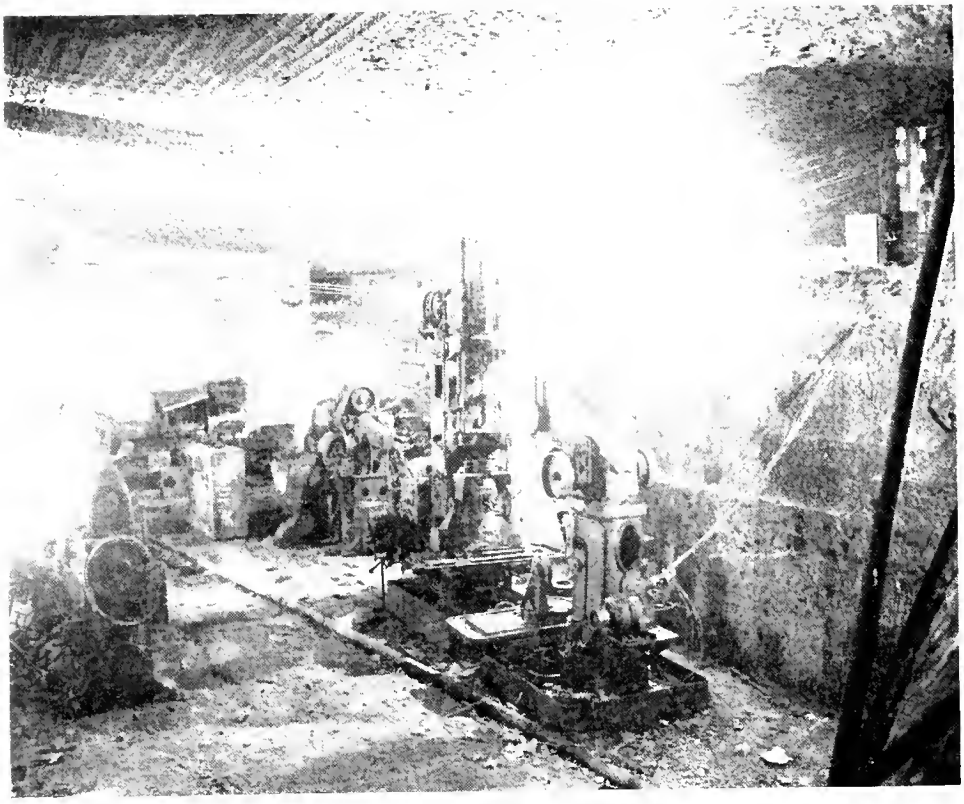


Photo No. 5. Cylinder barrel shop, Tomura plant at Oya Works.

Photo No. 6. Heat treatment shop, Tomura plant at Oya Works.

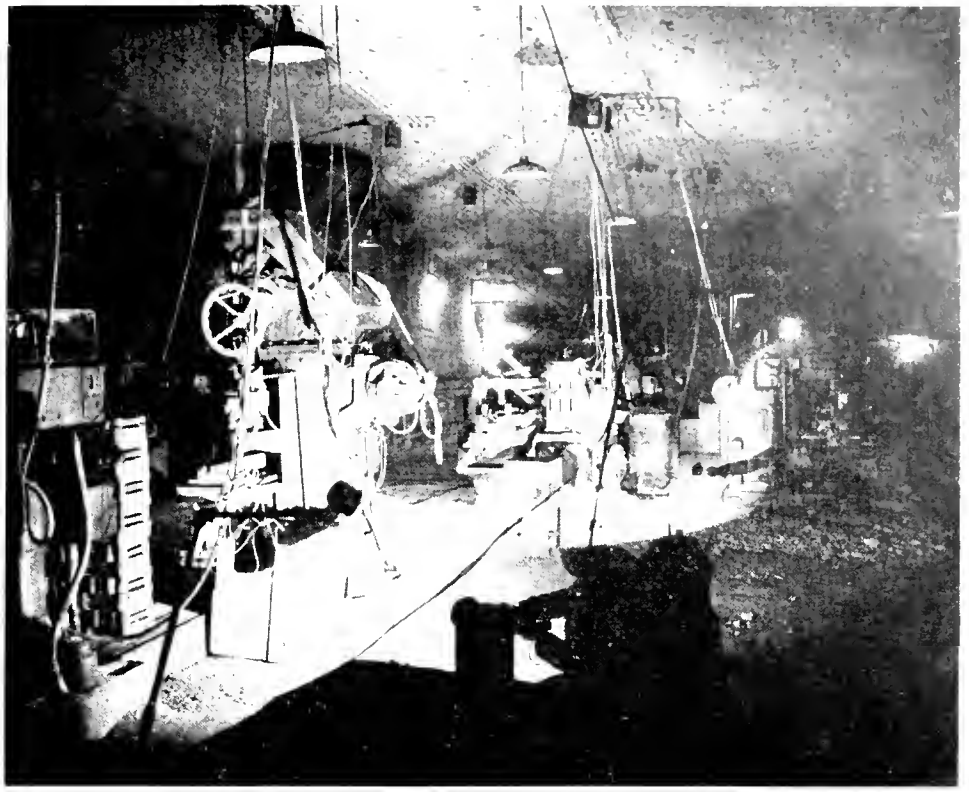


Photo No. 7. Articulating rod shop, Benten plant at Oya Works.

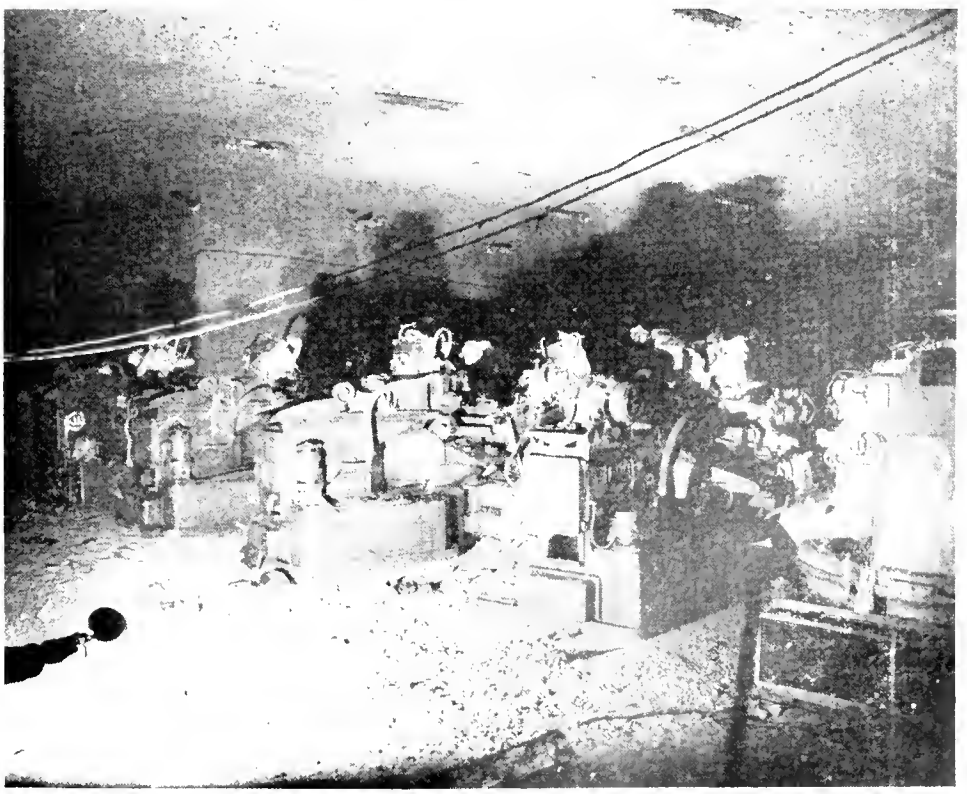


Photo No. 8. Gear shop, Benten plant at Oya Works.

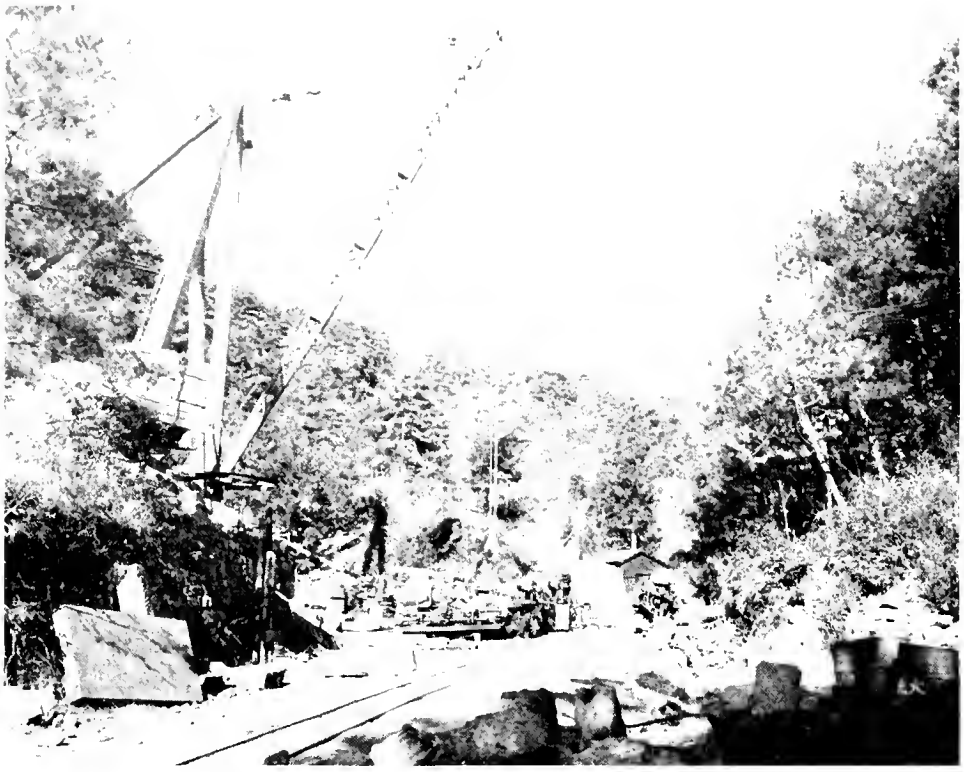


Photo No. 9. Entrance to Benten plant at Oya Works.

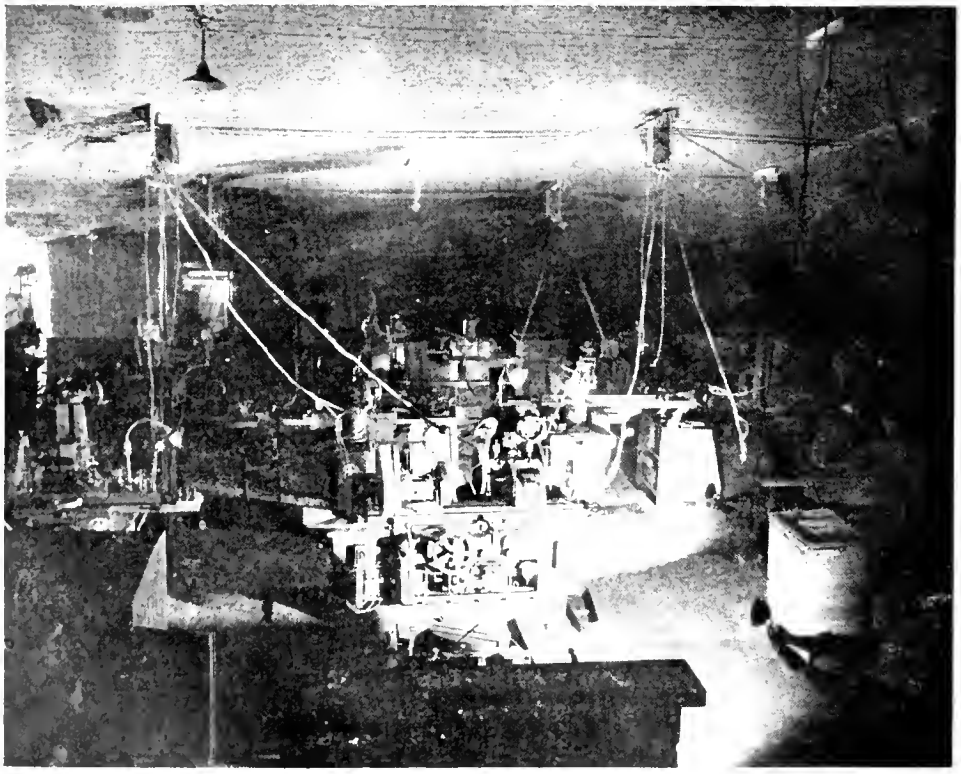


Photo No. 10. Jig and tool shop, Benten plant at Oya Works.

SHIROYAMA

troduction

In December 1944, the Nakajima Aircraft Co. nted to disperse the airframe production fa- ities of its Utsunomiya plant, but the Munitions nistry refused permission, saying it was not t necessary. Finally, in March 1945, permis- n was granted and dispersal to underground erns at Shiroyama began. This plant was op ted in conjunction with the Oya plant, pre- usly discussed.

Planned production at Shiroyama was three ng assemblies and three fuselages per day but the end of the war only four of each had been npleted. Manufacturing began late in April 5. The machine shop started first, then com- nent manufacture, and in July, wing and fuse- e assembly began.

Nearly all assembly facilities were to be dis- sed from Utsunomiya to Shiroyama, but some re to be retained at Utsunomiya because the ace at Shiroyama was inadequate.

ganization

Of a planned nineteen units in the works, with total floor area of 649,700 square feet, only ht units with 333,000 square feet of floor area e completed. Four of these (38,900 square t) were used as warehouses for tubing, ex- ded parts, duralumin bars, oil, and paints.

The largest of the other four units that actually into production was the Otomeyama plant 04,500 square feet) where sheet metal parts re produced. Photographs 11-14 show the en- nces and some of the presses.

The next largest was the Watanabeyama plant 3,500 square feet) housing the wing and fuse- e assembly and jigs for tail parts. Photo- graphs 15-16 show jigs and some of the main air- frame parts.

The Kaneiriyama plant (86,000 square feet) contained machine tools and electric heat treat- ment furnaces. Some space was used as a ware- house. See photographs 17-20.

The Tochigiyama unit, devoted to wing spar manufacture, contained only 14,100 square feet, and all machinery had been removed at the time the inspection was made.

An over-all layout of all parts of the Shiro- yama installations is shown in Figure 3. The po- sition of the photographer in taking each of the photographs on the preceding pages is indicated on the drawing by numbers corresponding with numbers on the photographs.

In July 1945, when dispersal was still going on from Utsunomiya to Shiroyama, the combined number of employees was 21,117. This figure in- cludes both direct and indirect employees; no further break-down was available.

Production

The only airplane type intended for production at Shiroyama was the Army fighter Frank (Jap- anese Ki-84). Nearly all sheet-metal parts and some machined parts were to be made here. Other machined parts came from the Tochig and Ot- awara plants of Nakajima but subcontractors supplied 50 percent of all parts other than sheet- metal parts.

Actual airframe production amounted to only four wing assemblies and four fuselages before the end of the war, but inasmuch as production was just getting under way, those figures can scarcely be used as any measure of capacity for the Oya plant. Three wing assemblies and three fuselages per day was the goal that had been planned.

Photo No. 11. Tunnel entrances (Otomeyama plant), Shiroyama.

Photo No. 12. Tunnel entrances (Otomeyama plant), Shiroyama.

Photo No. 13. Sheet-metal press (Otomeyama plant), Shiroyama.

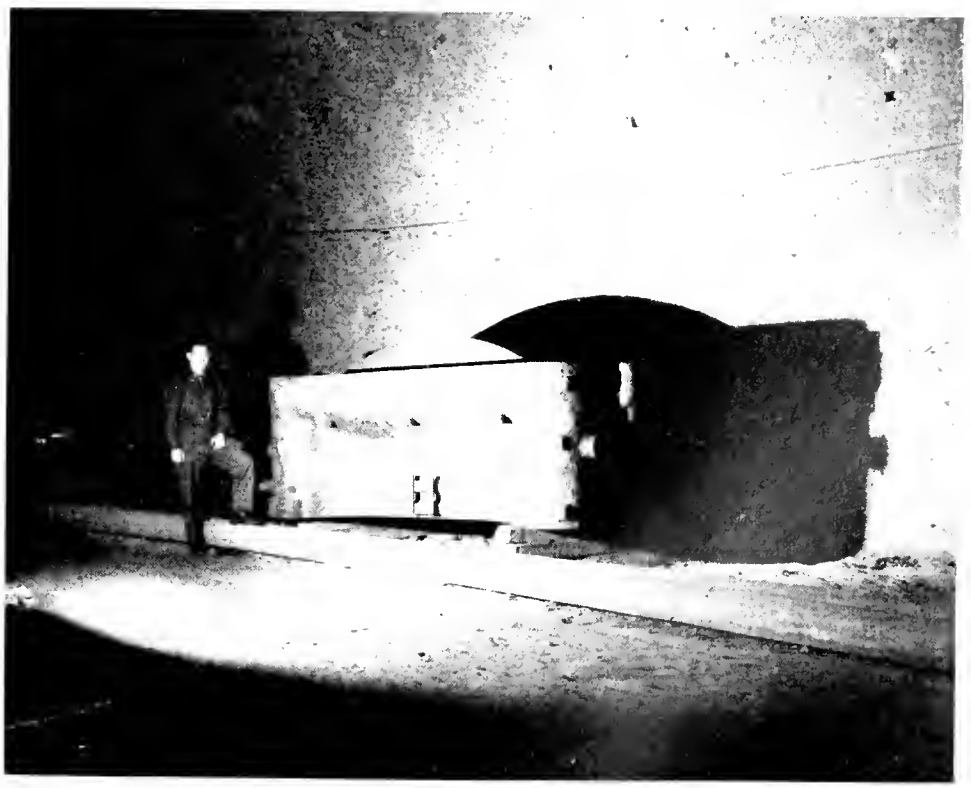


Photo No. 14. Part of 20-ton press (Otomeyama plant), Shiroyama.

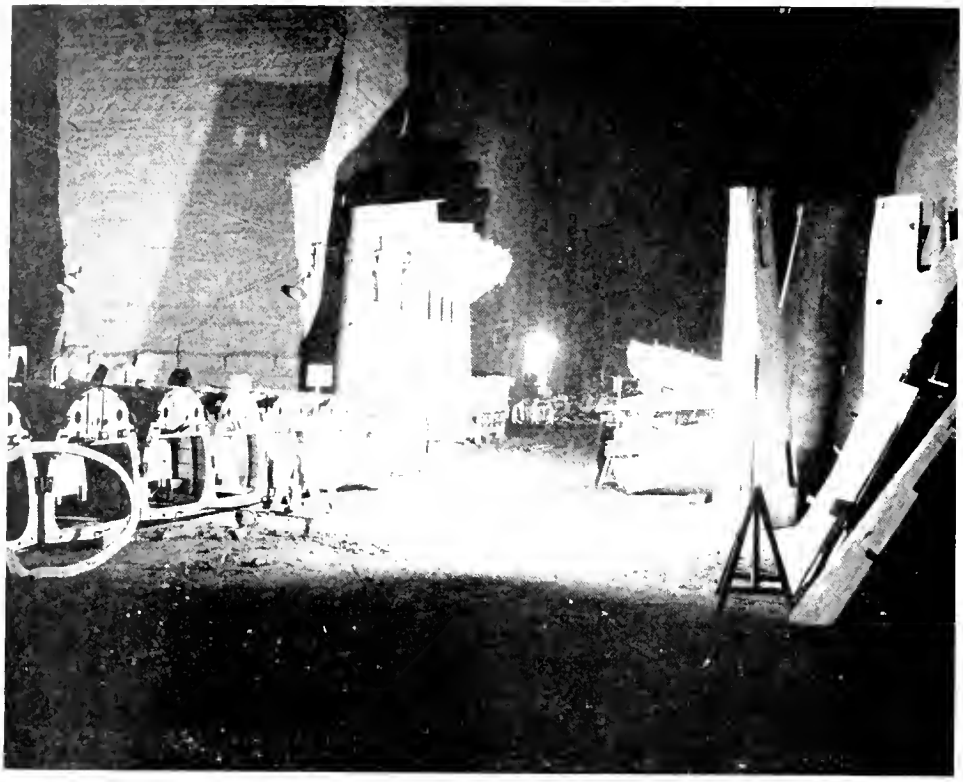


Photo No. 15. Fuselage assembly shop (Watanabe plant), Shiroyama.

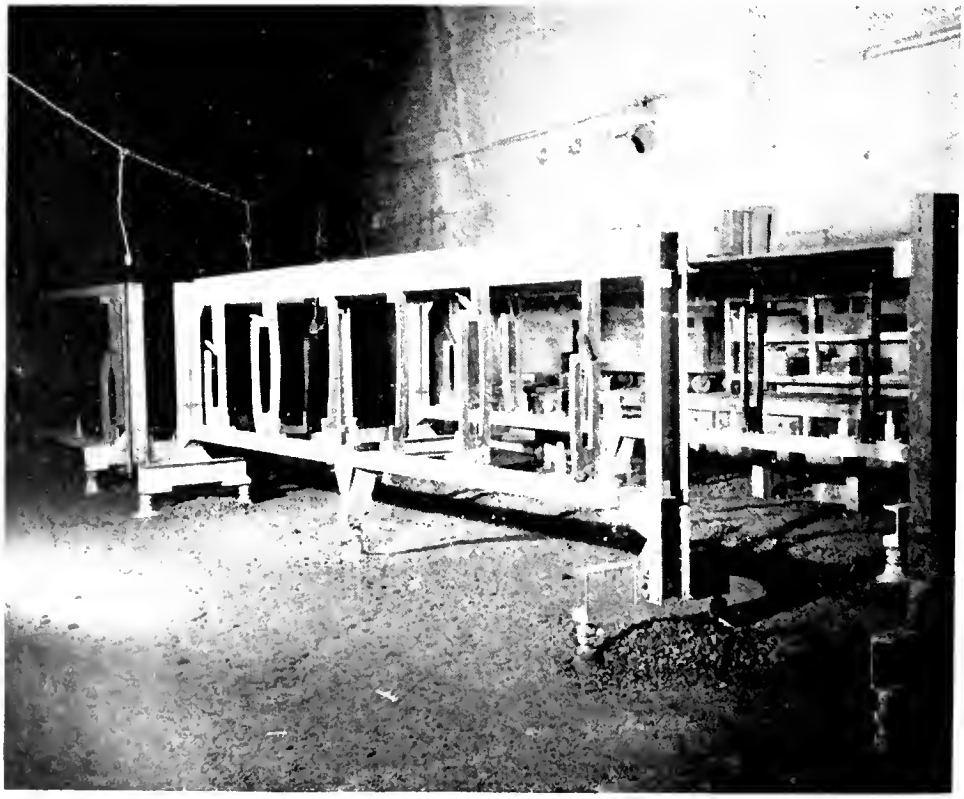


Photo No. 16. Horizontal stabilizer jigs (Watanabe plant), Shiroyama.

