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22 December 1945

RESTRICTED

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

Subject: Target Report - Camouflage of Japanese Ships and Naval Installations.

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

1. Subject report dealing with Target X-32 of Fascicle X-1 of reference (a), is submitted herewith.

2. The investigation of the target and the target report were accomplished by Lt. (jg) W.E. Champion, USNR, Lt. (jg) W.M. Kluss, USNR, and Lt. (jg) R.B. Palmer, USNR.

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Captain, USN

32414

CAMOUFLAGE OF JAPANESE SHIPS AND NAVAL INSTALLATIONS

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

FASCICLE X-1, TARGET X-32

DECEMBER 1945

U.S. NAVAL TECHNICAL MISSION TO JAPAN

SUMMARY

MISCELLANEOUS TARGETS

CAMOUFLAGE OF JAPANESE SHIPS AND NAVAL INSTALLATIONS

Investigation of Japanese naval camouflage revealed that the Japanese took little interest until the latter half of the war, when their strategic position stimulated interest in camouflage. Naval vessels were for the most part painted plain grey, while experiments were conducted in camouflaging aircraft carriers and merchant ships, resulting in more or less standard camouflaging for those respective types.

Elaborate concealment and camouflage was carried out on ships in port, but although all instances of this were done on much the same principles, no standardized system or doctrine was ever developed.

Camouflaging of shore installations was seen at its best in installations built completely or partly underground, while the standard methods, such as concealment with nets and painting, were employed for installations above ground. Camouflage painting of shore installations had as its purpose confusion of the enemy during actual bombing runs rather than counteraction of photographic reconnaissance and was based on elaborate theories of brightness and visibility developed by civilian experts.

No research was ever conducted on camouflaging against infra-red reconnaissance, and no special anti-infra-red materials or techniques were developed.

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REFERENCES

Japanese Personnel who Assisted in Gathering Documents:

Captain S. MAKINO, IJN, Navy Technical Department, TOKYO.
Lt. Comdr. MORI, IJN, Bureau of Naval Installations, TOKYO.
S. HOSHINO, Assitant Professor of Architecture, Tokyo Imperial University.
Comdr. H. MIYAGAWA, IJN, Shipbuilding Department, Yokosuka Navy Yard.
Captain SATO, IJN, Chief of Department of Maritime Affairs. TOKYO.
Lt. Comdr. I. UCHIDA, IJN, Design Section of Shipbuilding Department, Yokosuka Navy Yard.
Lt. Comdr. FUKUI, IJN, formerly of Design Section of Shipbuilding Department, Kure Navy Yard.
Ensign M. HAYASHI, IJN, Assistant Division Officer and Gunnery Officer of CV KATSURAGI.

Japanese Personnel Interviewed:

Vice Admiral YAMAGUCHI, IJN, Chief of Bureau of Naval Installations. (Administrative and organizational information; little actual knowledge of details.)
Captain S. MAKINO, IJN, (Little knowledge of the subject; limited organizational information.)
Captain KIJIMA, IJN, Bureau of Naval Installations. (Member of camouflage committee; well informed on general questions; hazy about details.)
Lt. Comdr. MORI, IJN, Bureau of Naval Installations. (Nine years experience in engineering; member of Air Raid Committee of Association of Civil Engineers; specialist on camouflage of oil tanks and air bases.)
S. HOSHINO, Assistant Professor of Architecture, Tokyo Imperial University. (Fourteen years experience; five years research on the visibility of objects; camouflage consultant for army, navy and civilian agencies; regarded by Japanese as an outstanding authority on camouflage of shore installations. Extremely competent.)
Major TAKAYAMA of No. 7 Tachikawa Air Technical Experiment Station. (No knowledge of the subject.)
Comdr. H. MIYAGAWA, IJN, Shipbuilding Dept., Yokosuka Navy Yard. (Specialist in painting. Authoritative source concerning camouflage for ships.)
Captain SATO, IJN, Chief of Maritime Affairs Department. (Adequate knowledge of the limited connection his department had with the subject.)
Lt. Comdr. I. UCHIDA, IJN, Design Section of Shipbuilding Department, Navy Yard, YOKOSUKA. (Very competent and well-informed on ship paint camouflage and ship concealment at YOKOSUKA. Nine years experience. Extremely cooperative.)
Captain S. INAGAWA, IJN, Naval Architect for Navy Technical Department. (Specialist in carriers; 21 years experience; well-informed on camouflage of carriers.)
Ensign M. HAYASHI, IJN, Assistant Division Officer and Gunnery Officer of CV KATSURAGI (Participated in actual camouflaging; excellent source for details.)
Captain AOKI, IJN, Naval Technical Laboratories at ZUSHI (Officer in charge of Naval infra-red research and cognizant of other infra-red research.)

Pertinent Reports of Other Intelligence Agencies:

Photo-Interpretation Report 816 - Interpron Two, Shipping Report of KURE. (Photo coverage of 24-28 July.) Includes list of photo coverage and discussion of ship concealment based on photo-interpretation.
USSBS - Physical Damage Report. "Camouflage" - Edited by Lt.(jg) Chaffee.
USSBS - Civilian Defense Division.
Target Reports - KOBE - pp. 136-140; KYOTO - pp. 89-91; NAGASAKI - pp. 133-137; OSAKA - pp. 166-170; TOKYO (in process).
(Discussion of camouflage of shore installations in those areas.)