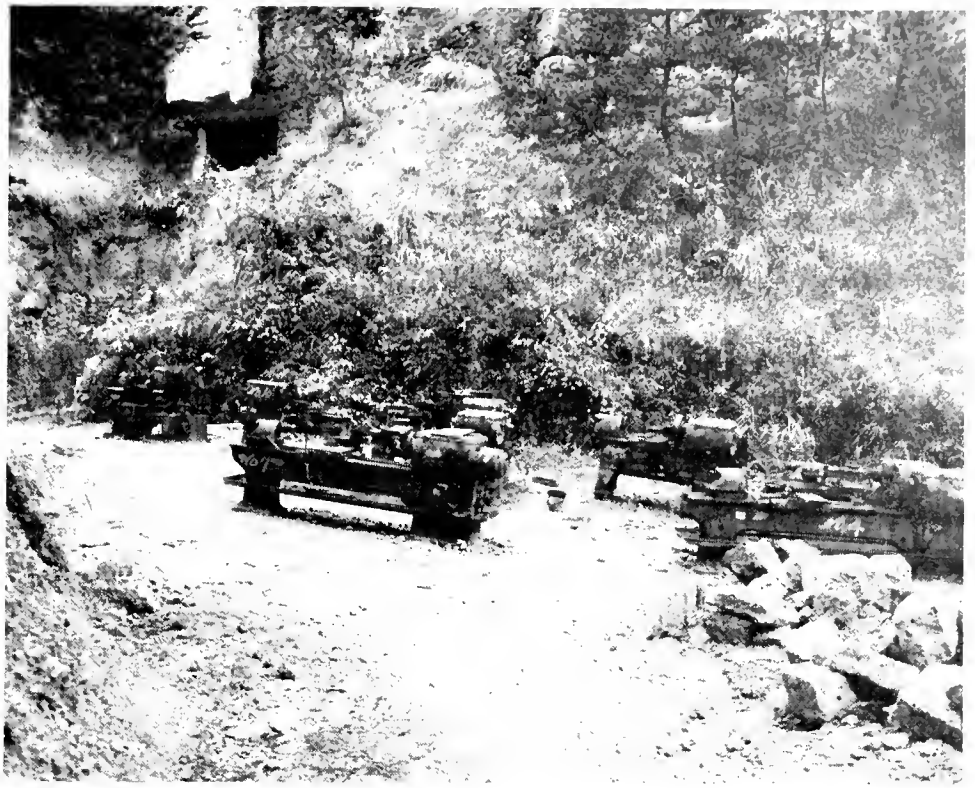


Photo No. 17. Machine tools awaiting installation underground, Kaneirivama Works at Shirovama.

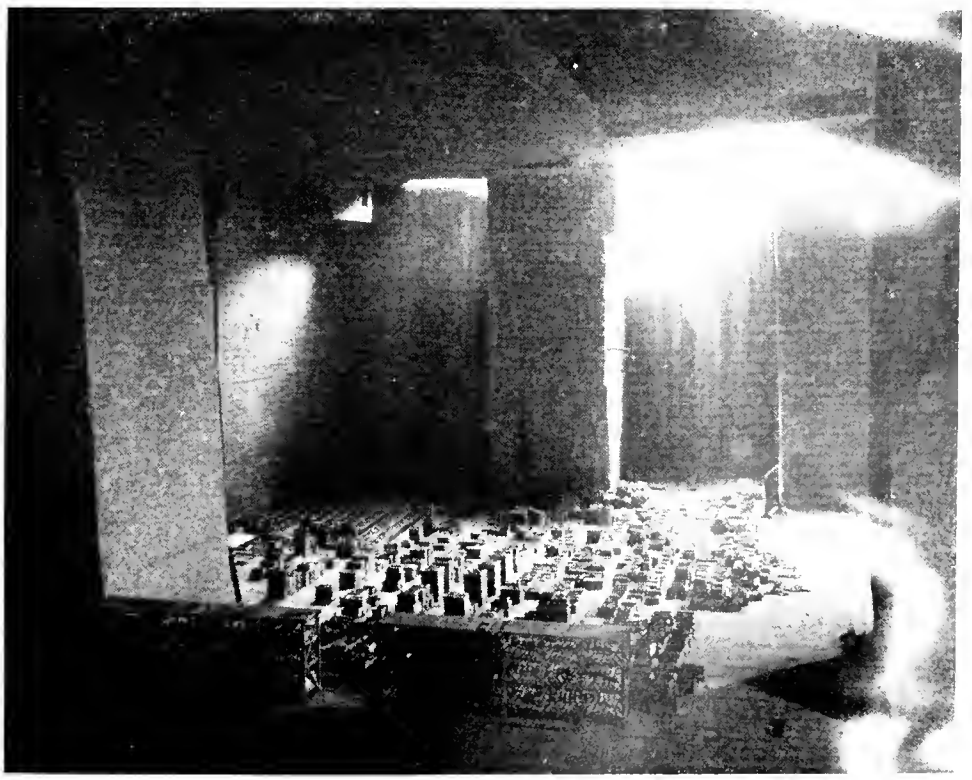


Photo No. 18. Warehouse and stockroom, Kaneirivama Works at Shirovama.

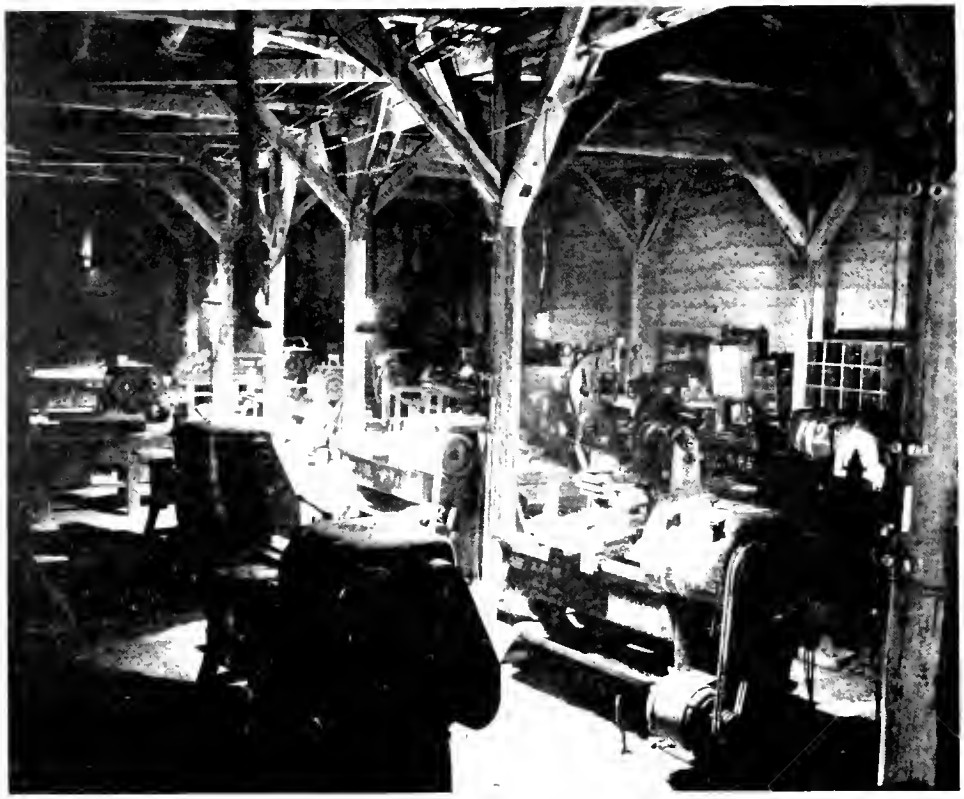


Photo No. 19. Machine shops for airframe parts, Kaneiriyama plant in Shiroyama.

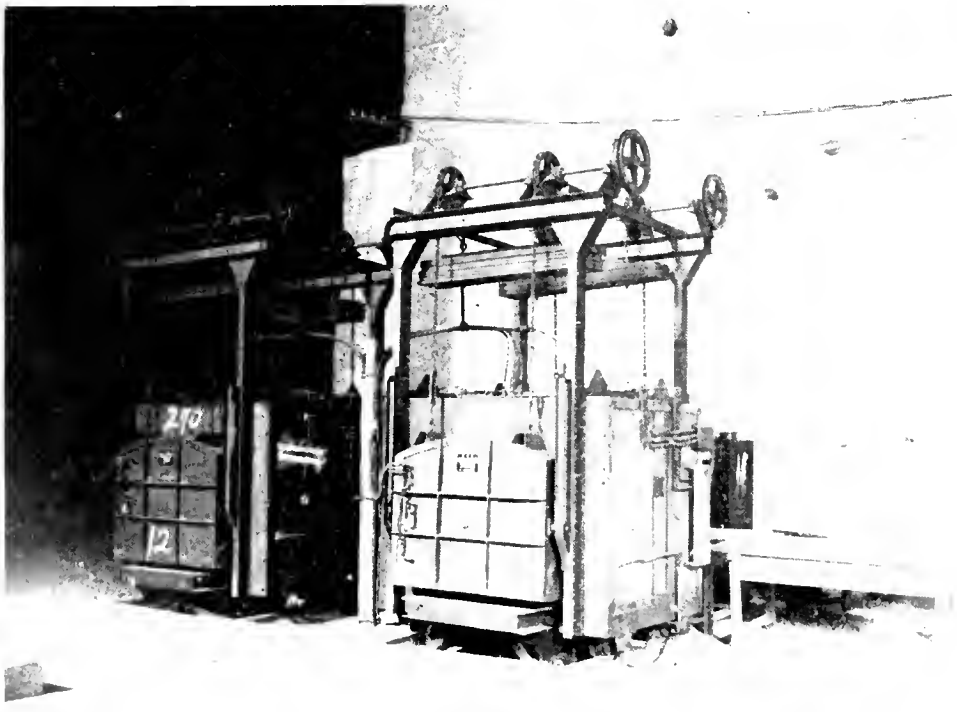
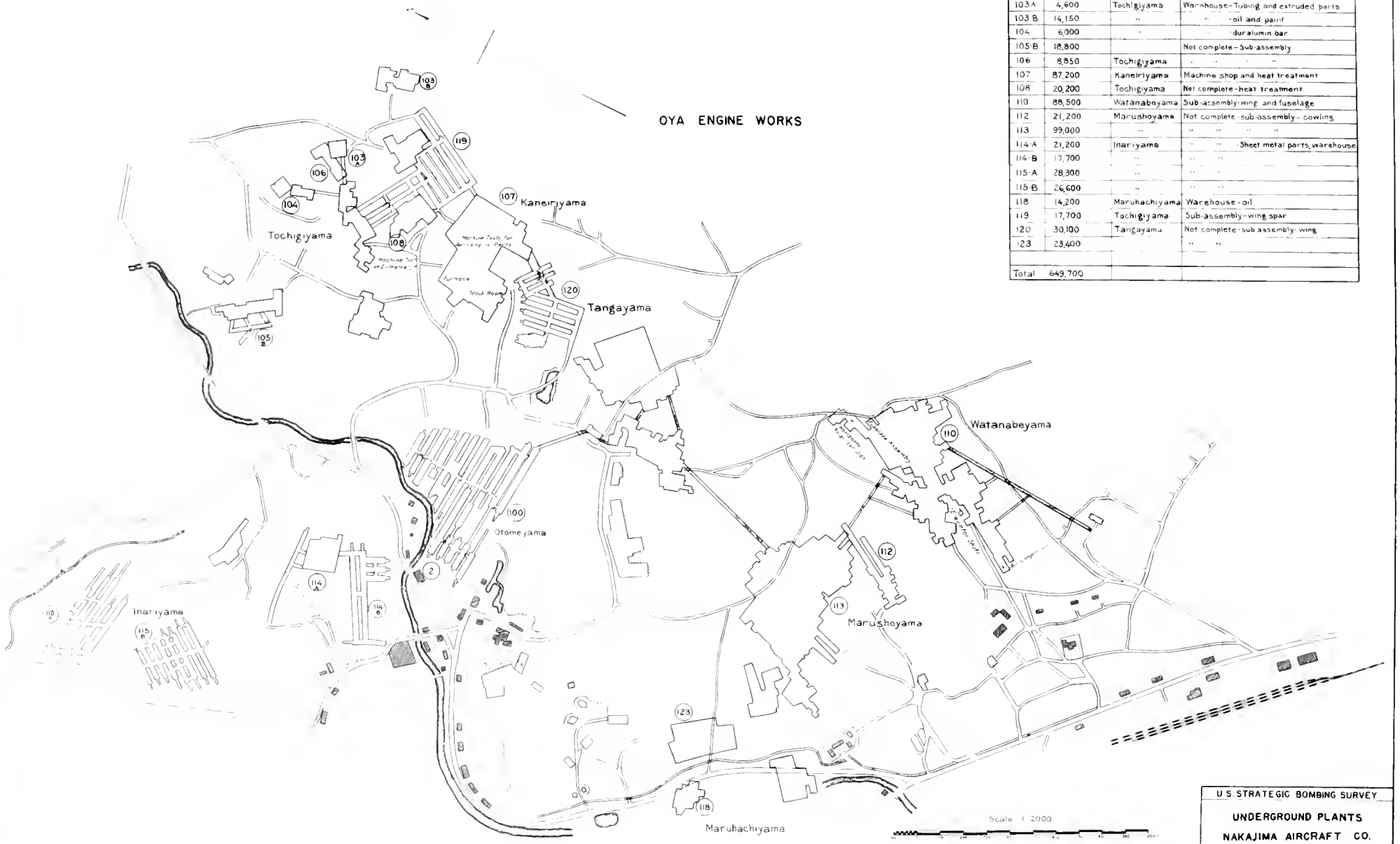


Photo No. 20. Electric heat treatment furnaces, Kaneiriyama plant at Shiroyama.



NO	AREA-SQ.FT	PLACE	DESCRIPTION
100	102,000	Otomeyama	Sheet metal parts
103-A	4,600	Tochigiyama	Warehouse-Tubing and extruded parts
103-B	14,150	"	" -oil and paint
104	6,000	"	" -duralumin bar
105-B	18,800		Not complete-Sub-assembly
106	8,850	Tochigiyama	" " " "
107	87,200	Kaneiriyama	Machine shop and heat treatment
108	20,200	Tochigiyama	Not complete-heat treatment
110	88,500	Watanabeyama	Sub-assembly-wing and fuselage
112	21,200	Marushoyama	Not complete-sub-assembly- cowling
113	99,000	"	" " " "
114-A	21,200	Inariyama	" " -Sheet metal parts, warehouse
114-B	17,700	"	" "
115-A	28,300	"	" "
115-B	26,600	"	" "
118	14,200	Maruhachiyama	Warehouse-oil
119	17,700	Tochigiyama	Sub-assembly-wing spar
120	30,100	Tangayama	Not complete-sub assembly- wing
123	23,400	"	" "
Total	649,700		

U.S. STRATEGIC BOMBING SURVEY

UNDERGROUND PLANTS

NAKAJIMA AIRCRAFT CO.

FIGURE 3

114387 O - 47 (Face p. 18)

ASAKAWA

This plant was a dispersed location of the asashi Works of the Makajima Aircraft Co. and as located in the steep hills on the west edge of akawa village which is two miles west of chioji in Tokyo prefecture.

It was planned that this plant would have 3,000 square feet of floor space and 1,200 maine tools for the production of 300 engines per nth and that it would be in production by July 45. However, at the end of the war in August, ly 6 out of 31 tunnels were completed, with an ea of 257,000 square feet excavated. Three hunred thirty machine tools were in place and had en producing engine parts since July. Ninety-e other machine tools had been delivered to the e but not installed.

The tunnels were laid out in three sections in a id network (Figure 4). No previous tunnels or nes had been in existence here so that the entire cavation was new. External evidence of this nt could be seen in the piles of spoil and in the w uncamouflaged surface buildings which were ed as offices and storehouses.

The tunnels were approximately 15 feet wide d 12 feet high and varied in length from 400 t to 1,200 feet. Because the rains caused the ofs of the tunnels to collapse in at least six ces, extensive timber shoring had been set.

The Nakajima Co. expected to manufacture gine parts in the underground works, with final sembly to be carried out in dispersed surface ildings farther up in the hills. By 15 August 45 about 10 engines had been completed. In dition there were about 300 crankcase castings ored in Tunnel 4, great stores of cylinder heads Tunnel 3, and many other stocks of engine parts machining. There were 18 engines in process assembly in two dispersed small hangar-type ildings.

For the conveyance of parts inside the tunnels, o of the tunnels had narrow-gage tracks while a third had a roller conveyor the length of the tunnel. Only hand methods were available in the rest of the plant.

Most of the usual types of machine tools were installed; engine lathes, turret lathes, drill presses, shapers, planers, grinders, etc. Eighty percent of the 330 installed machine tools were American-made, with such familiar company names as Brown and Sharpe, Cincinnati, Warner and Swazey, American Machine Tool, Bullard, and others in evidence.

The six tunnels in operation were used for machining the following:

No. 1. Cylinder heads.

No. 2. Cylinder barrels.

No. 3. Crankshafts.

No. 4. Propeller shafts.

No. 5. Propeller shafts.

No. 6. Engine accessories.

The chief problems of operating this plant were caused by wet floors and moist atmosphere. The floors in all tunnels examined (Nos. 1 through 6) were wet and in several places were under several inches of water. This caused much illness among the workers and serious corrosion of the machines. At the time of inspection the machines were covered with a layer of grease and waxed paper in an effort to preserve them. Even so, many of them were seriously corroded. Photographs 21-25 show machine tools and parts in the plant.

The manager of the plant reported that a shortage of new cylinders made it necessary to employ used cylinders in the manufacture of engines. This was verified in the assembly shop where the stock of used cylinders slightly outnumbered the new cylinders.

Asakawa was inspected on 24 October 1945.

714387—47—3

GENERAL ARRANGEMENT OF ASAKAWA (UNDERGROUND) PLANT

Corrected to 13 JULY 1945

AREA CHART				% COMPLETION to 10 Aug 1945
	WORKING AREA TUNNELS	PASSAGES	TOTAL	
A	131,116	57,178	188,294	80%
B	80,429	28,837	110,266	80%
C	30,408	10,483	40,671	65%
TOTAL	241,953	97,478	339,431	75%

KOSHU HIGHWAY

ASAKAWA STATION

UNDERGROUND FACTORY

CONTOUR

SURFACE BUILDING

LEGEND	
	PARTS MACHINED
a	SHAFT GEARS
b	REPRODUCTION GEAR
c	PLANETARY GEAR
d	CAM BOSS
e	SUPERCHARGER GEAR

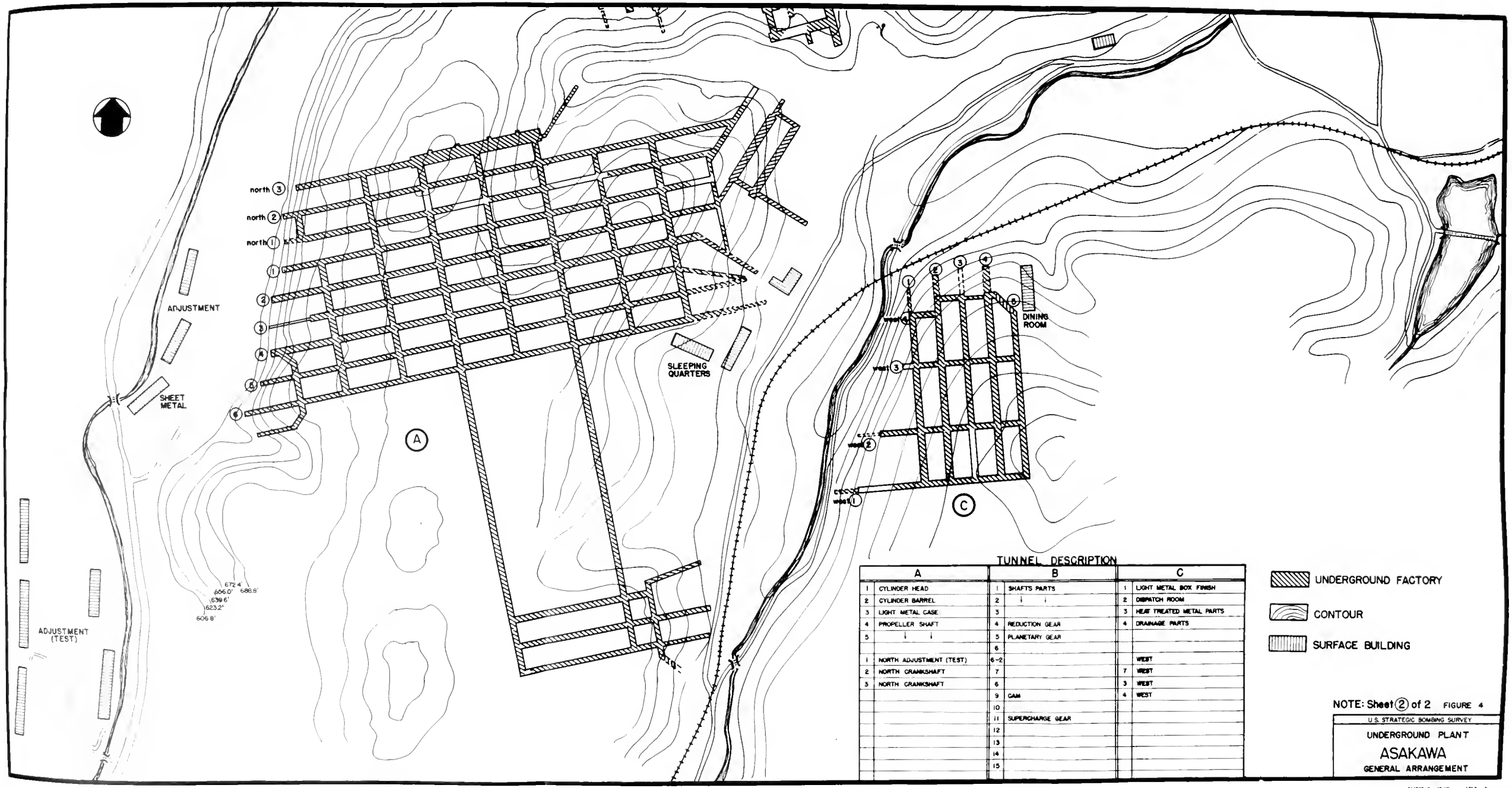
NOTE: Sheet ① of 2 FIGURE 4

U.S. STRATEGIC BOMBING SURVEY

UNDERGROUND PLANT

ASAKAWA

GENERAL ARRANGEMENT



TUNNEL DESCRIPTION

A		B		C	
1	CYLINDER HEAD	1	SHAFTS PARTS	1	LIGHT METAL BOX FINISH
2	CYLINDER BARREL	2	↓ ↓	2	DISPATCH ROOM
3	LIGHT METAL CASE	3		3	HEAT TREATED METAL PARTS
4	PROPELLER SHAFT	4	REDUCTION GEAR	4	DRAINAGE PARTS
5	↓ ↓	5	PLANETARY GEAR		
		6			
1	NORTH ADJUSTMENT (TEST)	6-2			WEST
2	NORTH CRANKSHAFT	7		7	WEST
3	NORTH CRANKSHAFT	8		3	WEST
		9	CAM	4	WEST
		10			
		11	SUPERCHARGE GEAR		
		12			
		13			
		14			
		15			

UNDERGROUND FACTORY

CONTOUR

SURFACE BUILDING

NOTE: Sheet (2) of 2 FIGURE 4

U.S. STRATEGIC BOMBING SURVEY

UNDERGROUND PLANT

ASAKAWA

GENERAL ARRANGEMENT

714387 O - 47 (Face p. 181) No. 1

GOKAN

The Gokan plant of the Nakajima Aircraft Co. ar Numata in Gunma prefecture was inspected Captain Richardson, the intelligence officer the 387th Infantry Regiment, 97th Division. he following data were obtained from him:

Sixteen tunnels, each about 600 feet long, had en excavated by 565 Chinese prisoners of war ho were housed nearby in a labor camp. Some 0 machine tools had been installed in the tunls while many other tools were stored outside, awaiting the completion of new areas. In parts of the plant, there were double rows of machine tools.

The floors at Gokan, as at Asakawa, were generally wet and, while some of the machinery was protected with grease and tarpaulins, many other machines were severely rusted.

A semiunderground plant was being built nearby to assemble the airframe parts which were to be machined in the underground section.

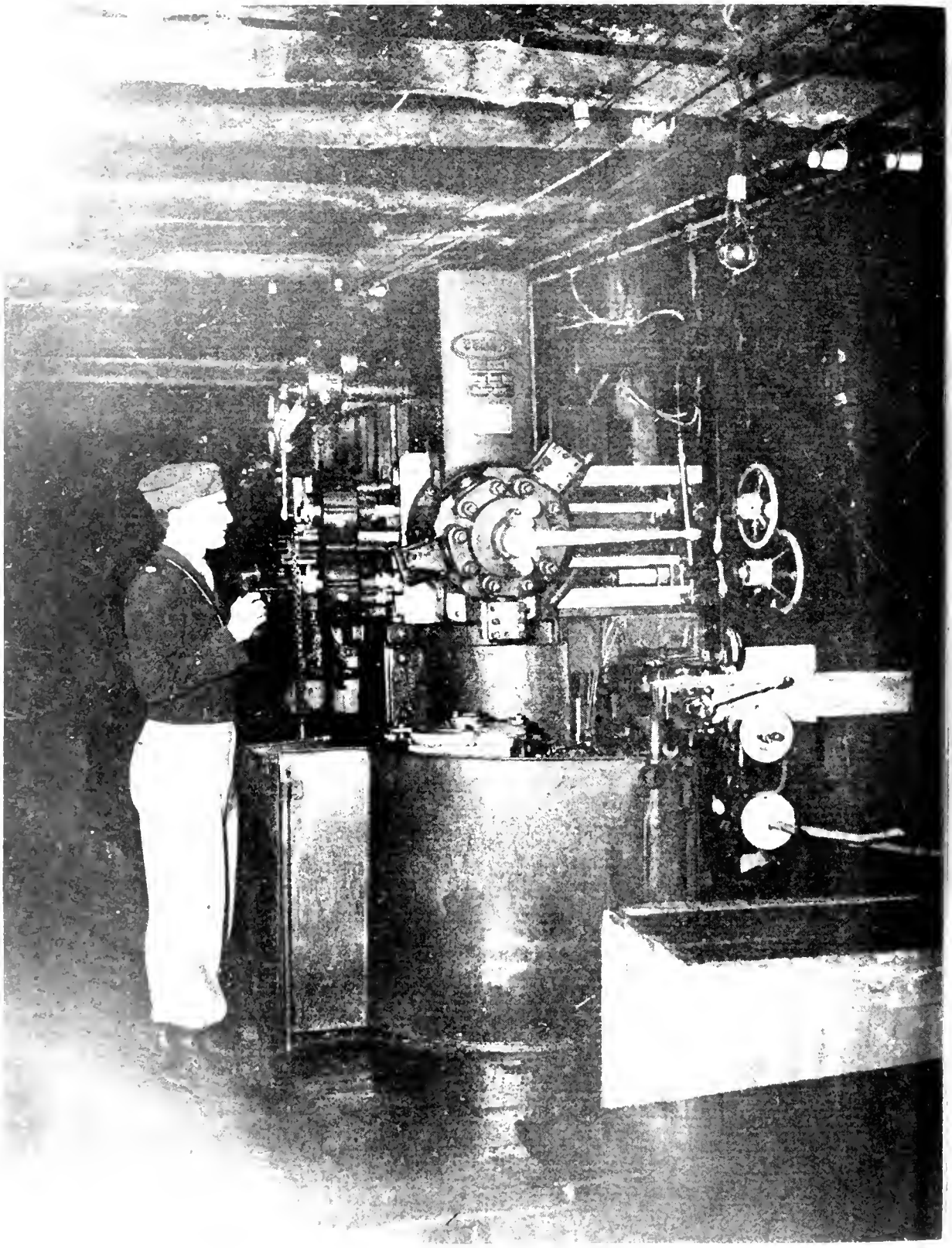


Photo No. 21. Asakawa underground plant.

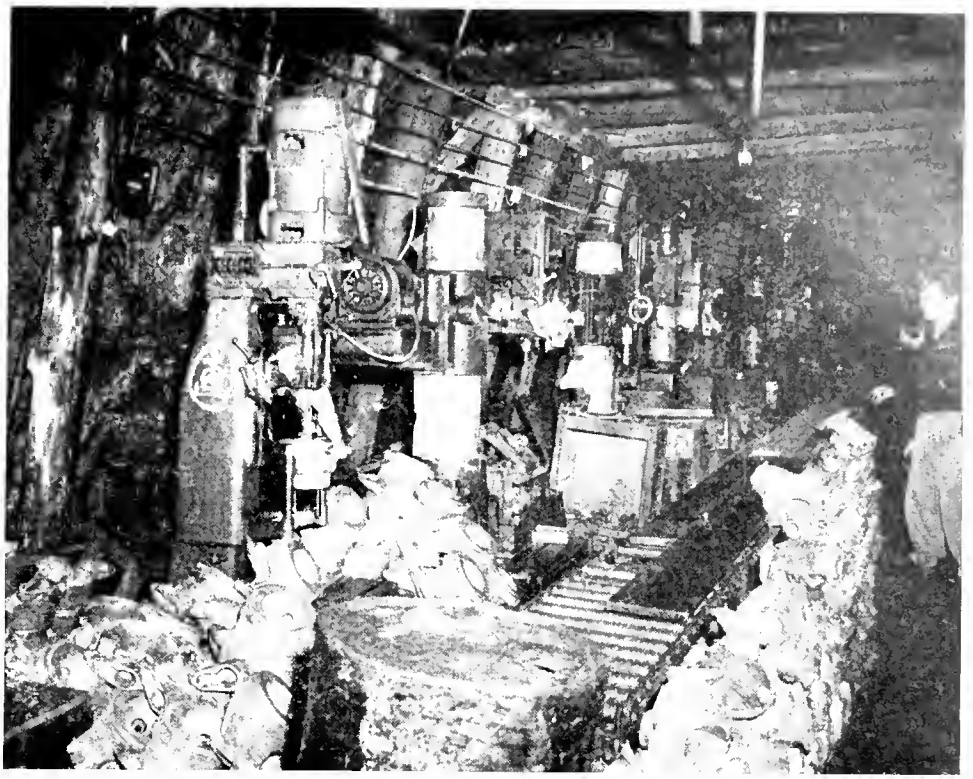


Photo No. 22. Asakawa plant cylinder heads awaiting machining. Note roller conveyor.

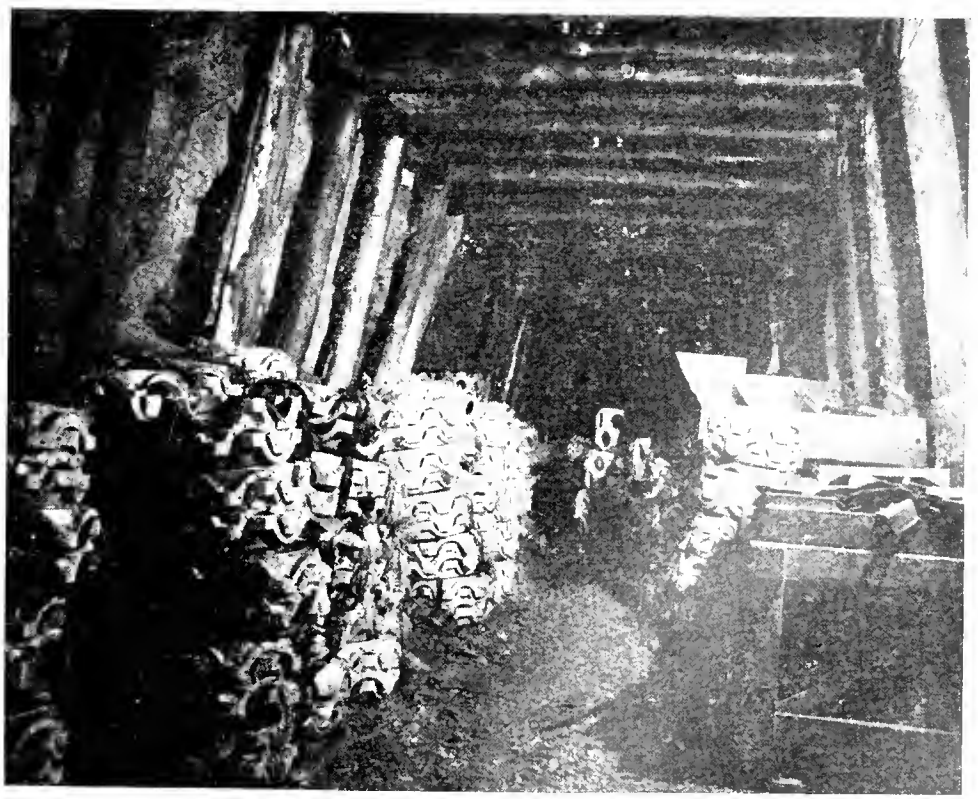


Photo No. 23. Asakawa plant. Cross-tunnel used for storage of engine parts.

Photo No. 24. Asakawa underground plant.

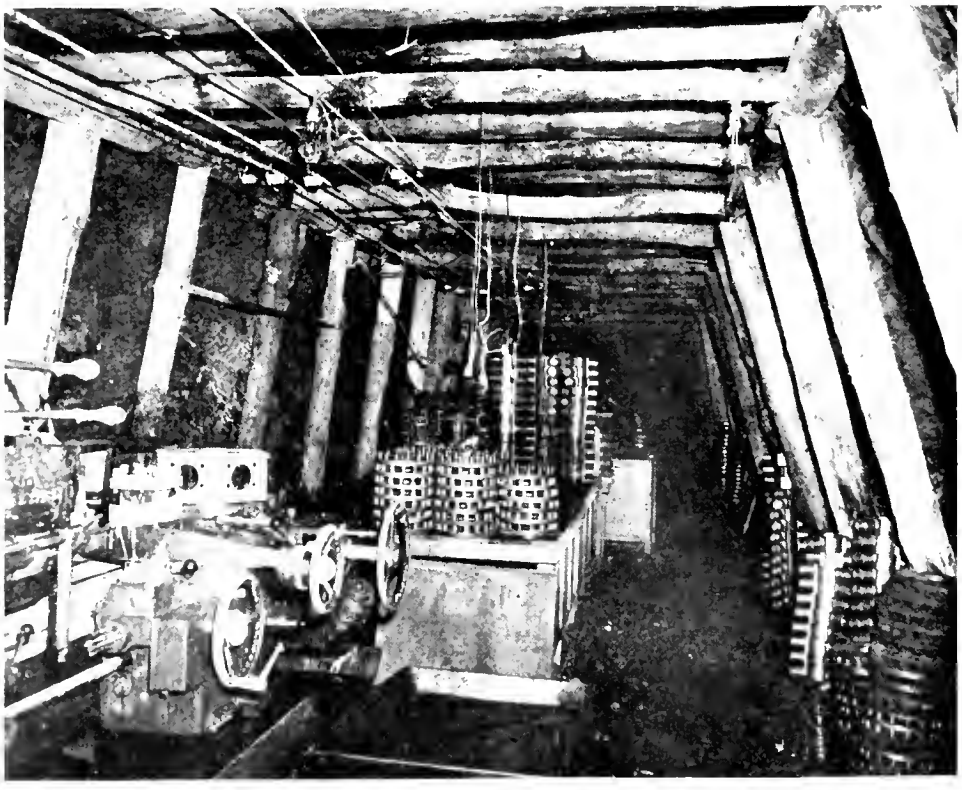


Photo No. 25. Asakawa underground plant.

YOSHIMATSU

One of the most advanced plants seen in Japan was the Yoshimatsu engine plant of Nakajima located near Matsuyama, 32 miles northwest of Tokyo. This plant, which was dispersed from the Omija Works, was 80 percent complete and was in production from 15 June until the end of the war. Although it was planned to make complete engines at this plant, only the machining of parts was actually carried out.

The Japanese aircraft industry was not the first organization to go underground at Matsuyama. That distinction goes to a group of cave dwellers of about 1,500 years ago. More than 100 caves pockmark the face of the cliff in which the aircraft tunnels are located. Each of these caves has an entrance about 4 to 5 feet square which opens into a hemispherical room about 8 to 10 feet in diameter (Photographs 26 and 27). These caves were the dwellings of some ancient tribe.

Farther along the cliff is another curiosity—the Madman's Hotel, which is an underground house started by Ninekichi Takahashi in Nishi-Yoshimimura. The house was begun in the thirty-seventh year of the reign of Meiji (1904) as a financial venture. He expected that it would take three generations to complete but by that time it would be such a curiosity that visitors would pay to see such a place and the Takahashi family would eventually become financially independent.

He worked for 20 years on the project and had 2 large rooms, 1 small room, numerous corridors, and the staircase to the second floor already carved. The entrance was flanked by 2 Grecian columns carved into the cliff side and led into the lobby, a room about 10 feet by 20 feet with the staircase in the rear center. The living room, 8 by 12 feet had stone tables, chairs, and fixtures. The dreams of Takahashi were not realized as his son abandoned what he considered to be a madman's project when the father died.

Both of these projects served a useful purpose for the Japanese in 1945, as they inspired the construction of an underground aircraft plant in this hill of sedimentary volcanic ash.

On 15 January 1945, this factory received orders to go underground and excavation was started shortly thereafter. As sections of the tunnel areas were completed, machine tools were installed and the machining of aircraft engine parts was begun. The first actual work was done on 15 June and continued until the end of the war.

The total planned area of this plant was 353,000 square feet, to be spread over six areas (Figure 5). The first five areas were completely excavated and three tunnels of the sixth area were completed, making a total excavated area of about 320,000 square feet. The total length of tunnel amounted to approximately 33,000 feet.

Each tunnel was 13 feet wide and varied in height from 11 feet to 13 feet to accommodate the use to which the tunnel was put. (Photographs 28–36).

The tunnels were fairly dry due to the peculiar desiccating quality of the volcanic-type rock through which they were carved. The temperature remained fairly constant underground throughout the year. Area No. 5 was shored up by timbers but most of the remainder needed no support. In many places concrete floors had been laid.

Four hundred fifty machine tools had been brought to the site but only 300 had been installed in the tunnels. Machines were set in the tunnels in single rows.

Corrosion of equipment became a problem almost at once. To combat this condition it was made the responsibility of each workman to keep his machine from rusting. To prevent corrosion, finished parts were removed from the tunnels immediately upon their completion.

Plans called for the manufacture of 300 engines per month in the underground plant, with final assembly in dispersed buildings in and near Matsuyama. Actual production, however, consisted only of master rods, cylinder heads, cylinder barrels, and crankshaft counterbalances. Between 200 and 300 of each of the above parts were completed by 15 August.

Evidence of this work was seen in the piles of master rods, counterbalances, and cylinders that were stacked beside the machine tools and in storage tunnels.

Eventual employment here would have been 4,000. However, only 500 were actually at work underground in August. K. Hirata was plant manager.

Transportation of parts to and from the plant was by truck.

Several unusual features were noted in this plant:

1. In area No. 4, nine heat-treatment pits were being dug in the tunnel floor. Each pit measured 8 feet wide, 6 feet deep, and 15 feet long.
2. Tall machines were countersunk into the floor of the tunnel so that the largest machines seen anywhere underground were in place here.
3. A power substation of three 250-kv.-a. transformers was built for each of the five completed areas.
4. Tunnel cross sections varied to suit the ne[illegible].

The entrances to Sections 1 and 6 were in sh[illegible] cliffs at least 75 feet high. The whole establi[illegible]ment was well concealed except for a built [illegible] area of 5 surface buildings (warehouses, offi[illegible], etc.) near the entrances to Number 4 area.

Yoshimatsu was inspected on 13 and 15 Nov[illegible]ber 1945.

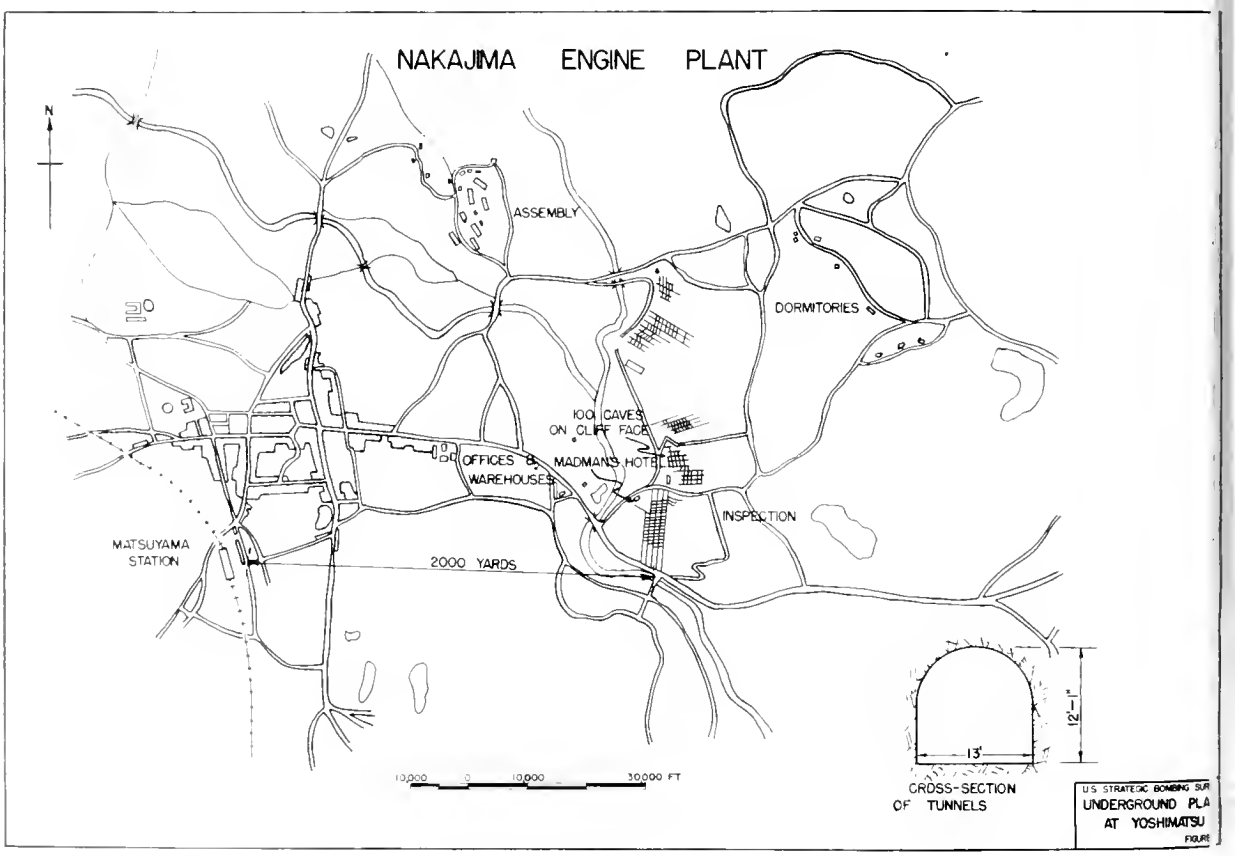


Photo No. 26. Ancient caves at Yoshimatsu.

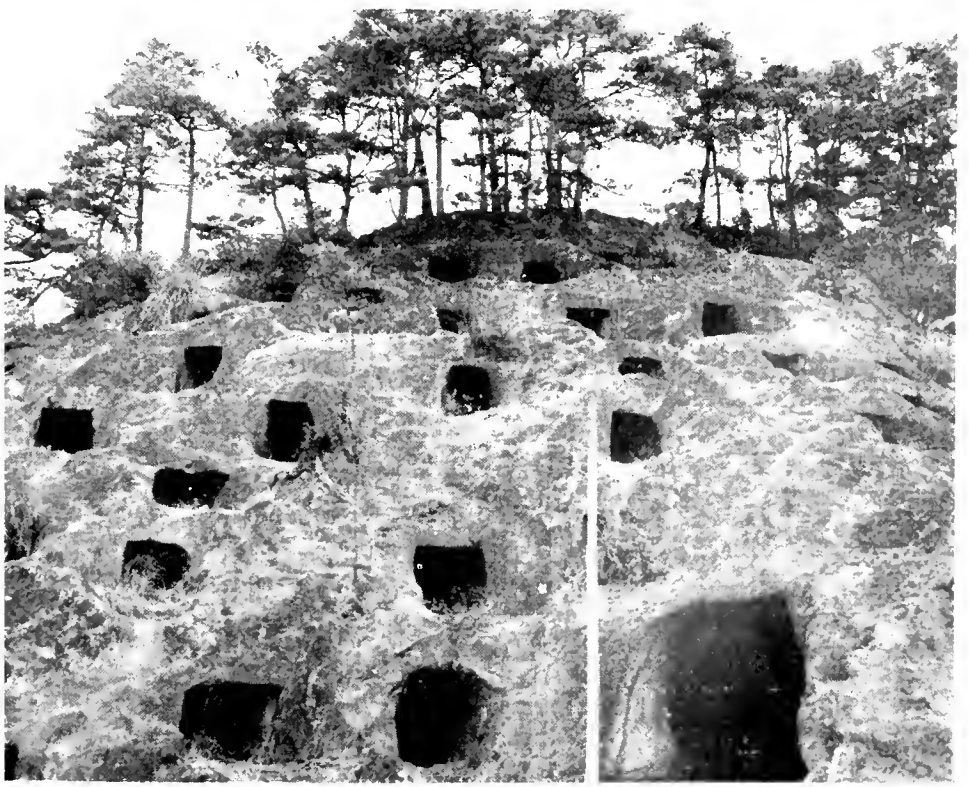


Photo No. 27. Close-up of ancient caves at Yoshimatsu.

Photo No. 28. Entrance to Nakajima tunnels at base of cliff, Yoshimatsu.

Photo No. 29. Entrances to tunnels, Yoshimatsu.

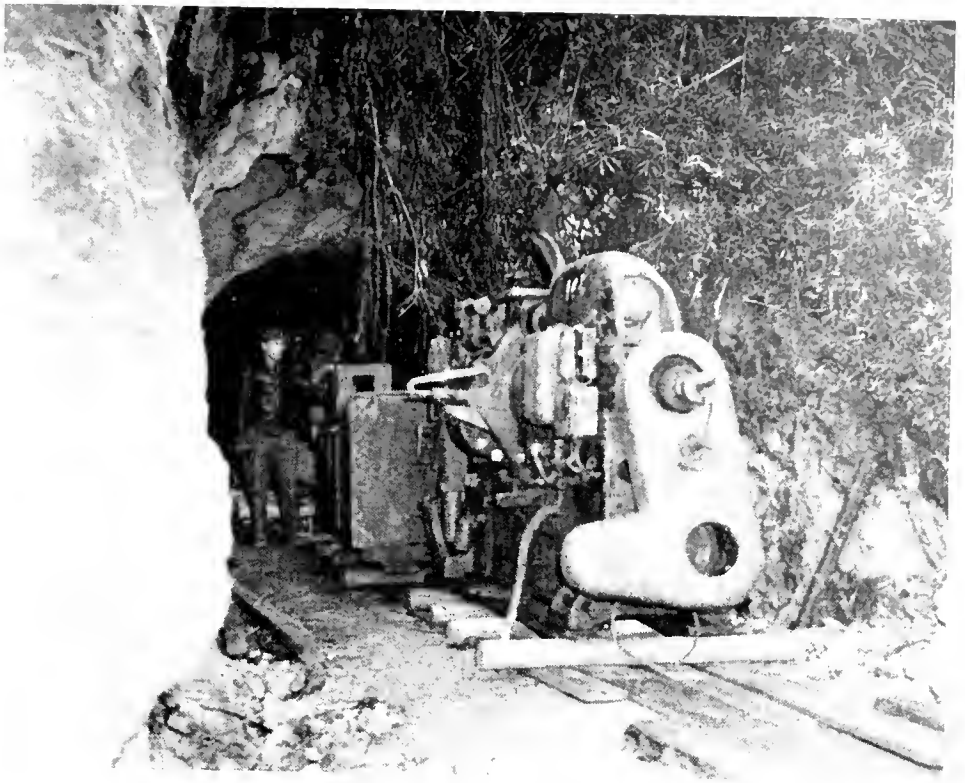


Photo No. 30. Machine tool in process of installation, Yoshimatsu.