INTRODUCTION

The problem of investigating Japanese naval camouflage was at first attacked by attempting to find if there was a central organization in the Japanese Navy which supervised and directed camouflage. It was soon established that camouflage was never developed in the Navy to the extent of having any organization, schools, or specific financial allotments, but that each subdivision in the Navy Ministry which met problems of camouflage handled them independently as they arose. Thus the investigation of camouflage fell naturally into three main fields, almost completely independent of each other:

1. Camouflage painting of ships, under the jurisdiction of the Navy Technical Department.

2. Concealment of ships (usually inoperational) in port by direction of fleet or the ship's commanding officer.

3. Camouflage of shore installations under the jurisidction of the Bureau of Naval Installations.

The investigation therefore was conducted in those three main fields, and the report is similarly organized. In each field it was attempted to determine the administrative organization for handling camouflage (if any), research and experimentation conducted, theories employed, historical development during the course of the war, general methods employed, and specific examples illustrative of fundamental methods of camouflage. Emphasis has been placed on principles, theories, and methods, rather than on individual details except as they have been used for illustration.

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THE REPORT

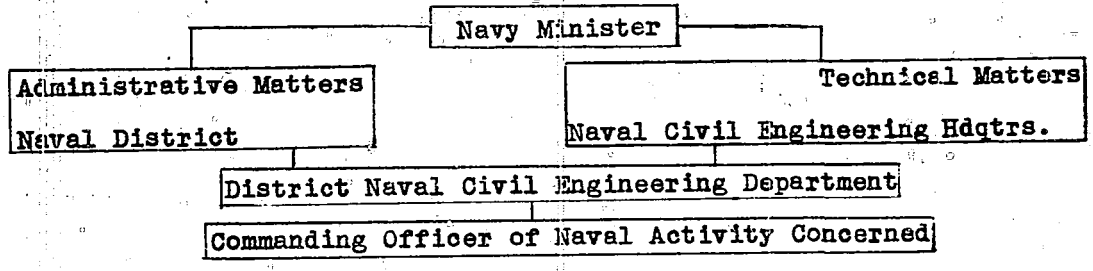
Part I - ORGANIZATION OF NAVAL CAMOUFLAGE

Japanese naval camouflage was divided between the Naval Construction Bureau's installation organization and the Naval Technical Department group handling both naval and maritime vessels and their camouflage. Vice Admiral YAMAGUCHI stated that camouflage was rather disorganized and ineffective in general, and the administration did seem plagued by a cumbersome lack of centralization and often by misinterpretation of plans and research. Conspicuously bad examples could often be traced to independent action on the part of individuals not qualified to plan camouflage.

A. Shore Installation Camouflage

Until 1944 the Navy Construction Bureau administered its camouflage program as shown in Diagram A. In order to speed up decisions, authority was delegated to the Naval Districts to initiate work on all but very large installations, such as airfields. In either case, a Commanding Officer requested the order for a camouflage job from the delegated authority. Occasionally, purely technical matters would originate with Naval Civil Engineering Headquarters rather than the Navy Ministry, even prior to the 1944 change.

Diagram A



A camouflage committee was organized under the Civil Engineering Headquarters, headed by the Chief of the Administrative Department. The committee met twice a month and included:

No. 1 Department Chief
No. 2 Department Chief
Nos. 3,6 Section Heads (Civil Engineers)
Nos. 4,7 Section Heads (Construction Corps)
Lt. Comdr. MORI, Specialist in camouflage of oil tanks and air bases from December 1944 until end of the war
Captain KIJIMA and other experts and engineers

Directives were formulated by this committee and issued by the head of the Naval Construction Bureau. Two types were in use:

General, concerning techniques and methods developed by research and sent out to all appropriate commands, and

Specific, sent to the particular commanding officer involved, and for information to other commands to use as ready reference material in case similar problems were encountered.

A camouflage Manual of which 2000 copies were distributed was mainly the work of Lt. Comdr. MAEDA, with Professor HOSHINO as adviser. This document has been forwarded to Washington Document Center as NavTechJap Document ND-50-5035.

It consisted in part of edited directives. Later, after use in the field, it was revised and republished.

Any research which was done was carried out by No. 2 Department, headed by Rear Admiral GONDO, with headquarters at NUMAZU. There were several agencies and individuals who contributed to this work in various degrees.

Lt. Comdr. SASAMA, now in SHANGHAI, was an architectural engineer who did considerable research.

Professor Shoichi HOSHINO was graduated from Tokyo Imperial University in architecture, became assistant professor there, and later developed probably the most extensive research on the subject of camouflage in Japan. Although he worked for Army, Navy, and civilian interests, he worked only on shore installations. He began this work in 1936 when the Ministry of Education's Committee for Advancement of Science first advanced him an annual laboratory expense allotment of ¥ 5000 which was continued until the end of the war. Professor HOSHINO worked first with models and trial solutions; later; with experience gained from models, he tried direct solutions to camouflage problems. This work was done first at the University and later at the Tachikawa Air Technical Experiment Station. Here he flew to some extent, carrying out experiments with visibility. Results of this work were published in scientific journals, and were also turned over to TACHIKAWA in document form.