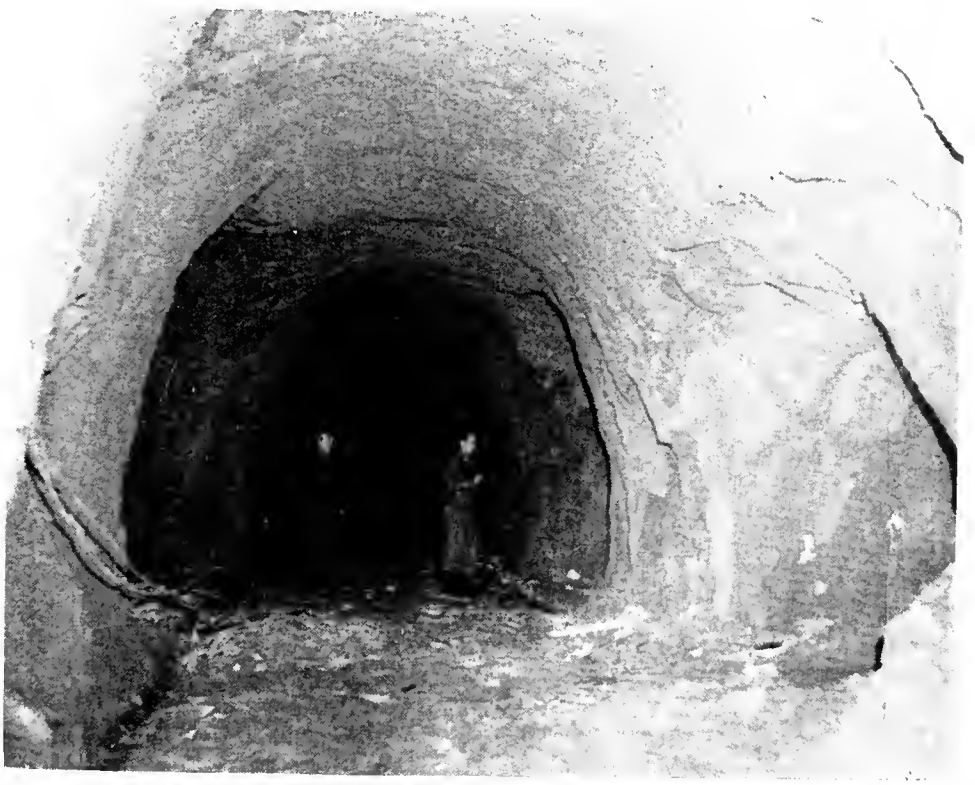


Photo No. 31. Tunnels at Yoshimatsu.

Photo No. 32. Machine tool in process of installation, Yoshimatsu.

Photo No. 33. Machine tools in position, Yoshimatsu.

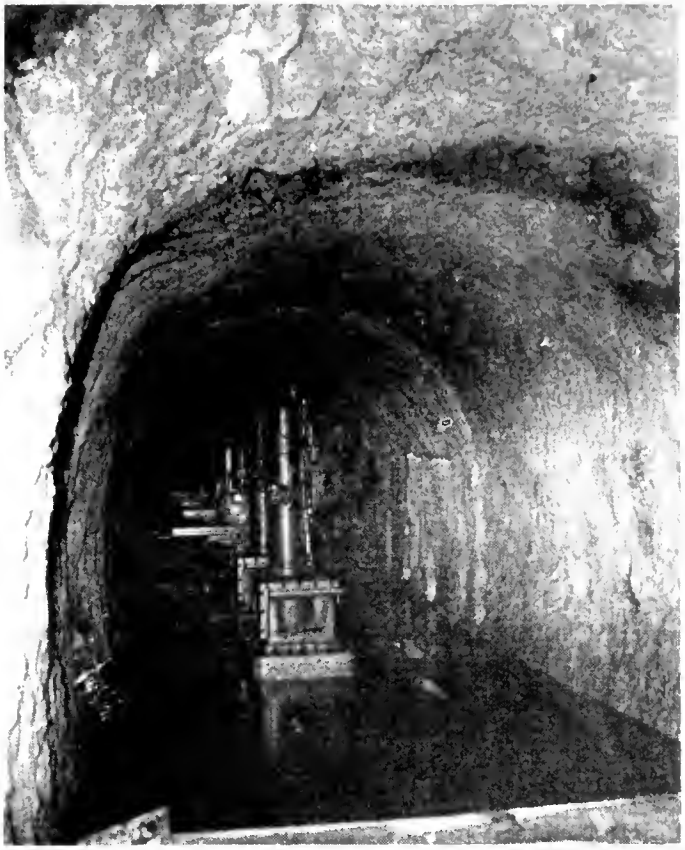


Photo No. 34. Machine tools standing in water. Landslide had formed a dam near entrance.

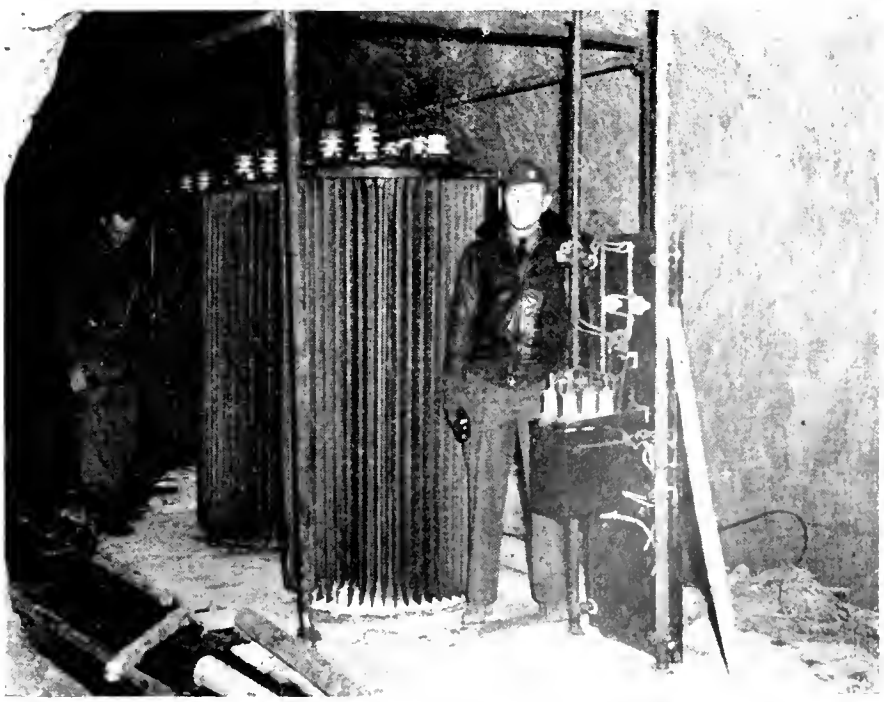


Photo No. 35. Three 250-kv.-a. transformers, Yoshimatsu.

Photo No. 36. Heat treatment pits under construction, Yoshimatsu.

YABUTSUKA

The Yabutsuka airframe plant, located 6 miles orthwest of Ota, Gumma prefecture, was a dis-ersed location of the Ota Works of the Nakajima ircraft Co.

It was not possible to inspect the tunnels of his plant on the date of visit, 13 November 1945, ecause all entrances had caved in. The local apanese attributed the collapse to the torrential ctober rains and denied that any explosion had aled them. At several entrances it was possible look over the landslide into the tunnels where could be seen that water was standing from 1 4 feet deep.

Thirty tunnels, each 13 feet wide and 11 feet high, were completely excavated and shored up with timbers. This represented one-half of the projected area.

Excavation was started in January 1945 by 1,500 men working on a 10-hour shift. Planned lay-out is shown in Figure 6.

No machine tools were installed or even brought to the site.

This plant was almost inaccessible. Only one very narrow road which would barely permit passage of a jeep led to the site of the plant.

YUSENJI

Yusenji, 4 miles west of Komatsu in Ishikewa refecture on the northwest coast of Japan, was dispersed airframe plant of the Handa Works the Nakajima Aircraft Co.

The underground areas of this plant were the yriad and irregular caverns of ancient firebrick nd modern stone quarries. In prewar years many the modern buildings of Tokyo and Osaka had en constructed from building stone dug out of is site.

Of a planned area of 214,000 square feet, about ,000 square feet were ready for use, while 100 400 machine tools planned were in operation. The plant was designed to produce small air-ame parts, metal fittings, and similar items for e C–6 scouting plane. Production on a small ale began late in June 1945 but only a few parts ere completed by the end of hostilities. The con-rsion of the caverns for aircraft production be-n in February 1945 under Navy supervision and mpletion was set for the end of September, but ly 30 percent progress had been made by 15 ugust.

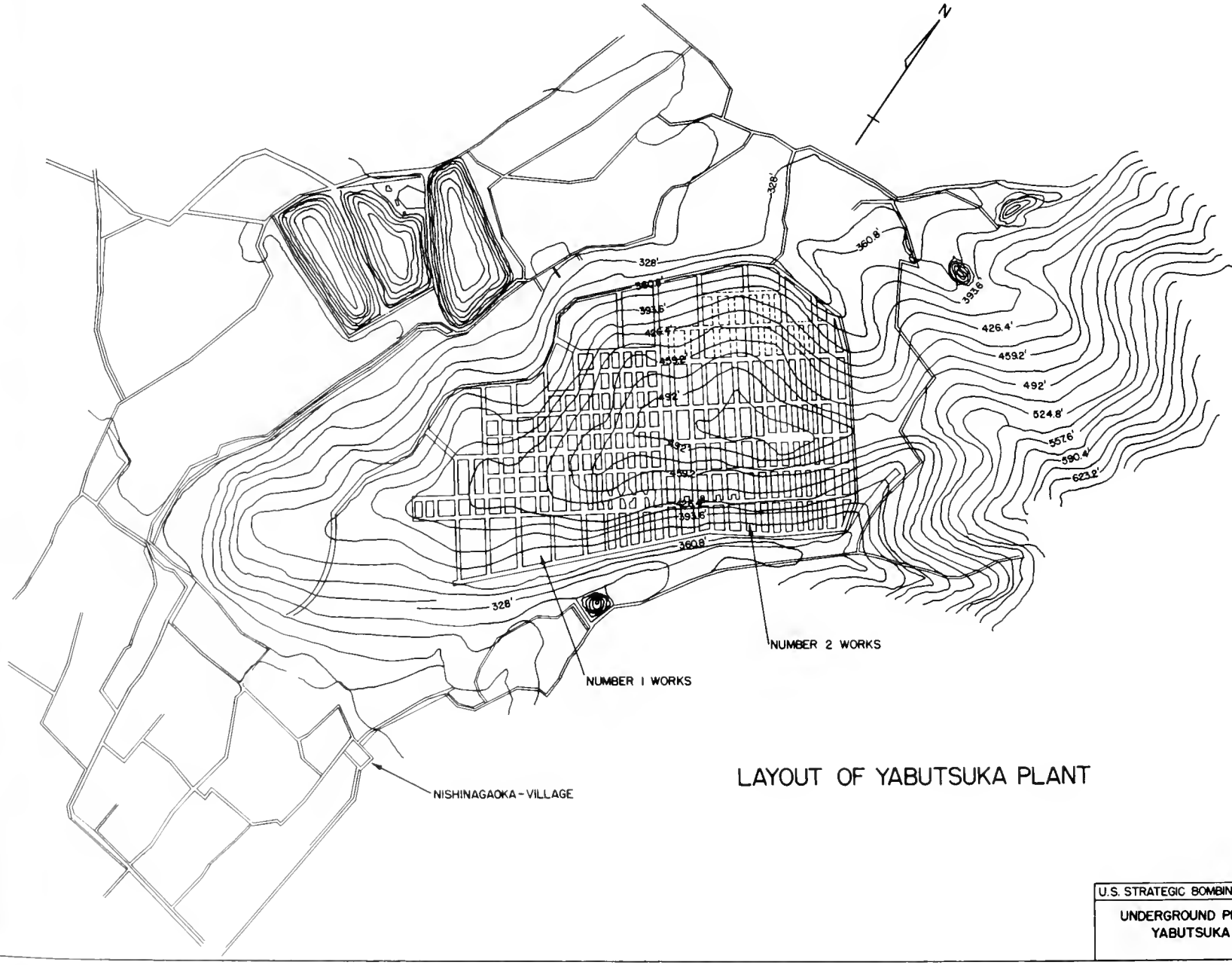
An extensive network of tunnels and quarries is hidden under the hills with only a few entrances and some new spoil to reveal their existence to the photo interpreter. Small entrance tunnels about 9 feet wide and 6 feet high with extensive and heavy shoring led into the main galleries which were of irregular shape (Fig. 7).

Concrete bases had been laid on which to mount the machine tools and the cavern floors were dry.

Yusenji was easily accessible by highway and electric railroad from Komatsu. The actual tunnel level is only a few feet above sea level.

Of all the underground factories seen, this one seemed among the best from the standpoint of transportation, concealment, and working conditions.

One half mile north of the Nakajima site was another hill with a similar network of caverns, which housed great stores of munitions that were being removed by United States troops on 20 November 1945, the date of inspection.



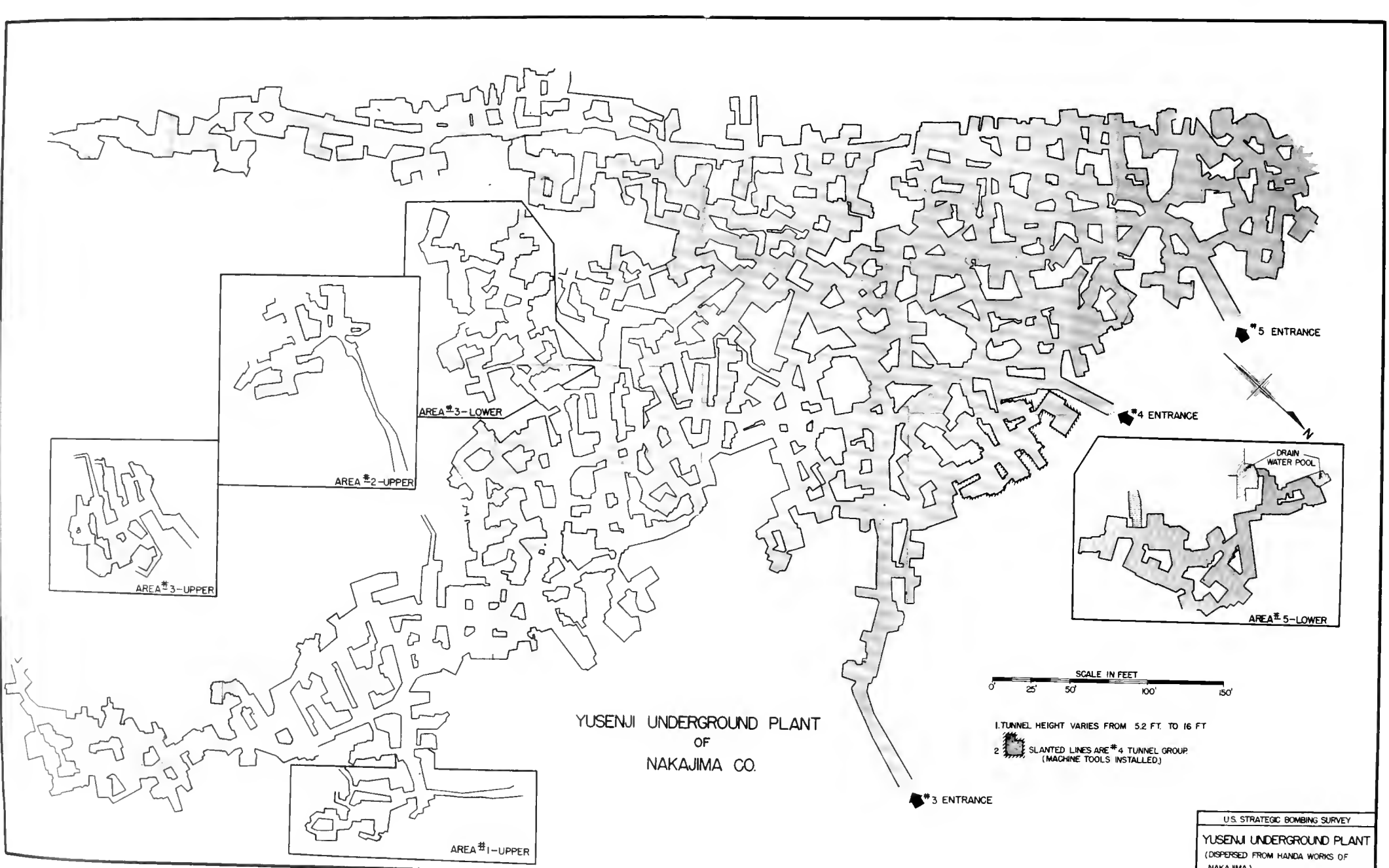
LAYOUT OF YABUTSUKA PLANT

U.S. STRATEGIC BOMBING SURVEY

UNDERGROUND PLANT
YABUTSUKA

FIGURE 6

714387 O - 47 (Face p. 32) No. 1



714387 O - 47 (Face p. 32) No. 3

PART II

UNDERGROUND PLANTS OF MITSUBISHI AIRCRAFT CO.

KATSURA

The Katsura plant of Mitsubishi No. 8 Engine Works was located at Mameda, one-quarter mile north of Katsura station, southwest of the city of Kyoto. Not strictly an underground plant, it was an interesting use of a railroad viaduct to conceal and protect a shop.

The space under the viaduct where it crossed a highway was enclosed by the erection of mud walls along the steel and concrete trestles. The area thus enclosed amounted to 25,000 square feet.

Seventy-two machine tools had been installed and were in operation from June 1945. The entire plant was used for the machining of all master rods for Kasei 25 engines.

It was evident that the plant had been an efficient one. It was clean, well lighted, and dry, with an orderly arrangement of machine tools.

In external appearance there was no evidence to reveal the location of this plant to the photo interpreter.

The plant was inspected on 30 October 1945.

OTANI

The Otani plant was a dispersal location of the Mitsubishi No. 8 and No. 14 Engine Works and was situated at Otani, 1 mile southwest of Otsu, a city 6 miles east of Kyoto.

Two abandoned railroad tunnels, 2,160 and 2,200 feet long respectively, were used as gear-cutting and grinding shops for the aforementioned plants. Thirty-six different kinds of gears were machined here on 286 machine tools belonging to No. 8 Works and 25 tools belonging to No. 14 Works.

Installation of machine tools began 16 March 1945 and was completed in April. Full production was carried out for about 2½ months.

A total of 700 persons was employed in the plant. Many of the employees were girl students who "worked very hard but not too well." More than half of the machine shop employees were students.

The tunnels were reasonably dry but the manager reported that there was always trouble with moisture, which caused worker illness and corrosion of machines and tools.

Six wooden buildings were erected in the valley at the southwest end of the tunnels. These buildings were to be used for heat treatment, carbonization, and copper plating but were not completed by the war's end. They were not camouflaged nor was it intended to do so.

The plant was inspected on 31 October 1945.

KIYOTAKI

Kiyotaki was a dispersal of Mitsubishi No. 14 Engine Works and was located in two abandoned streetcar tunnels 5 miles west of Kyoto.

The plant was very similar to Otani and came into production in May 1945, just ten days after Otani. The tunnels were 1,970 feet long and housed 120 machine tools.

Machining of exhaust valves was the only operation to take place here.

714587 -47—4

KUKURI

The Kukuri plant of the Mitsubishi No. 4 Engine Works was located in the hills three miles southeast of Hiromi, about 20 miles northeast of Nagoya (Fig. 8).

An elaborate network of 38 tunnels totaling 23,000 feet in length was excavated in a ridge of sedimentary-type rock. The total planned area was 360,000 square feet, of which 270,000 square feet were completed. In cross section the tunnels measured 16 feet wide and 11.5 feet high (Figs. 9 and 10).

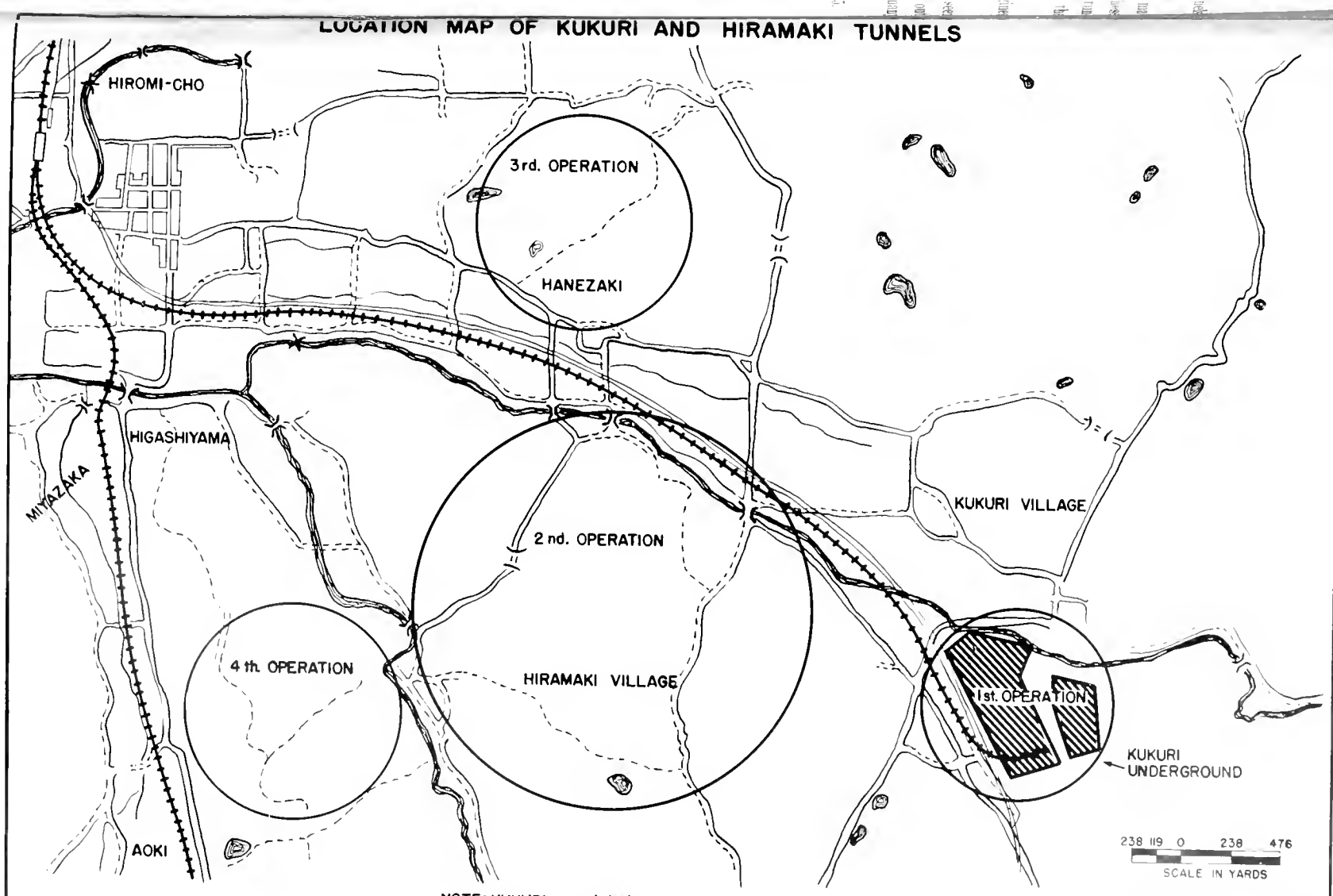
During construction the tunnels were cut entirely through the hill so that the machine tools could be handled directly into each tunnel. After the machines were in place it was intended to close and conceal the entrances to all but three tunnels which would then become the only entrances.

One hundred sixty-four of a planned 800 machine tools were installed underground. These machines were lined along both sides of the tunnels, leaving an aisle about four feet wide in the center.

This plant was supposed to manufacture engines but no actual production was achieved.

These tunnels were among the better ones seen in Japan. They were very dry, well laid out, had smooth floors, and seemed roomier than many others (Photographs 37–40).

Kukuri was inspected on 3 November 1945.

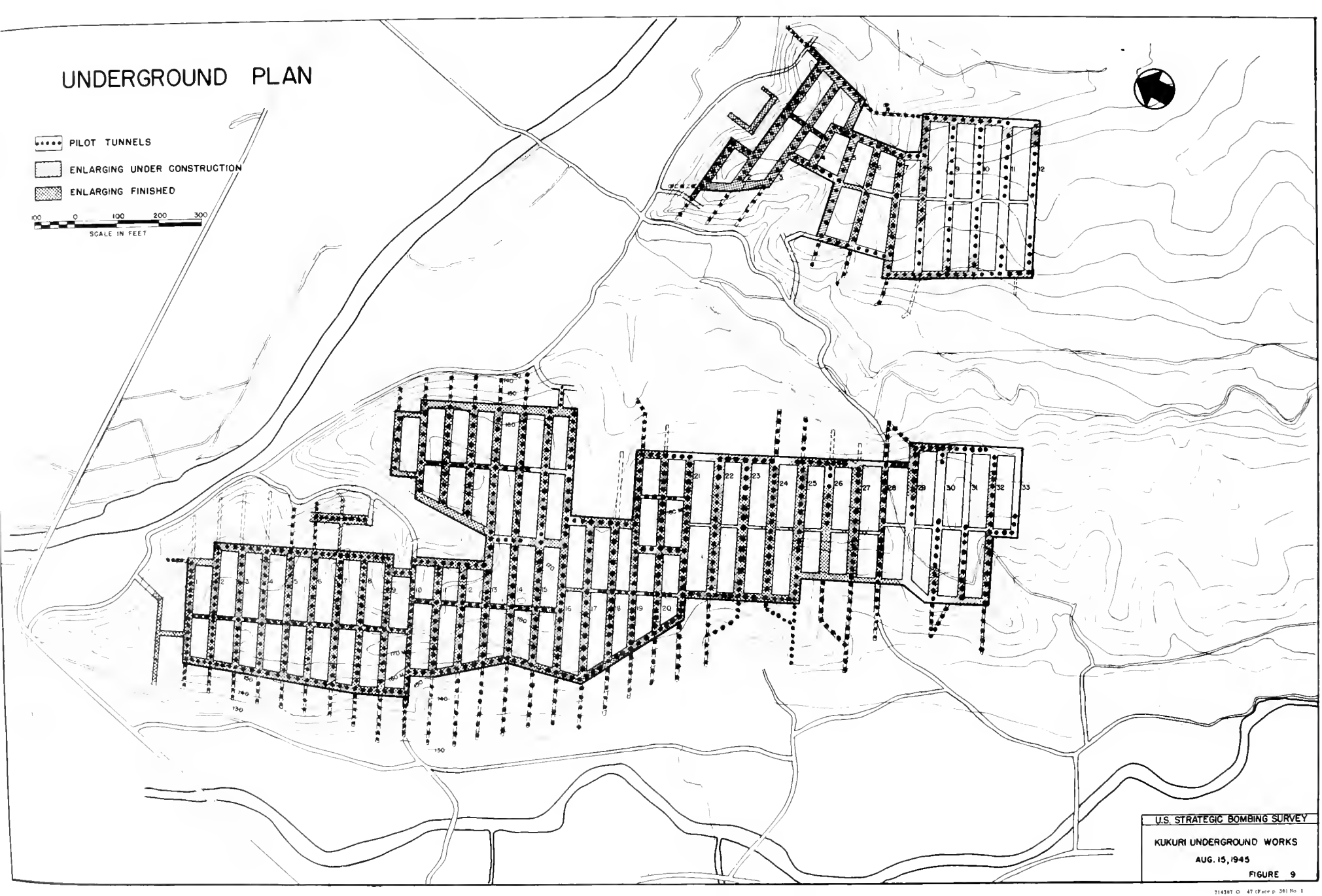


NOTE: KUKURI completed.
Detailed plan available for others.
MITSUBISHI had no plans as excavation was still proceeding under Army at 15 Aug. 1945.

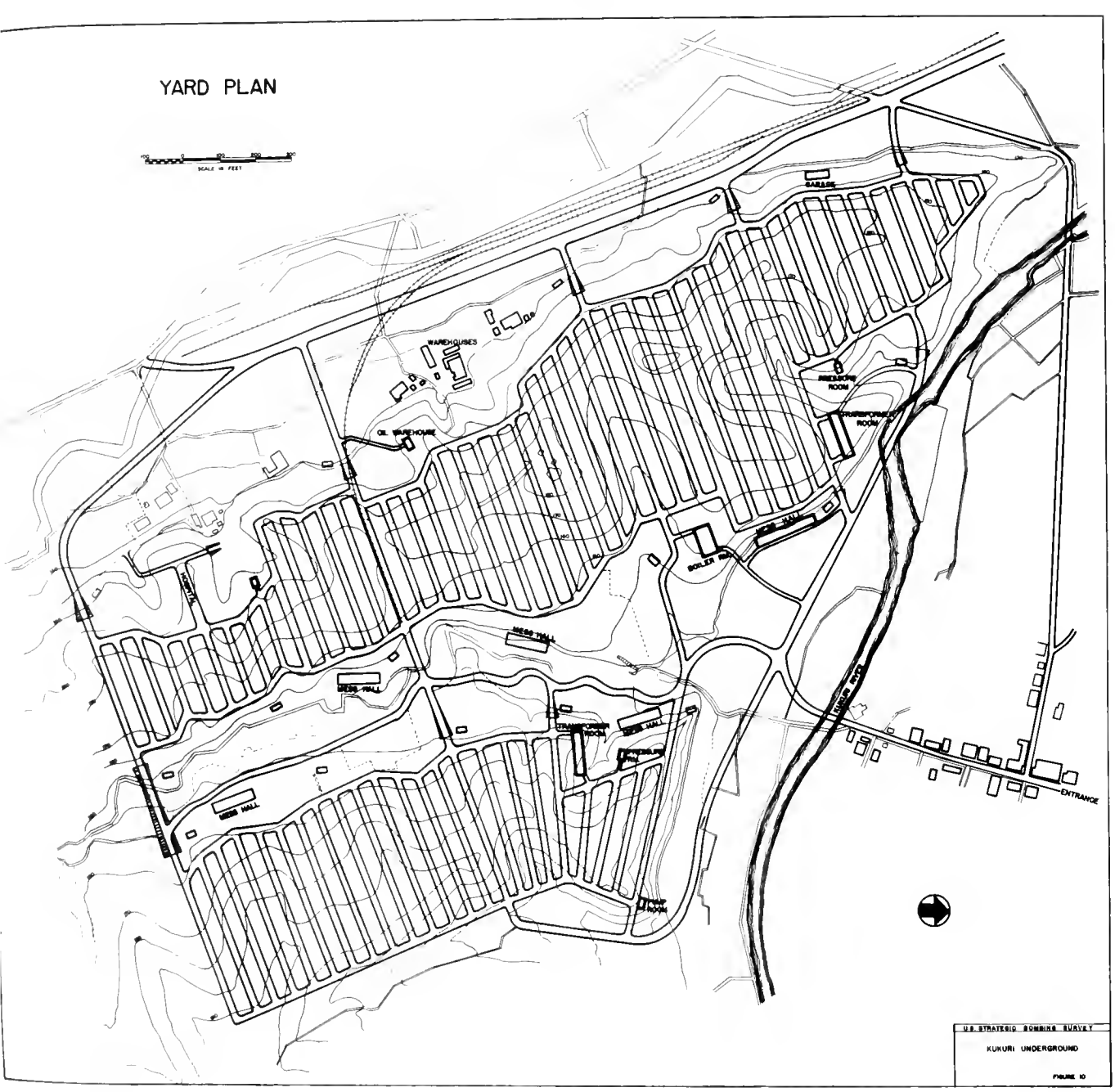
U.S. STRATEGIC BOMBING SURVEY

KUKURI & HIRAMAKI UNDERGROUND WORKS

FIGURE 8



716387 O 47 (Face p. 361 No. 1



U.S. STRATEGIC BOMBING SURVEY

KUKURI UNDERGROUND

FIGURE 10

714387 O - 47 (Face p 36) No. 2

Photo No. 37. Machine shop at Kukuri.

Photo No. 38. Kukuri plant. Small tunnel used for installation of machine tools.

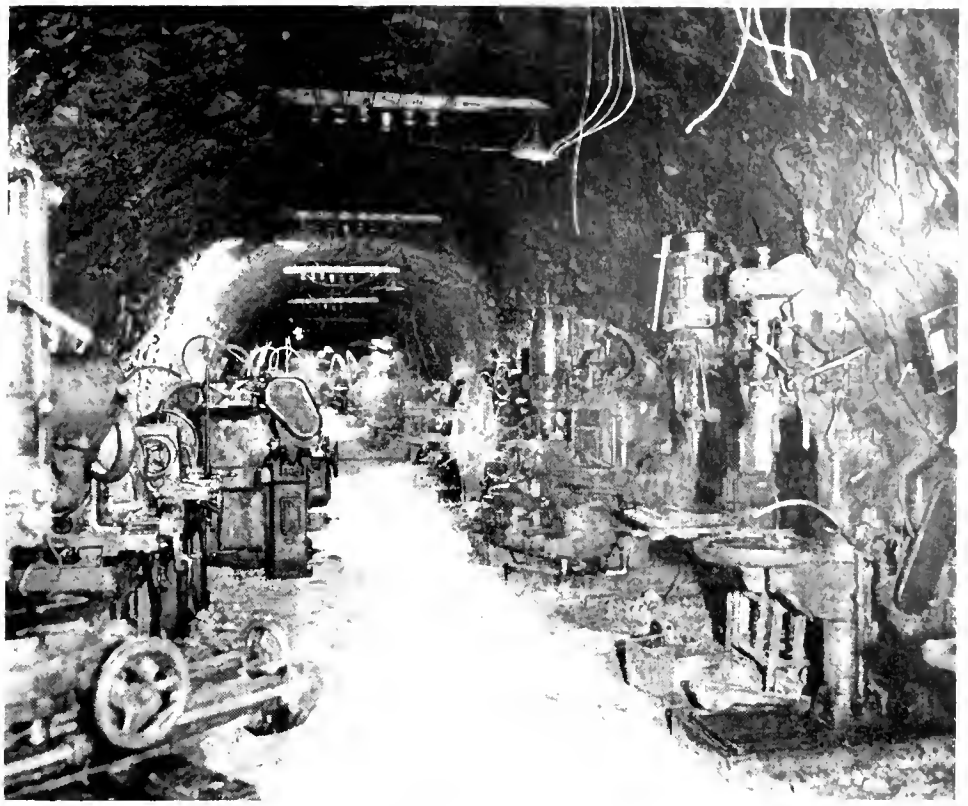


Photo No. 39. Kukuri plant. Two long rows of machine tools

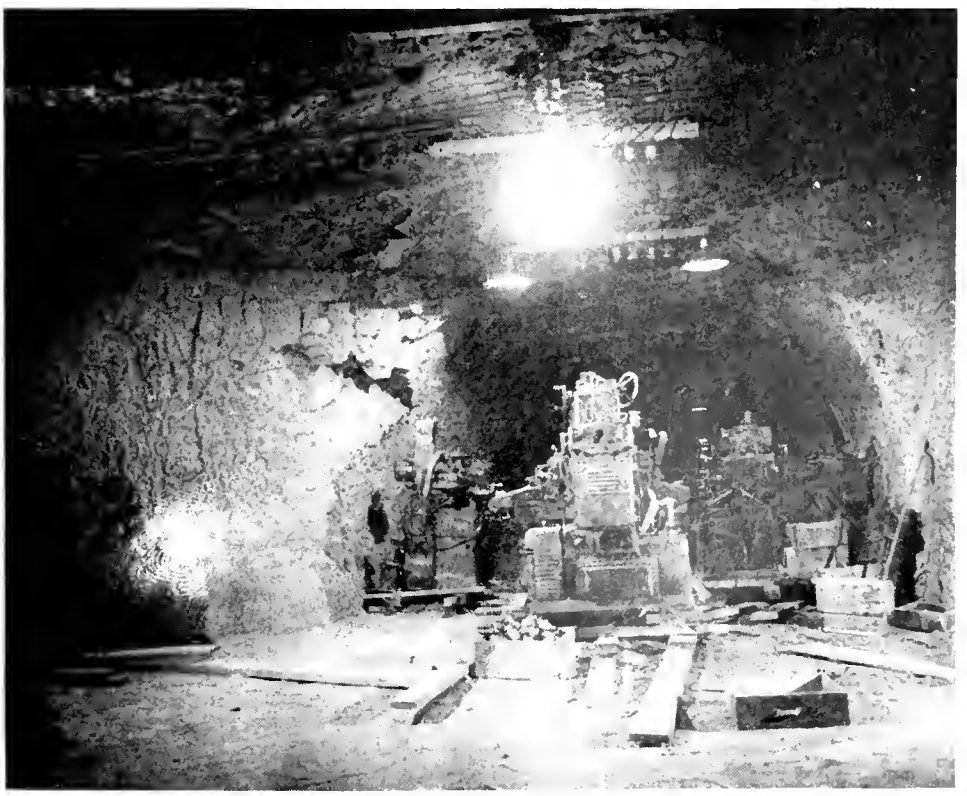


Photo No. 40. Kukuri plant. Machine tools being installed.

NIKODA

The Nikoda underground plant of the Mitsubishi No. 5 Airframe Works was situated in the hills 6 miles west of the city of Ueda in Nagano prefecture.

Orders for dispersal into the Ueda area were received by Mitsubishi from the Army in April 1945. The actual excavation of the underground plant was supervised by the Army. The technicians in charge came to Nikoda after completion of the Central Army Underground Headquarters at Matsushiro, between Nagano and Ueda. Three areas were planned with 17, 6, and 15 tunnels, respectively. Each tunnel was to be 13 feet wide and 10 feet high and shored with timber to prevent roof collapse.

The production goal was an output of 50 Ki–83 aircraft per month in conjunction with a nearby semiunderground plant. However, no production was realized and no machine tools were install At the war's end the underground plant was per cent complete, the power installations were per cent complete, and the semiunderground pl was 45 per cent complete, with 33 buildi erected.

The schedule called for total completion of underground plant in September 1945.

At the time of inspection the tunnels were and damp. When asked what precautions agai worker illness and machine corrosion had b taken, the plant manager replied that there v no time to study any problem other than that getting the machines underground.

Transportation of material to and from plant was expected to be by truck only.

The interviews and inspection were conduc on 12 November 1945.

MATSUMOTO

The Mitsubishi No. 1 Airframe Works had a combined underground and semiunderground plant under construction several miles southeast of Matsumoto in Nagano prefecture.

This plant was designed to produce 20 experimental aircraft per month. The planned area was 252,000 square feet, all of which was excavated, but only 40 percent of it was ready to receive machine tools. No machine tools had been installed, however, and there was no production.

Plans were made in February 1945 to go underground at this location and work began on the tunnels in April under the supervision of the Army. Although the original survey conducted by the Army concluded that no shoring would be needed, the rock proved unsafe and extensive shoring with timber became necessary. It was planned to use concrete to support the weak spots in the tunnels but a shortage of cement prevented this. In fact, timber also became scarce very soon, when three times as much timber as calculated was needed.

An insufficient number of mining engineers added to construction problems.

Transportation, however, proved to be the chief problem in going underground, first, in the movement of machine tools and equipment from Nagoya to Matsumoto and later, to transport terials to the underground site. Transport to underground plant from Matsumoto was by tru over narrow and poorly maintained roads.

The schedule called for 50 percent complet and the beginning of production in June 1945 for total completion in August. Due to the d culties already enumerated, only 40 percent c pletion was reached in August.

The familiar comment was again stated he the great haste of dispersal left only time to c sider the basic problem of getting the mach tools underground and out of reach of the An ican bombers. Such serious considerations protection of machinery against corrosion, ve lation, and worker health were postponed. Even ally, Mitsubishi hoped to solve these problems heat and ventilation.

Parts fabrication for Ki–83, Ki–67, Reppu, a Taiyo was to take place underground. Fi assembly was to be accomplished in the 150 se underground buildings in the surrounding hi Testing was to be done in semiunderground bui ings at nearby Murai airfield.

The date of inspection of Matsumoto was November 1945.

OGAMI

The Ogami underground plant of Mitsubishi No. 1 Airframe Works was located 10 miles south of Ikoka in Toyama prefecture. A semiunderground plant at Hannya-mura was operated in close conjunction with Ogami.

This plant was still under construction by the government and had not yet been taken over by Mitsubishi. The excavation was 30 percent complete but progress toward actual production was only 10 percent advanced.

Tunnel cross sections measured 13 feet by 10 feet after shoring had been erected. The maximum tunnel length was 1,150 feet. No machine tools had been installed.

Ogami was inspected on 18 November 1945.

NUKATANI

The Nukatani underground plant of Mitsubishi No. 12 Engine Works, four miles south of Kanazawa, was one of the most unusual plants to be visited.

The necessity for performing a certain amount of mountain climbing to an altitude of 750 feet lent a strange air to the Nukatani underground plant. The plant was accessible only on foot up a narrow, recently constructed road which was washed out in many places by the heavy October rains.

Ancient caverns, from which the people of a past age extracted fire brick, were at first intended by the Japanese Navy to be used as a Naval arsenal. Early in April 1945, the Navy started work on making the tunnels and caverns usable but late in the same month abandoned the project and turned it over to Mitsubishi for aircraft-engine production.

Mitsubishi subcontracted the construction of the plant and the company was to be reimbursed later by the government. Because of the inaccessibility of the site, it became necessary to initiate a large civil road building project to the plant, a residential building program, and a bridge construction program to span the steep chasms to the plant.

Mitsubishi did not approve of Nukatani but was under constant pressure from the government to build a plant at this location. The company's objection was based on the knowledge that, in addition to being inaccessible, the plant also would probably be out of production for four months each year because of the heavy snows in northwest Honshu during the winter months. Furthermore, the problem of transportation of both workmen and products presented even more serious problems than those which already had caused great difficulty in other more desirable locations.

Despite these considerations, the plant was constructed to house one of their more important works to produce exhaust turbines and fuel injection pumps. Beginning 10 July 1945, machine tools were laboriously pulled up the mountain road by hand and roller means and by the end of the war 146 machine tools were in place. In addition, 253 tools were stored at the base of the hill in shrines and schoolyards. Almost all of the machine tools were of American make, because of the high degree of accuracy required in making these parts.

Actual production had not yet begun but was anticipated within a short time.

The caverns and tunnels were very dry and in many places concrete floors were laid. It was not necessary to shore up the caverns as natural pillars and the strength of the rock itself were sufficient support.

Located on many levels throughout the mountain, the tunnels ranged in elevation from 650 to 800 feet above sea level. The average cavern was 20 feet wide while the height varied from 12 to 20 feet (Fig. 11).

During the early summer of 1945 the Japanese Navy made aerial reconnaissance of the area and reported that the new road revealed the location of the plant.

Nukatani was visited on 19 November 1945.

SHAKUTANI

Shakutani, located one mile west of Fukui city in Fukui prefecture, was an underground dispersal of Mitsubishi No. 18 Engine Works.

This plant was an elaborate arrangement of caverns and tunnels consisting of four completed underground areas as well as a semiunderground plant (Fig. 12). So skillfully were the semiunderground plants built into the hillside that one building was almost passed during an inspection trip before it was noticed.

Caverns from which Shakutani stone—a famous Japanese building stone—had been removed, furnished the space for this plant. Work was started in February 1945 to ready the caverns for use by the Mitsubishi Co. and the movement of machinery into the plant began in April.

The machine tools, of which 296 had been installed, were only in the process of alignment and testing, and it was claimed by the company that no production was achieved.

This plant was well advanced (considered percent complete by the Mitsubishi Co.) by t average standard of underground plants. In ad tion, it was near the local ground level and w easily accessible by highway.

The caverns and tunnels were very dry, nev theless, most of the machine tools were corrod The caverns followed the seam of building sto and were therefore of varied size, on many diff ent levels, and of generally high ceilings (12 to feet). Only one landslide occurred during t October rains.

The machine tools for one area were lower into the tunnels through a vertical shaft 60 f long.

This plant was to produce gears and light me parts for engines.

The date of inspection was 21 November 19

SABAE

Stone quarries 300 feet above ground level provided the setting for the Shinyokoe plant of the Mitsubishi No. 18 Engine Works at Sabae in Fukui prefecture.

This plant consisted of two sections, the first being in the stone quarries well up into the hill, the second consisting of a grid of newly excavated tunnels at ground level at the base of the hill.

The quarry section was a series of caverns with large rooms and lofty ceilings. One room was fully 75 feet long, 25 feet wide, and 18 feet high. Concrete floors had been laid in many places and throughout the tunnels it was exceptionally dry.

As may be seen from the attached drawings, (Figs. 13A and 13B) the caverns are not systematic but wind about in eccentric patterns and are on many levels. At one place a broad flight of stone stairs elicited the comment "It's just like a cathedral underground."

This upper section of the plant had been wired for electric power. Two 200 kv—a. transformers and a switchboard had been installed.

Twenty six machine tools were in position in preparation for the production of cylinder heads. A large stock of unmachined cylinder heads was on hand but it was maintained by company officials that no productive work had emanated fro this plant by 15 August 1945.

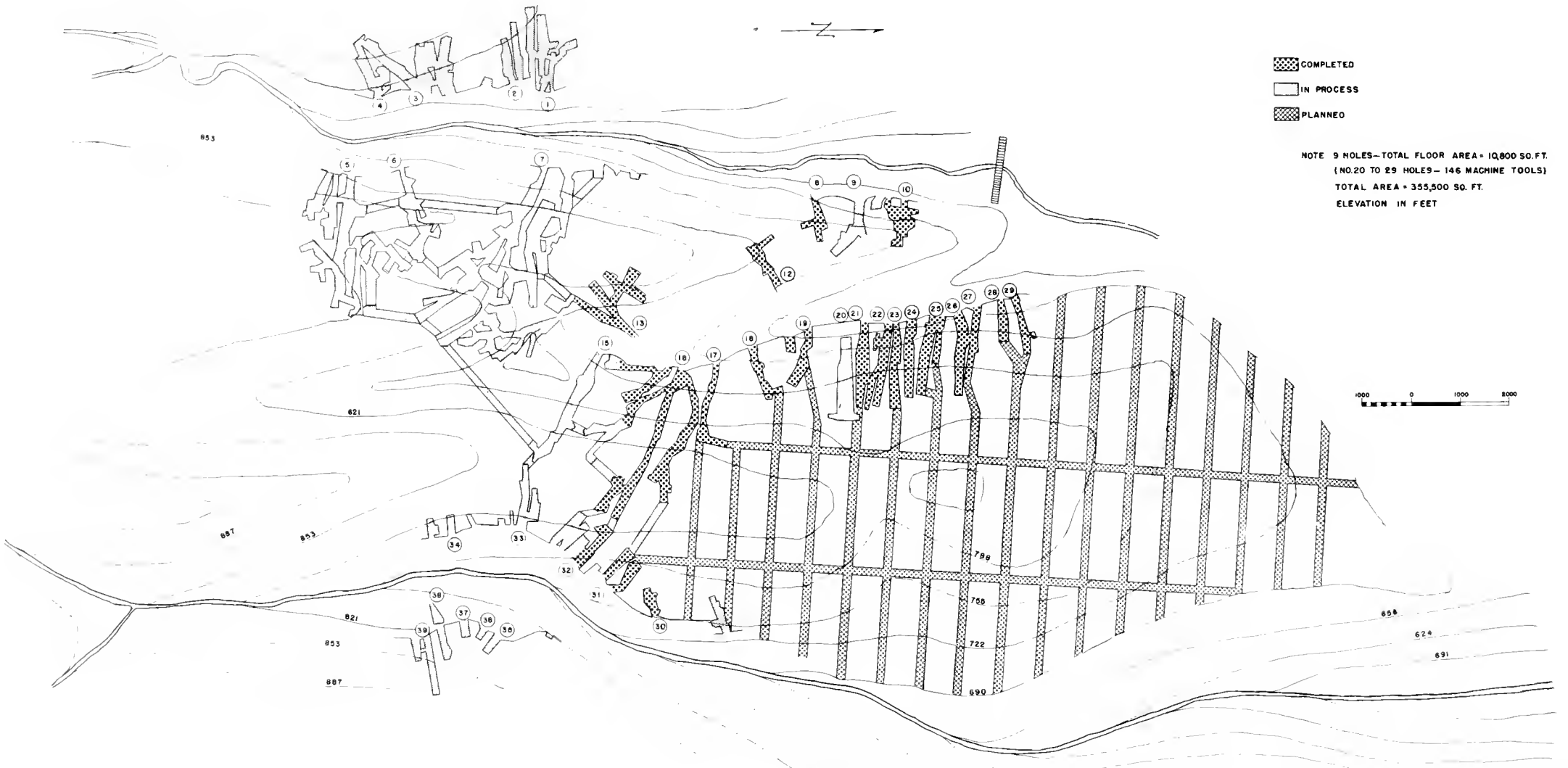
The newly excavated tunnels near the base the hill were among the best of this type that we seen (Fig. 14). The rock was dry and solid a no supporting timbers were needed to reinfor the roof. Some extremely roomy tunnels (underground standards) were inspected. Sever tunnels were 20 feet by 10 feet in cross secti dimensions. A total of 13 tunnels, each about 3 feet long, had been completed but no machine too were installed.

The entire lay-out of this plant was excellent concealed from the standpoint of aerial reconnai sance. Only a very small amount of spoil wa visible and the roads were almost completely co ceiled by trees. The plant was accessible Sabae by an existing road.

The impression gained was that this plan would have become a good producer of engin parts within two months and that it would hav been comparatively safe from direct bombin attack.

The Sabae area was inspected on 21 Novembe 1945.

UNDERGROUND FACTORY MITSUBISHI CO.

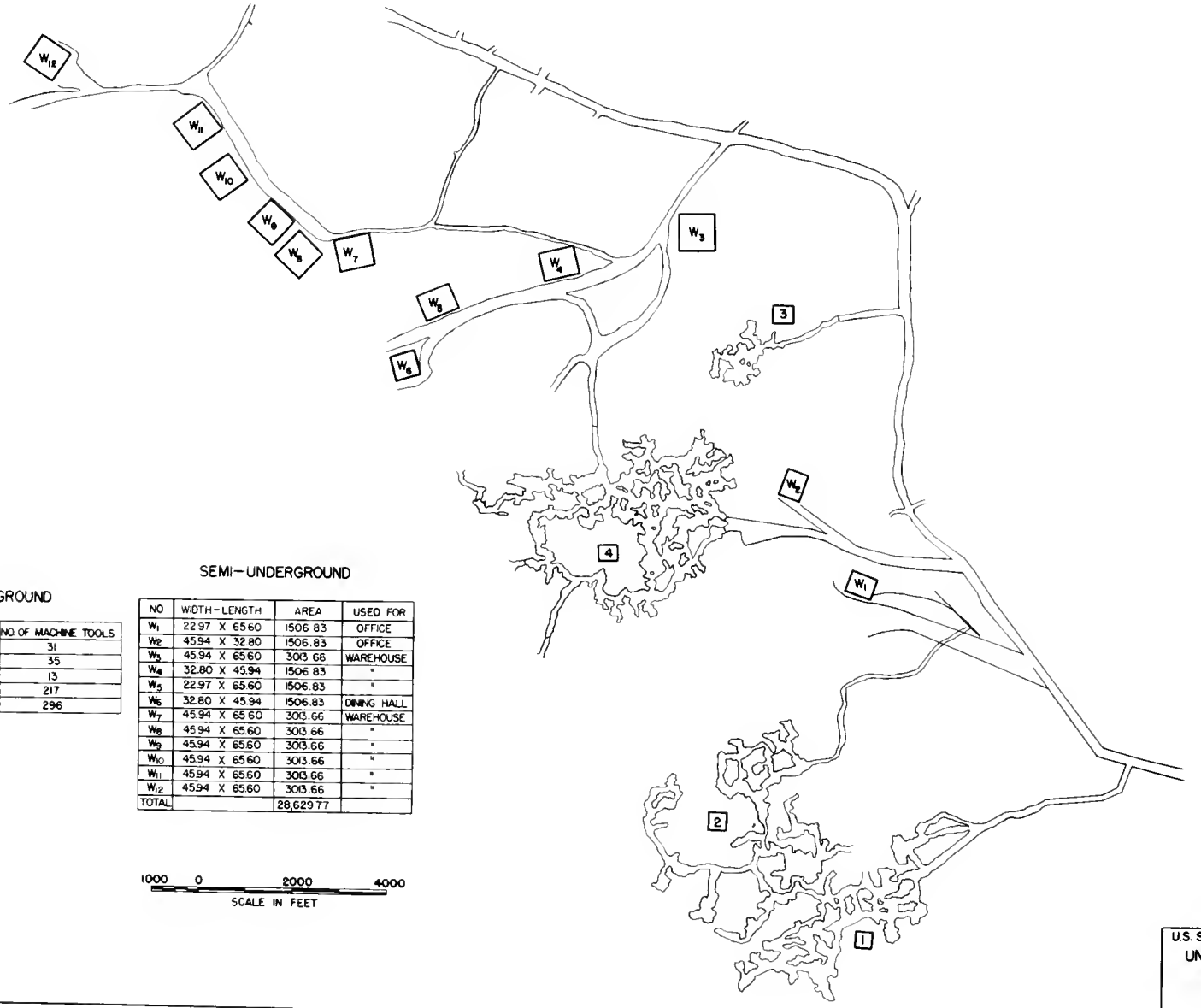


U.S. STRATEGIC BOMB SURVEY

UNDERGROUND PLANTS
NUKATANI

FIGURE 11

LAYOUT OF SHAKUTANI PLANT



UNDERGROUND

NO OF HOLE	AREA	NO OF MACHINE TOOLS
1	34,432	31
2	34,862	35
3	5,380	13
4	48,420	217
TOTAL	123,094	296

SEMI-UNDERGROUND

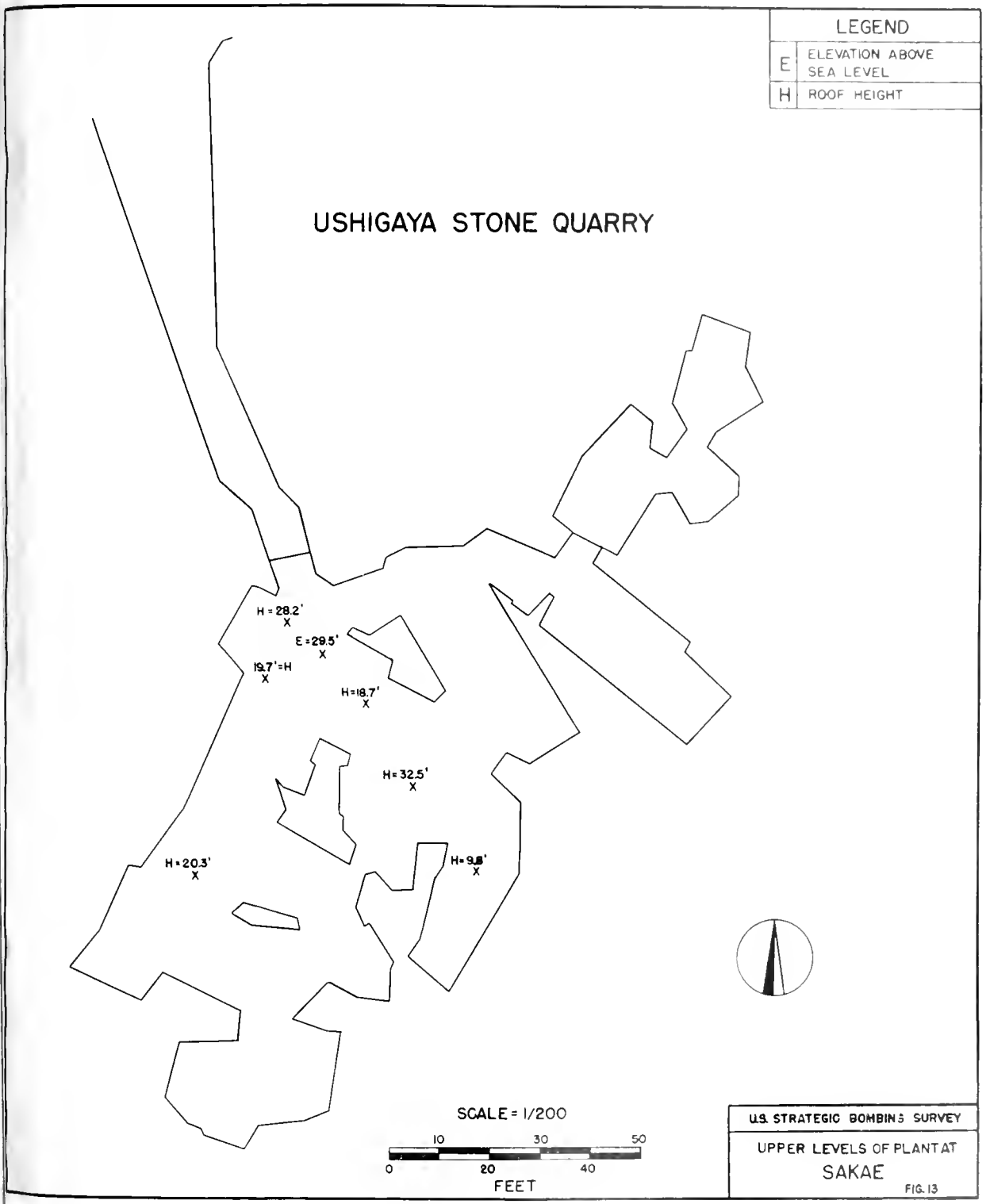
NO	WIDTH-LENGTH	AREA	USED FOR
W_1	22.97 X 65.60	1506.83	OFFICE
W_2	45.94 X 32.80	1506.83	OFFICE
W_3	45.94 X 65.60	3013.66	WAREHOUSE
W_4	32.80 X 45.94	1506.83	"
W_5	22.97 X 65.60	1506.83	"
W_6	32.80 X 45.94	1506.83	DINING HALL
W_7	45.94 X 65.60	3013.66	WAREHOUSE
W_8	45.94 X 65.60	3013.66	"
W_9	45.94 X 65.60	3013.66	"
W_{10}	45.94 X 65.60	3013.66	"
W_{11}	45.94 X 65.60	3013.66	"
W_{12}	45.94 X 65.60	3013.66	"
TOTAL		28,629.77	

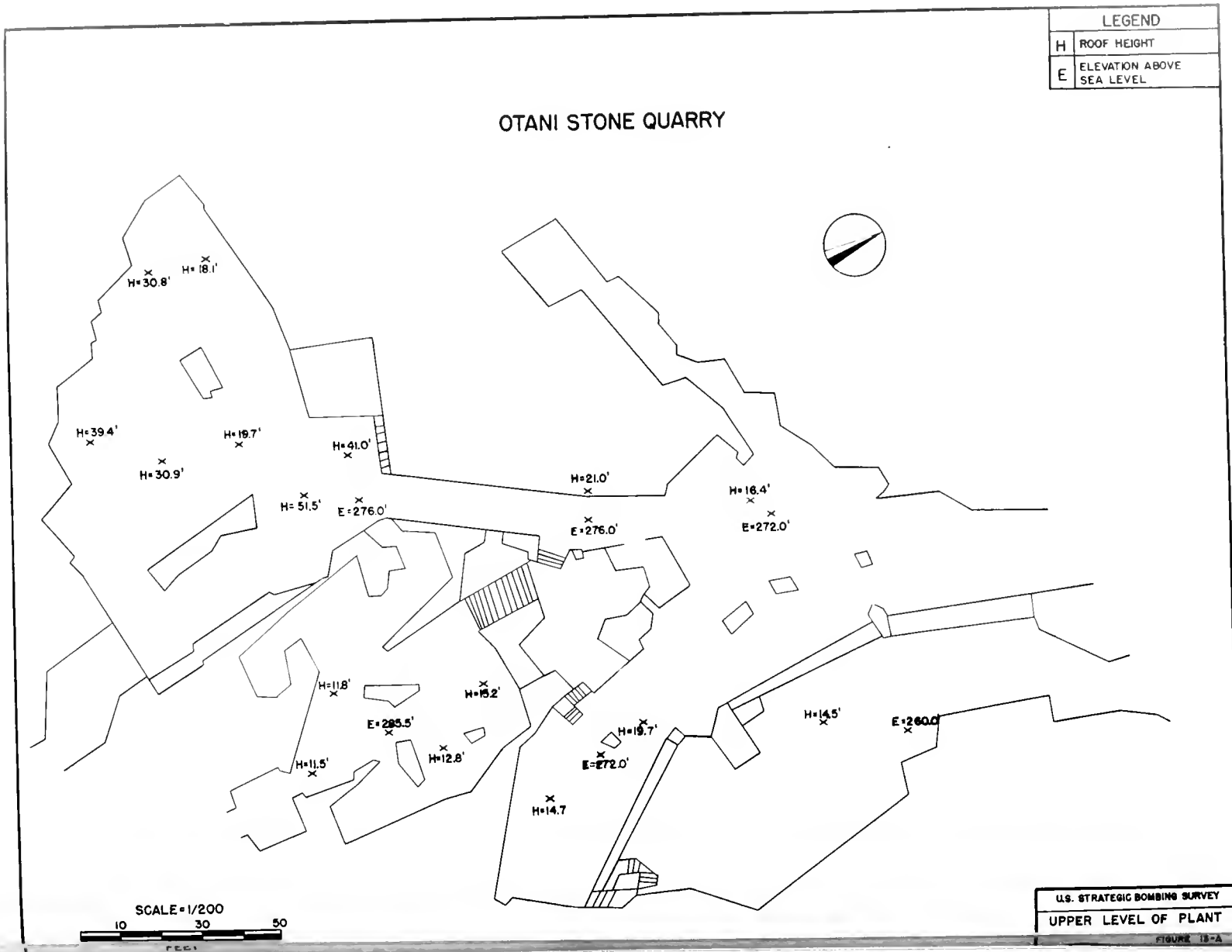
1000 0 2000 4000
SCALE IN FEET

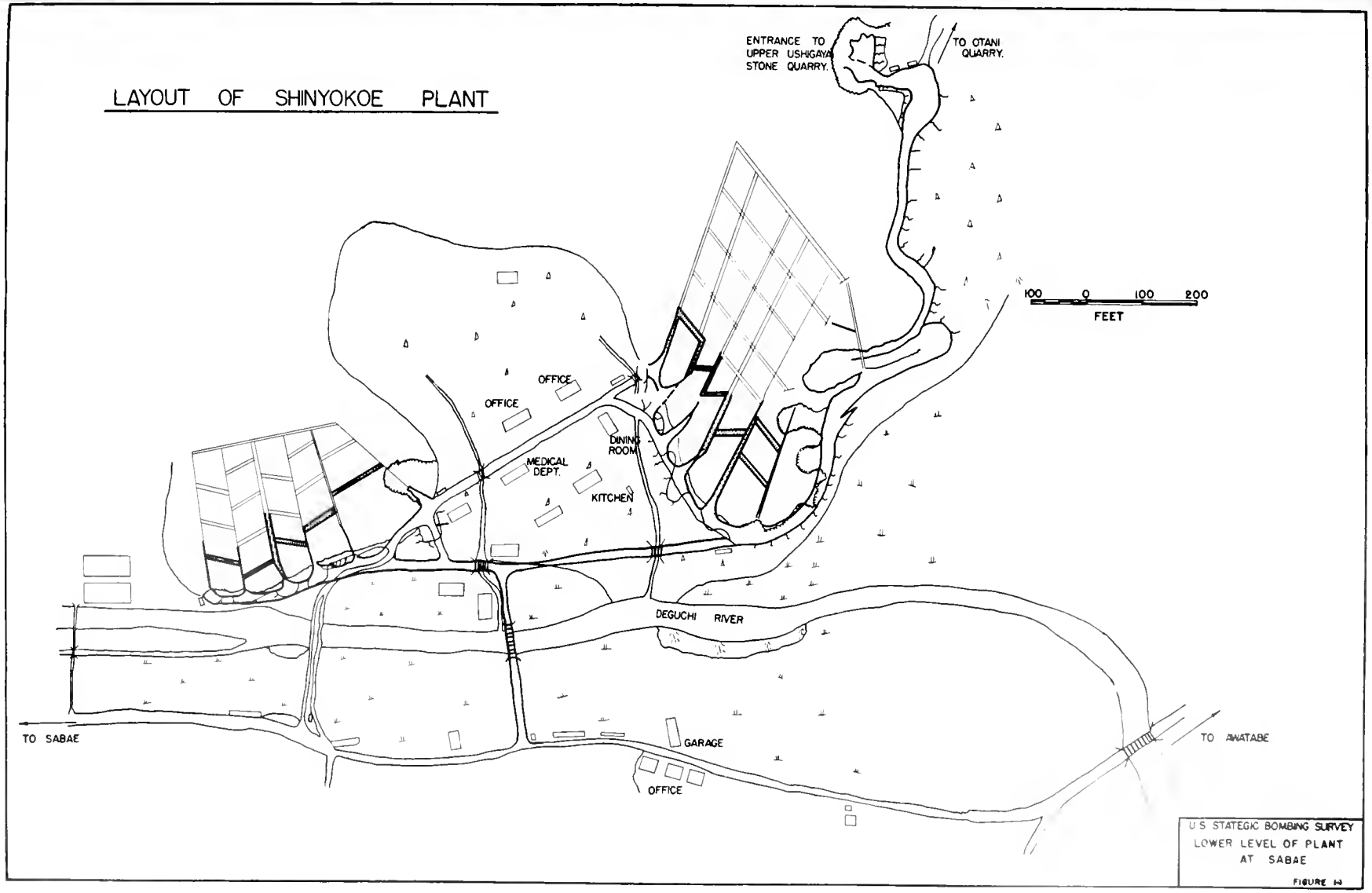
U.S. STRATEGIC BOMBING SURVEY
UNDERGROUND PLANTS
SHAKUTANI

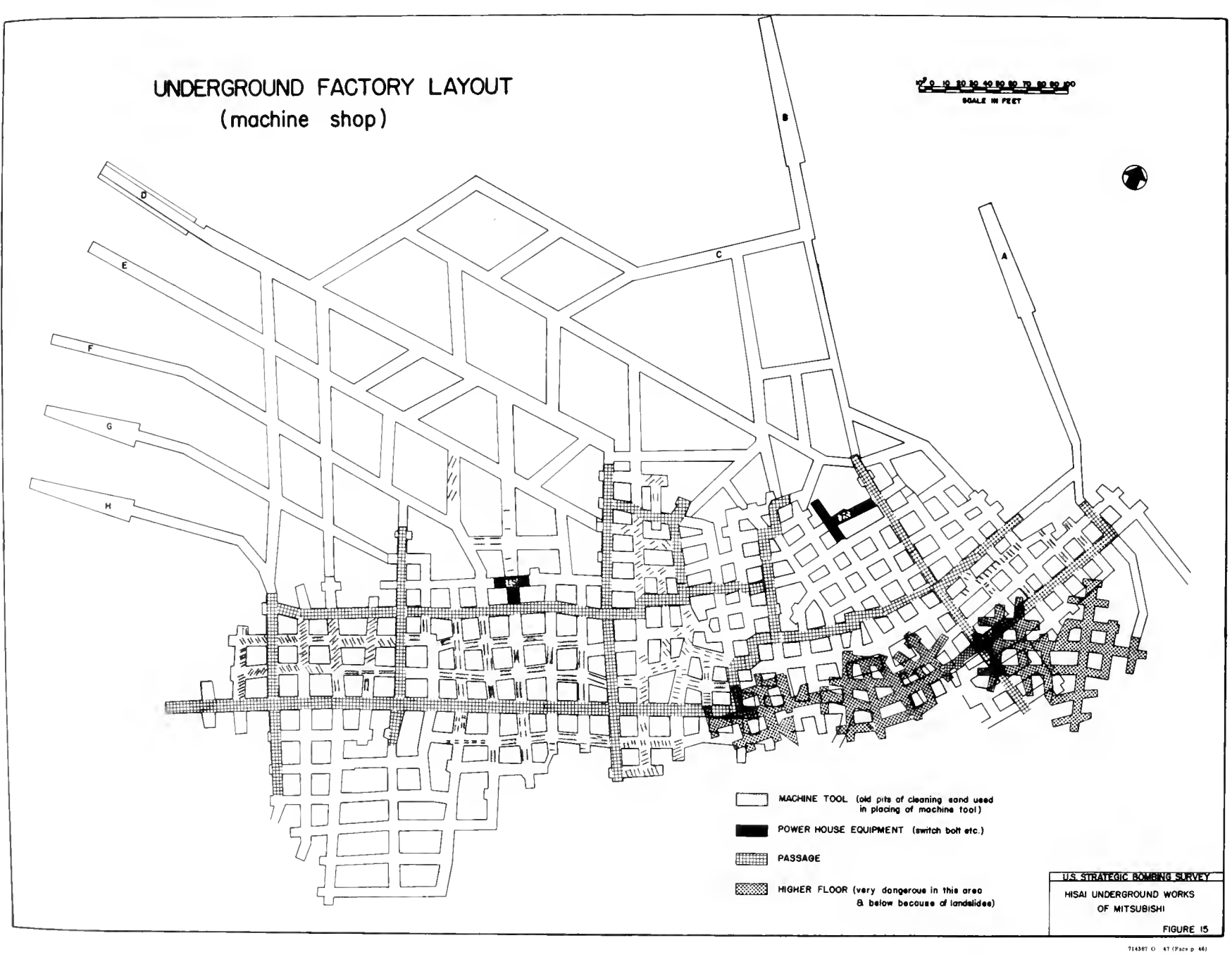
FIGURE 12

714307 O - 47 (Face p. 43) 2


LEGEND
E ELEVATION ABOVE SEA LEVEL
H ROOF HEIGHT
USHIGAYA STONE QUARRY
H = 28.2'
E = 29.5'
19.7' = H
H = 18.7'
H = 32.5'
H = 20.3'
H = 9.8'
SCALE = 1/200
10 30 50
0 20 40
FEET
U.S. STRATEGIC BOMBING SURVEY
UPPER LEVELS OF PLANT AT
SAKAE
FIG. 13


LEGEND
H ROOF HEIGHT
E ELEVATION ABOVE SEA LEVEL
OTANI STONE QUARRY
H=30.8'
H=18.1'
H=39.4'
H=19.7'
H=41.0'
H=30.9'
H=51.5'
E=276.0'
H=21.0'
E=276.0'
H=16.4'
E=272.0'
H=11.8'
H=15.2'
E=285.5'
H=11.5'
H=12.8'
H=14.7
H=19.7'
E=272.0'
H=14.5'
E=260.0'
SCALE=1/200
10 30 50
FEET
U.S. STRATEGIC BOMBING SURVEY
UPPER LEVEL OF PLANT
FIGURE 13-A


LAYOUT OF SHINYOKOE PLANT
ENTRANCE TO UPPER USHIGAYA STONE QUARRY.
TO OTANI QUARRY.
100 0 100 200
FEET
OFFICE
OFFICE
DINING ROOM
MEDICAL DEPT.
KITCHEN
DEGUCHI RIVER
TO SABAE
GARAGE
OFFICE
TO AWATABE
U.S. STATEGIC BOMBING SURVEY
LOWER LEVEL OF PLANT
AT SABAE
FIGURE 14



714387 O 47 (Face p 46)

HISAI

The Hisai plant (Fig. 15) was only one of a series of underground plants in tunnels which had been dug previously to obtain sand for abrasives. The Navy, Aichi Aircraft Co., and the Sumitomo Co., in addition to Mitsubishi, had underground plants here, all of which were to work in conjunction with the Tsu Naval Arsenal in producing aircraft and engines.

The Hisai underground plant, located in the low hills southwest of Nagoya, was a part of the Mitsubishi No. 3 Airframes Works.

At Hisai, entrances led down to a working level some 40 feet deep. The tunnels had been hollowed out of the sandy rock and very little shoring was necessary (Photographs 41–47).

Concrete had been laid as machine beds but there was no other paving. The machines were crowded and working space was restricted. The communications tunnels were served by rail and cable car.

The plant was very damp. Working conditions were poor, the machines were rusting, and pumping was necessary after a rain.

The estimated capacity of the plant when finished was 1,500 workers and 540 machine tools, actually, 300 tools were installed, beginning in June 1945.

This plant was dangerous in several areas because the tunnels were on two levels and the collapse of sections was imminent.

Photo No. 41. Machine tools en route to Hisai.

Photo No. 42. Entrance at Hisai.

Photo No. 43. Narrow-gauge railroad leading to entrance at Hisai.

Photo No. 44. Flooded tunnel at Hisai.

Photo No. 45. Interior at Hisai.

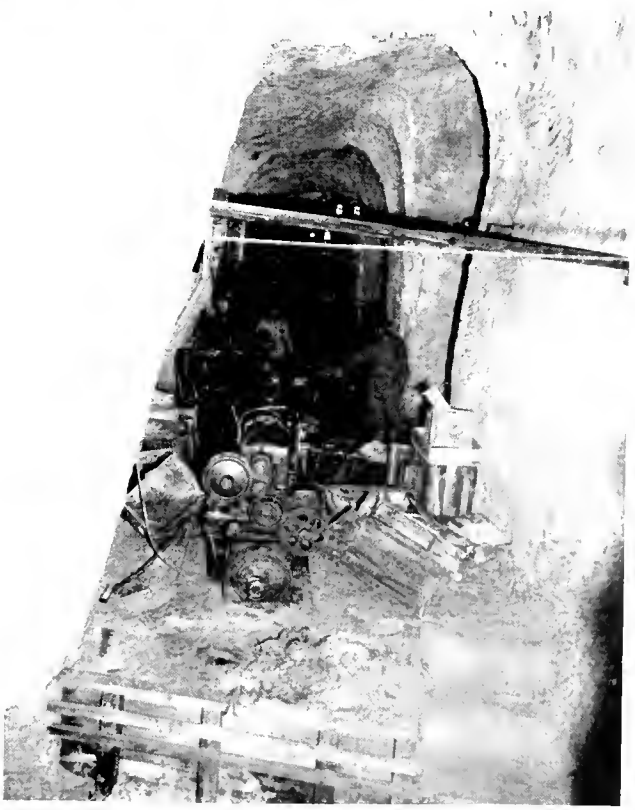


Photo No. 46. Interior at Hisai.

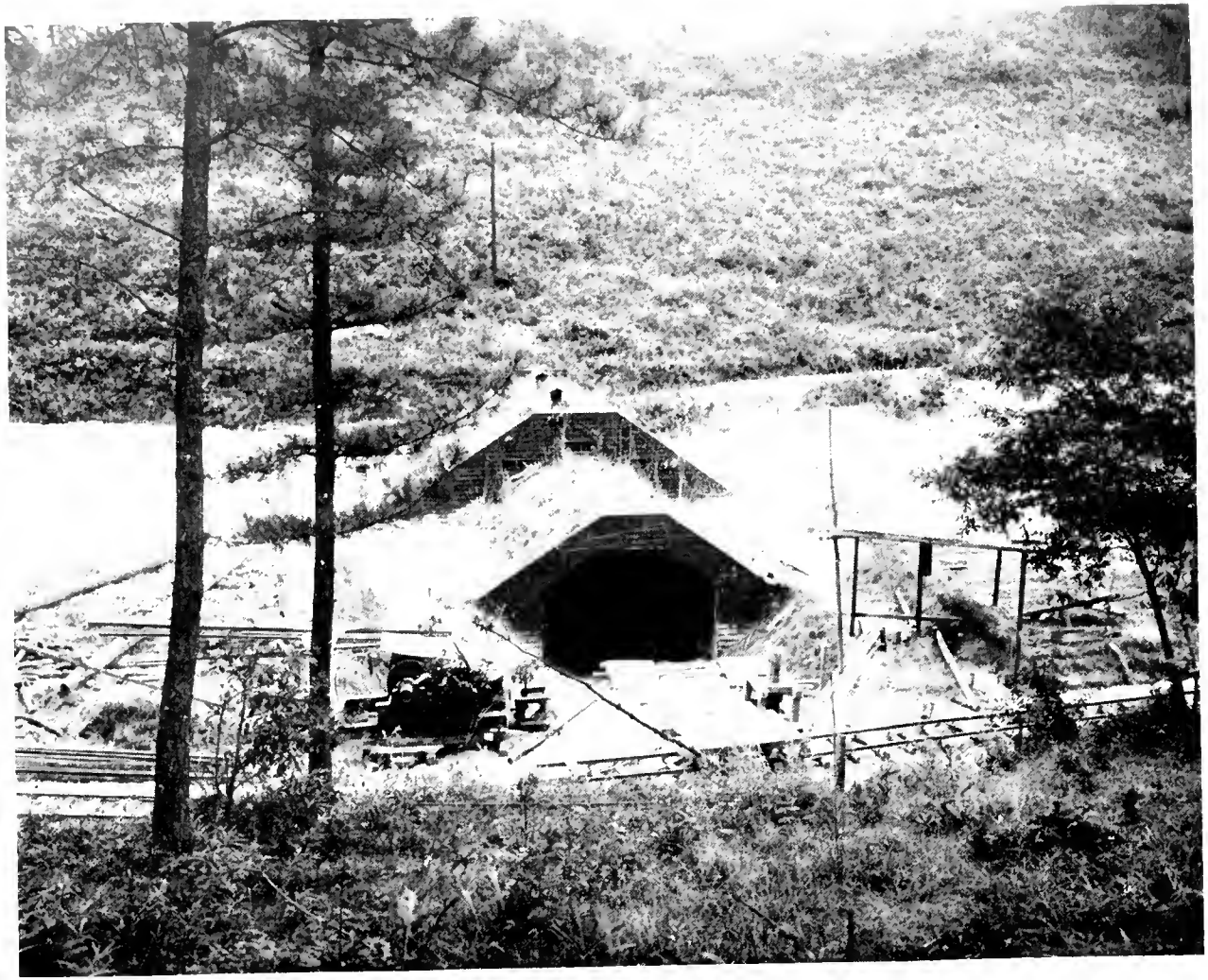


Photo No. 47. Entrance to Hisai.

PART III

MINOR AIRCRAFT COMPANIES

SOGO DEPARTMENT STORE PLANT OF THE SUMITOMO COMPANY

In Osaka, the second and third basements of the Sogo Co. Department Store were used by the Sumitomo Co. for the machining of propeller parts.

Not strictly an underground plant, these basements were inspected to complete the picture of the various types of underground installations.

A total of 167 machine tools operated here for a period of 3 months in what appeared to be an orderly and well-managed production line.

The machine tools had been lowered into the basements through holes that had been cut in the sidewalk adjoining the building. This work had been carried out at night so as to conceal the whole operation. The heavier machines were in the third basement and the lighter ones in the second basement.

In great contrast to the tunnel plants, these basements offered no unusual operational problems, were clean, light, dry, and efficient. Furthermore no external evidence was visible to the photo interpreter of the actual work taking place here.

This plant was visited on 30 October 1945.

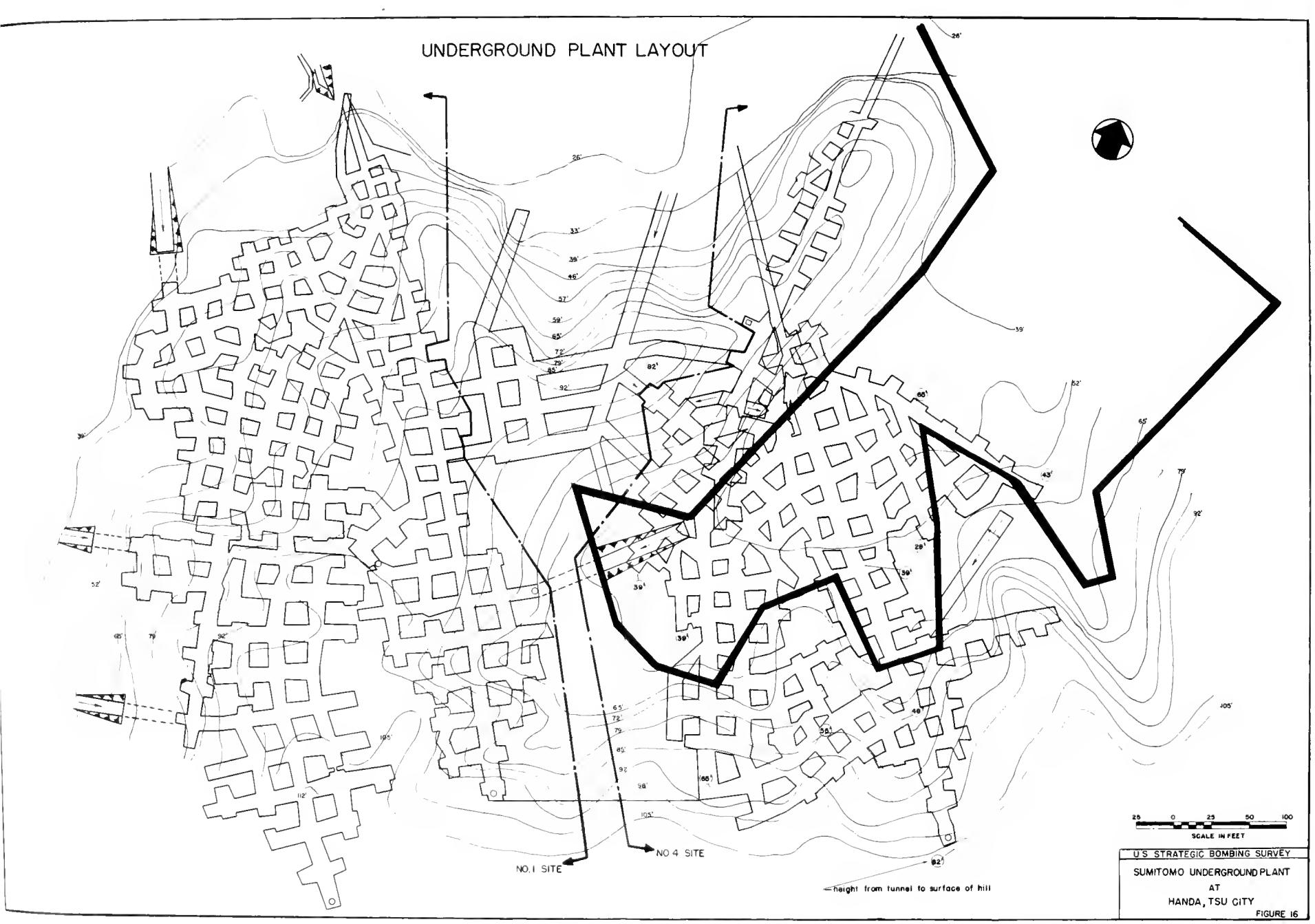
HANDA

The Handa underground plant of the Sumitomo Co. was a part of the network of underground plants southwest of Tsu (40 miles southwest of Nagoya) to serve the Tsu Naval Arsenal (Fig. 16). This plant was similar, but superior to, the Hisai plant of Mitsubishi which adjoined it. The tunnels were enlarged out of tunnels which had been dug previously to furnish sand for abrasives. Frequent shoring, cement spray on the walls, drip guards over the machines, concrete floors, sloping levels, and drainage gutters were characteristics of this plant. Pumping was necessary on occasion to remove the water. (Photographs 48–51.)

There were no rail communication tunnels as at Hisai and the machines were moved in by hand.

Enlarging of tunnels began in March 1945 and completion was planned for September. Of a planned 4,500 employees and 640 machine tools, 725 employees and 271 machines were at work.

Handa was to produce propeller parts. The plant was in operation but only a few parts had been finished.



T16387 O - 47 (Face p. 94)

Photo No. 48. Interior at Handa.

Photo No. 49. Entrance at Handa.

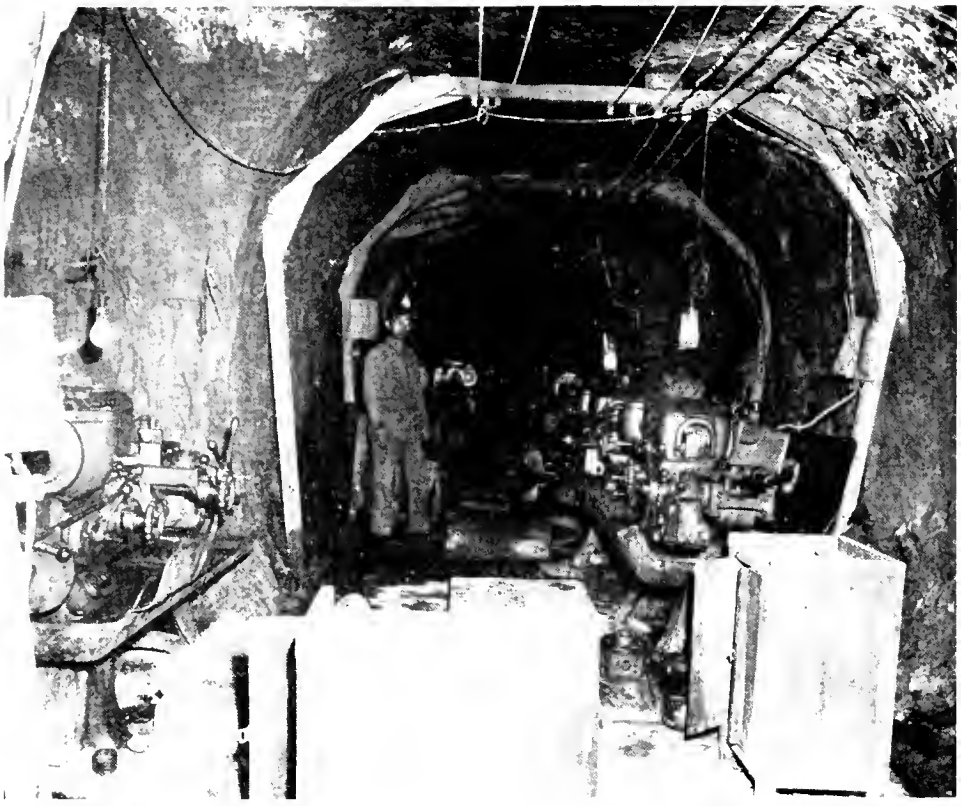


Photo No. 50. Handa plant. Tunnels in sand mines near Tsu City.

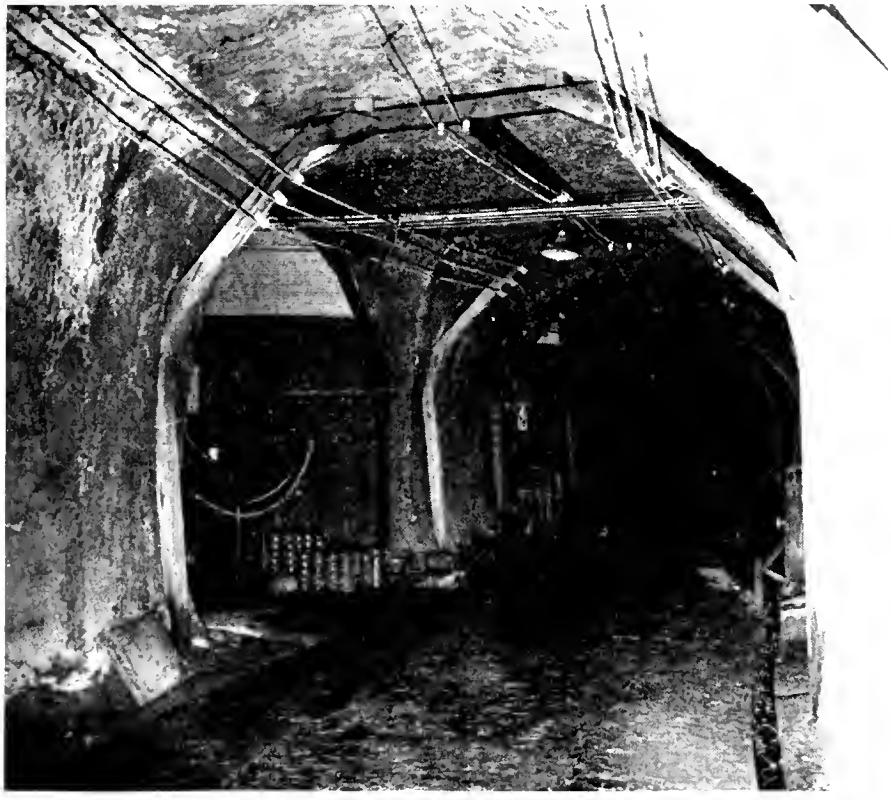


Photo No. 51. Handa plant. (Note production tunnels opening into communications tunnel.)

TAKATSUKI

The Takatsuki underground plant of the Kawasaki Aircraft Co. was located near Nariai village on the outskirts of Takatsuki, which is midway between Osaka and Kyoto.

Originally intended for use as a central Army warehouse, these tunnels were begun in November 1944 by the government. Their use by Kawasaki was not ordered until February 1945. A force of 3,500 Koreans living in the valley was engaged in the construction of this plant.

The tunnels, totaling a planned 300,000 square feet of floor area, were laid out in two adjoining hills, but only one area had reached any appreciable stage of completion (Fig. 17).

The completed tunnel system was halfway up a roughly circular hill, 1,680 feet in height. Laid out in a grid network were 16 tunnels with 100,000 square feet of floor area and a planned machine tool capacity of 550. However, only six tunnels were near production. Forty machine tools and electric power had been installed and production was to get under way on or about 20 August 1945.

Mute evidence of the cessation of the war could be seen in the abandonment of machine tools poised over the edge of a cliff, preparatory to being hauled into the tunnels. Steel plates were used as a base for sliding the tools into place in the tunnels.

At the time of inspection, 30 October 1945, the tunnels were fairly wet despite the fact that several of them were faced with concrete. Timber, expected to last for year and a half, was used in many places as shoring.

At a later date the company expected to install electric heating and ventilating.

This plant was constructed for the purpose of making parts for the Ha-140 in-line engine for Tony II.

SETO

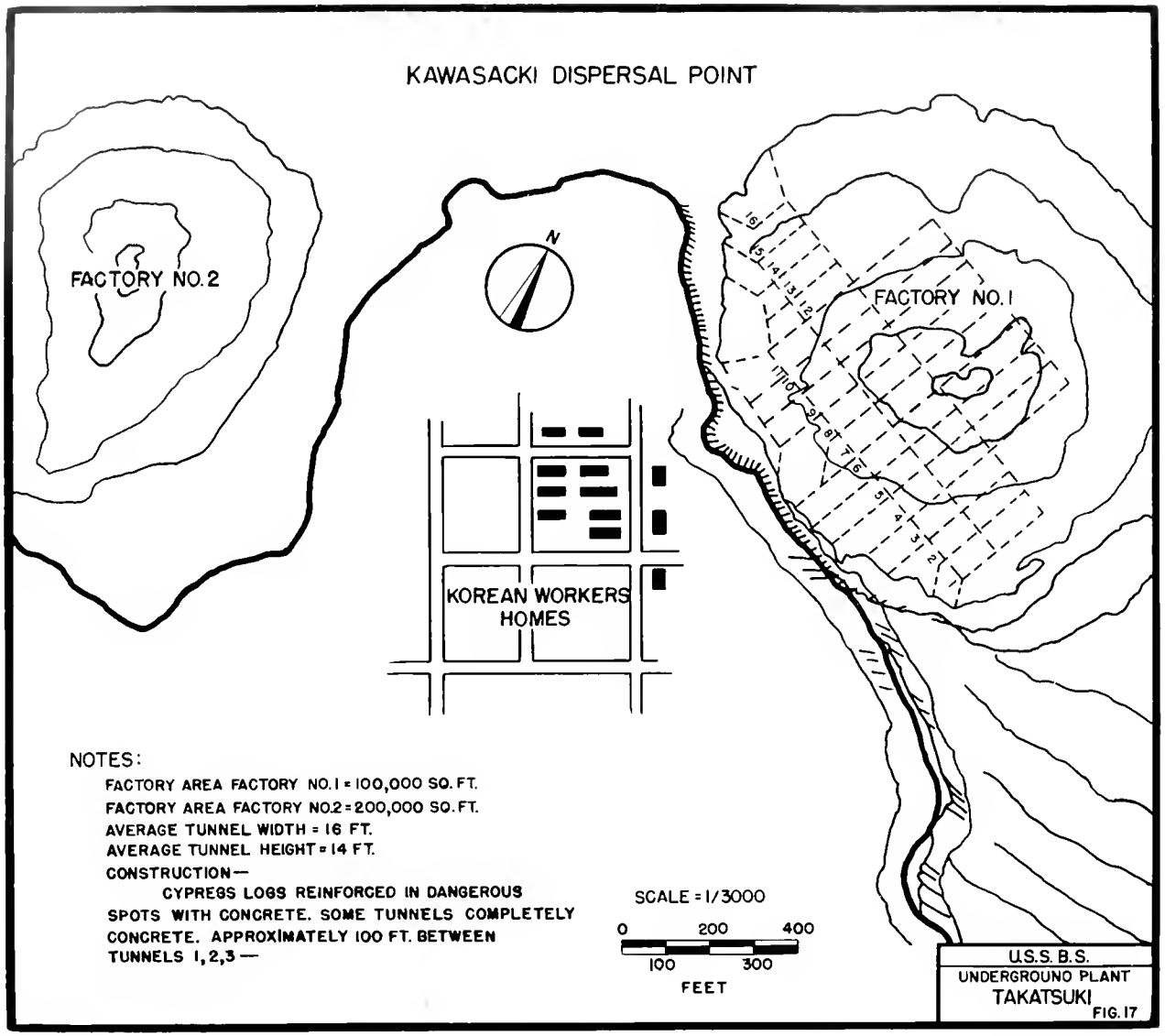
The Aichi Aircraft Co. dispersed a part of its works to the hills north of Seto, a town about ten miles east of Nagoya.

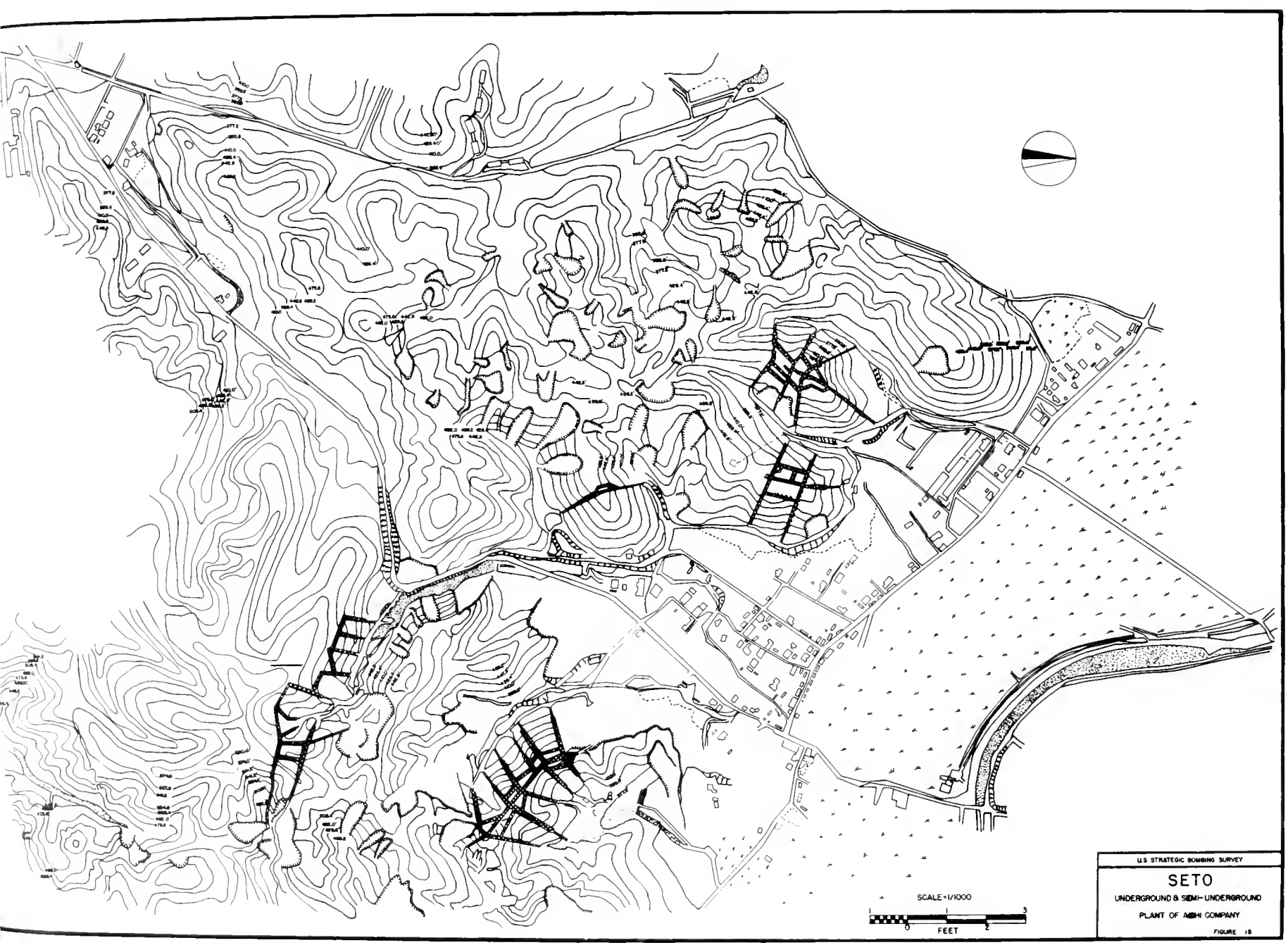
A planned and completed floor area of 110,000 square feet was excavated in five areas, under five adjoining hills. However, only 45,000 square feet were in use.

The tunnels formed an irregular pattern (Fig. 18). They were fairly spacious but, in the usual fashion of underground plants were wet and damp. Shoring was necessary throughout. (Photographs 52–61.)

This plant was to make wings for Judy at first, and later, to make the entire airframe except for final assembly.

It was planned to install 800 machine tools, of which about half were ready for use. Production was under way by 15 August 1945 but only a few wing spars were made.


KAWASACKI DISPERSAL POINT
FACTORY NO.2
N
FACTORY NO.1
KOREAN WORKERS HOMES
NOTES:
FACTORY AREA FACTORY NO.1 = 100,000 SQ. FT.
FACTORY AREA FACTORY NO.2 = 200,000 SQ. FT.
AVERAGE TUNNEL WIDTH = 16 FT.
AVERAGE TUNNEL HEIGHT = 14 FT.
CONSTRUCTION—
CYPRESS LOGS REINFORCED IN DANGEROUS SPOTS WITH CONCRETE. SOME TUNNELS COMPLETELY CONCRETE. APPROXIMATELY 100 FT. BETWEEN TUNNELS 1,2,3 —
SCALE = 1/3000
0 200 400
100 300
FEET
U.S.S. B.S.
UNDERGROUND PLANT
TAKATSUKI
FIG. 17



U.S. STRATEGIC BOMBING SURVEY

SETO

UNDERGROUND & SEMI-UNDERGROUND

PLANT OF AICHI COMPANY

FIGURE 18

Photo No. 52. Cave-in of machine shop at Seto.

Photo No. 53. Entrance in spur of hill at Seto.

Photo No. 54. Camouflaged entrance at Seto.

Photo No. 55. Entrance at Seto.

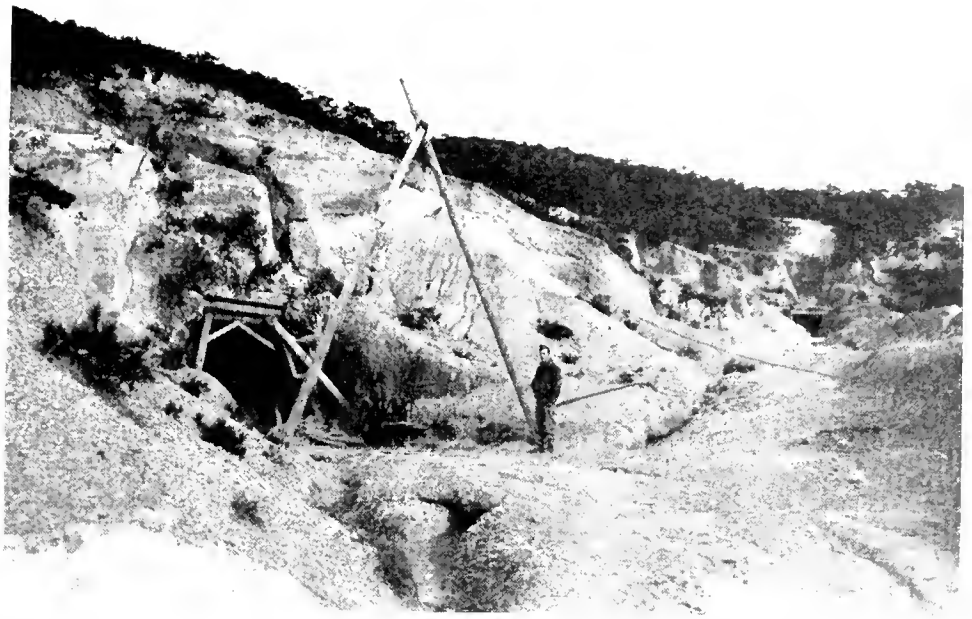


Photo No. 56. Entrance at Seto.

Photo No. 57. Surface building at Seto.

Photo No. 58. Seto plant. (Note extensive shoring.)

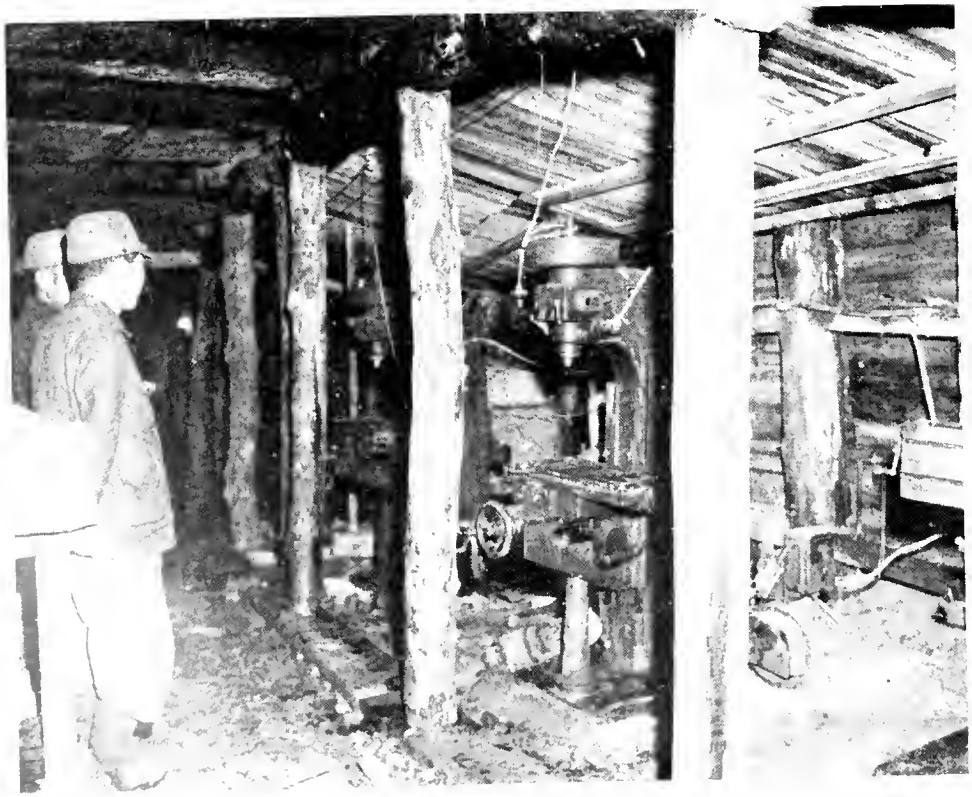


Photo No. 59. Seto plant. (The tight working quarters shown here were not uncommon.)

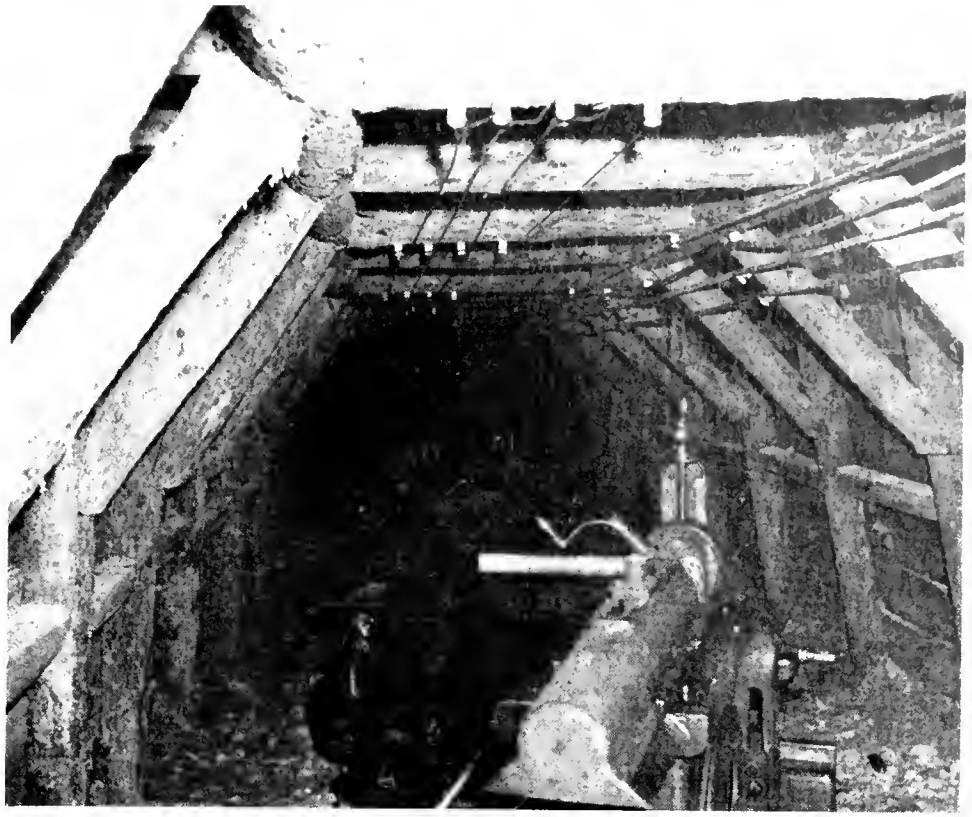


Photo No. 60. Interior at Seto.

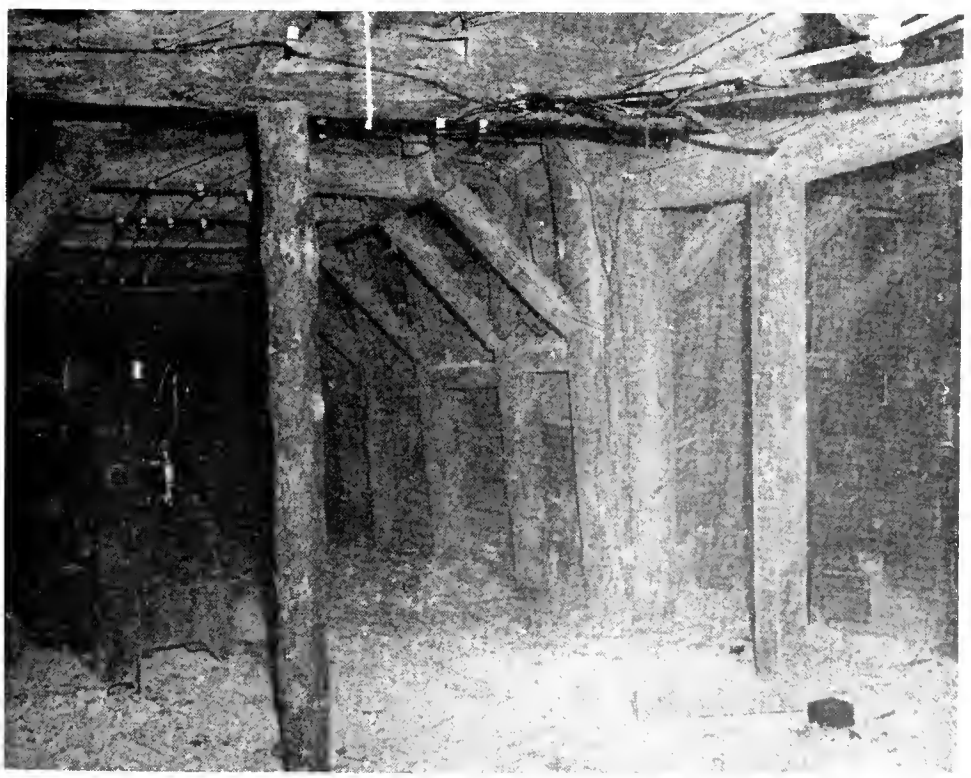


Photo No. 61. Interior at Seto.

HIRO PLANT OF 11TH NAVAL AIR DEPOT

Plans for underground production were made in April 1944. Construction and conversion of the tunnels were begun in November 1944. The first movement of equipment to the underground tunnel was in January 1945. The principal underground facilities were converted from a large underground hangar which had been built in 1940, and an adjoining road tunnel. Actual production was begun in these tunnels at the end of January 1945. It was planned to move all the smaller machines to these tunnels. One-half of the remaining large machines were to stay in the surface buildings at Hiro, while the other half were to be moved to Takihara. This movement was to completed by June 1946. At the time of the raid on Hiro on 5 May 1945, over 90 percent the small and medium-sized machines had alrea been moved underground. At the end of the w about 99 percent of the machines had been stalled in the underground plants.

In June 1945, the Hiro Navy Yard converted facilities for making marine engines to the ma facture of aircraft parts. Its machines were cluded in the underground dispersal. Plans these underground plants called for product of 400 engines a month by April 1945.

UNDERGROUND PLANTS

Intelligence Check

Wartime knowledge of Japanese underground installations was extremely meager. The Allies knew the locations of only three installations and nothing more. This was probably due to the fact that the underground program was not really begun until the last year of the war and there was not enough time for the information to seep out into Allied hands.

Another cause was the difficulty of finding underground tunnels through air photo interp tation. Postwar photography and interpretati even when based on information supplied USSBS, was unable to find most of the entran at the locations that had been studied by USS And it was impossible to state how extensive underground plant might be or what activity being conducted in it.

The principal way of learning about un grounds would seem to be by POW interrogati augmented by air photographs.

CONCLUSIONS

The Japanese underground installations were begun too late for them to be able to save the production of aircraft. In any event, their existence could not have overcome other problems such as shortages of vital raw materials and fuel.

Construction methods do not reveal anything that is new or that is not already known to the civil engineering profession. Only the profusion of tunnels, caves, and mines is impressive.

Inherent dampness wreaked havoc with precision machinery and with the health, morale and ability of workers. Air-conditioning and water drainage were necessary for any long period of operation, if machinery was to be protected against rust and corrosion and still be in use. In addition, workers need to be fortified with an adequate diet. Workers also need plenty of light to work by. Sun lamps would probably have been beneficial to the workers.

Underground production probably suffered from the lack of free and simple transport such as is obtainable in a compact, well-planned surface factory.

Interdiction of highways and railroads leading to an underground retarded production by obstructing the receipt of materials and the delivery of finished goods. Destruction of electric power sources might have had the same effect.

The principal advantages of an underground installation are that it is hard to find, makes a very poor target and would probably be safe from any weapon used in the second World War. Heavy gases would make an underground untenable but could be countered by air purification devices. Bacteria would be effective against workers whose vitality and resistance had been lowered by working underground.

However, in spite of the disadvantages, it would seem advantageous for any nation to put some of its more vital production facilities into adequately prepared underground locations. If the Japanese had made an earlier start on their underground program their underground and dispersal plants might have constituted a more serious problem for the Allies.

UNITED STATES STRATEGIC BOMBING SURVEY

LIST OF REPORTS

The following is a bibliography of reports resulting from the Survey's studies of the European and Pacific wars. Those reports marked with an asterisk (*) may be purchased from the Superintendent of Documents at the Government Printing Office, Washington, D. C.

European War

OFFICE OF THE CHAIRMAN

1 The United States Strategic Bombing Survey: Summary Report (European War)
2 The United States Strategic Bombing Survey: Over-all Report (European War)
3 The Effects of Strategic Bombing on the German War Economy

AIRCRAFT DIVISION

(By Division and Branch)

*4 Aircraft Division Industry Report
5 Inspection Visits to Various Targets (Special Report)

Airframes Branch

6 Junkers Aircraft and Aero Engine Works, Dessau, Germany
7 Erla Maschinenwerke G m b H, Heiterblick, Germany
8 A T G Maschinenbau, G m b H, Leipzig (Mockau), Germany
9 Gothaer Waggonfabrik, A G, Gotha, Germany
10 Focke Wulf Aircraft Plant, Bremen, Germany
11 Messerschmitt A G, Augsburg, Germany — Over-all Report; Part A; Part B; Appendices I, II, III
12 Dornier Works, Friedrichshafen & Munich, Germany
13 Gerhard Fieseler Werke G m b H, Kassel, Germany
14 Wiener Neustaedter Flugzeugwerke, Wiener Neustadt, Austria

Aero Engines Branch

15 Bussing NAG Flugmotorenwerke G m b H, Brunswick, Germany
16 Mitteldeutsche Motorenwerke G m b H, Taucha, Germany
17 Bavarian Motor Works Inc, Eisenach & Durrerhof, Germany
18 Bayerische Motorenwerke A G (BMW) Munich, Germany
19 Henschel Flugmotorenwerke, Kassel, Germany

Light Metal Branch

20 Light Metals Industry of Germany — Part I, Aluminum; Part II, Magnesium
21 Vereinigte Deutsche Metallwerke, Hildesheim, Germany
22 Metallgussgesellschaft G m b H, Leipzig, Germany
23 Aluminiumwerk G m b H, Plant No. 2, Bitterfeld, Germany
24 Gebrueder Giulini G m b H, Ludwigshafen, Germany
25 Luftschiffbau, Zeppelin G m b H, Friedrichshafen on Bodensee, Germany
26 Wieland Werke A G, Ulm, Germany
27 Rudolph Rautenbach Leichmetallgiessereien, Solingen, Germany
28 Lippewerke Vereinigte Aluminiumwerke A G, Lunen, Germany
29 Vereinigte Deutsche Metallwerke, Heddernheim, Germany
30 Duerener Metallwerke A G, Duren Wittenau-Berlin & Waren, Germany

AREA STUDIES DIVISION

*31 Area Studies Division Report
32 A Detailed Study of the Effects of Area Bombing on Hamburg
33 A Detailed Study of the Effects of Area Bombing on Wuppertal
34 A Detailed Study of the Effects of Area Bombing on Dusseldorf
35 A Detailed Study of the Effects of Area Bombing on Solingen
36 A Detailed Study of the Effects of Area Bombing on Remscheid
37 A Detailed Study of the Effects of Area Bombing on Darmstadt
38 A Detailed Study of the Effects of Area Bombing on Lubeck
39 A Brief Study of the Effects of Area Bombing on Berlin, Augsburg, Bochum, Leipzig, Hagen, Dortmund, Oberhausen, Schweinfurt, and Bremen

CIVILIAN DEFENSE DIVISION

*40 Civilian Defense Division– Final Report
41 Cologne Field Report
42 Bonn Field Report
43 Hanover Field Report
44 Hamburg Field Report– Vol I, Text; Vol II, Exhibits
45 Bad Oldesloe Field Report
46 Augsburg Field Report
47 Reception Area in Bavaria, Germany

EQUIPMENT DIVISION

Electrical Branch

German Electrical Equipment Industry Report
Brown Boveri et Cie, Mannheim Kafertal, Germany

Optical and Precision Instrument Branch

Optical and Precision Instrument Industry Report

Abrasives Branch

The German Abrasive Industry
Mayer and Schmidt, Offenbach on Main, Germany

Anti-Friction Branch

The German Anti-Friction Bearings Industry

Machine Tools Branch

Machine Tools & Machinery as Capital Equipment
Machine Tool Industry in Germany
Herman Kolb Co., Cologne, Germany
Collet and Engelhard, Offenbach, Germany
Naxos Union, Frankfort on Main, Germany

MILITARY ANALYSIS DIVISION

The Defeat of the German Air Force
V-Weapons (Crossbow) Campaign
Air Force Rate of Operation
Weather Factors in Combat Bombardment Operations in the European Theatre
Bombing Accuracy, USAAF Heavy and Medium Bombers in the ETO
Description of RAF Bombing
The Impact of the Allied Air Effort on German Logistics

MORALE DIVISION

The Effects of Strategic Bombing on German Morale (Vol I & II)

Medical Branch

The Effect of Bombing on Health and Medical Care in Germany

MUNITIONS DIVISION

Heavy Industry Branch

The Coking Industry Report on Germany
Coking Plant Report No. 1, Sections A, B, C, & D
Gutehoffnungshuette, Oberhausen, Germany
Friedrich-Alfred Huette, Rheinhausen, Germany
Neunkirchen Eisenwerke A G, Neunkirchen, Germany
Reichswerke Hermann Goering A G, Hallendorf, Germany
August Thyssen Huette A G, Hamborn, Germany
Friedrich Krupp A G, Borbeck Plant, Essen, Germany
Dortmund Hoerder Huettenverein, A G, Dortmund, Germany
Hoesch A G, Dortmund, Germany
Bochumer Verein fuer Gusstahlfabrikation A G, Bochum, Germany

Motor Vehicles and Tanks Branch

*77 German Motor Vehicles Industry Report
*78 Tank Industry Report
79 Daimler Benz A G, Unterturkheim, Germany
80 Renault Motor Vehicles Plant, Billancourt, Paris
81 Adam Opel, Russelheim, Germany
82 Daimler Benz-Gaggenau Works, Gaggenau, Germany
83 Maschinenfabrik Augsburg Nurnberg, Nurnberg, Germany
84 Auto Union A G, Chemnitz and Zwickau, Germany
85 Henschel & Sohn, Kassel, Germany
86 Maybach Motor Works, Friedrichshafen, Germany
87 Voigtlander, Maschinenfabrik A G, Planen, Germany
88 Volkswagenwerke, Fallersleben, Germany
89 Bussing NAG, Brunswick, Germany
90 Muehlenbau Industrie A G (Miag) Brunswick, Germany
91 Friedrich Krupp Grusonwerke, Magdeburg, Germany

Submarine Branch

92 German Submarine Industry Report
93 Maschinenfabrik Augsburg-Nurnberg A G, Augsburg, Germany
94 Blohm and Voss Shipyards, Hamburg, Germany
95 Deutschewerke A G, Kiel, Germany
96 Deutsche Schiff und Maschinenbau, Bremen, Germany
97 Friedrich Krupp Germaniawerft, Kiel, Germany
98 Howaldtswerke A G, Hamburg, Germany
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