At one time, HOSHINO instructed 40-50 officers in a two weeks camouflage course in Manchuria but aside from this he did no teaching. He feels there were few examples where teaching of any kind was done, and certainly there were no organized schools or programs of training. His work was of prime importance as far as shore installations research was concerned.

Checking of installation camouflage was done by naval aviators who made reports to the Chief of the Naval Construction Bureau. Also, a system was in effect whereby any naval personnel could volunteer reports of either good or bad examples.

Two monthly bulletins published by professional organizations were utilized by the Navy. These were the "Association of Architectural Engineers' Journal" and "Singapore's Association of Civil Engineering" publication. Copies of these have been forwarded to Washington Document Center under NavTechJap Document No. ND50-5034.

B. Naval and Maritime Vessel Camouflage

The Naval Technical Department began its camouflage program in March 1943, when a committee met temporarily to discuss the program's development. A committee was organized under the direction of the Kokai Gakko at YOKOSUKA. This committee was selected by the Minister of the Navy and included representatives of the following:

1. Navy Ministry
2. Navy General Staff
3. Air Corps
4. Yokosuka Navy Yard
5. Optical laboratory

The representatives of the Yokosuka Navy Yard were Lt. Comdr. Isamu UCHIDA of the Ship Design Section and Comdr. Hideto MIYAGAWA, a paint research man who later supervised all ship painting at YOKOSUKA.

The actual experimentation was carried out by the Kokai Gakko. The committee met three or four times between March and July in order to direct this work. In July a smaller, more permanent group was designated to carry on the work. This committee was made up of Capt. SHIWA, Comdr. MIYAGAWA. Lt. Comdr.

UCHIDA, Lt. NAKAGAWA of the Air Corps, and one optics representative. This group met two or three times a month.

The primary function of both of these committees, to formulate a technique for painting the flight deck of carriers, was not altered to any extent throughout the war. However, they acted also as a general standing committee for camouflage problems encountered in all naval vessels and did some work on maritime vessels as well.

A sub-committee, also headed by Capt. SHIWA and including Lt. Comdr. YOSHIDA, published an annual handbook on ship painting from the camouflage point of view.

Inspection of vessels was carried out by naval aviators in much the same way as it was handled for installations.

The chain of command in matters of merchant ship camouflage was from the Navy Minister to the Maritime Affairs Department, headed by Captain SATO, to the Maritime Control Committee. This committee had under its jurisdiction a maritime camouflage committee which did all work in research and regulation of maritime camouflage. It had several submarine officers as members, and was primarily interested in defense against submarine attack, since it felt that any merchant ship camouflage against planes was useless. This committee designated the Resident Naval Officer (ZAIKIN BUKAN) as the inspector for privately owned merchant ships. Other matters were handled directly with the owners of the merchant ships.

Part II - CAMOUFLAGE PAINTING OF SHIPS

At the beginning of the war all ships, naval and merchant, were painted a dark grey. This grey, later lightened to a silver grey, was maintained during the war for combatant ships other than carriers and submarines. Naval auxiliaries, merchant ships, and aircraft carriers were camouflaged in colors obtained through experimentation and research.

Dazzle painting, never used on warships, was used on only a few auxiliaries and merchantmen early in the war. The few ships painted with dazzle patterns were painted according to the captain's personal ideas, and no general orders for such painting were issued. The scattered examples were for the most part ships whose function required their lying at anchor much of the time, such as repair ships, seaplane tenders, etc. Many such examples of camouflage were copies of patterns seen in pictures of foreign ships, or the results of the captain's imagination. Among the few examples of design resulting from actual experimentation are those of Lt. Comdr. FUKUI, who designed and painted ships with dazzle camouflage at Singapore in 1942.

The following principles of camouflage were the result of the work of FUKUI who alone conducted experiments on camouflage (official naval research on camouflage did not begin until 1943):

1. Use of black and white slanting lines to break up sharp angles.
2. Use of dark grey on curved surfaces, such as the fantail, because in shadow the grey shows very dark and in the sun it reflects no light, so that contrast of light and shadow are kept at a minimum.
3. Use of a large white area at the bow so that the bow wave cannot show, and thus make it difficult to judge ship's speed.
4. Use of white on the top of the funnel to make it appear shorter.
5. Converging lines on the funnel to make a raked funnel appear vertical.
6. Camouflage pattern lines continuing across the after and forward sections of the bridge so as to make it look as if it were in the same plane as the hull of the ship, and so confuse the observer as to the ship's heading. The principle here is to leave no de-

finite background against which to judge angle or planes of various portions of the ship.

7. The camouflage is not designed to be seen at right angles, but to give its best effect when seen at an angle of thirty or sixty degrees from the ship's head.

At the request of the ship's captain and of the squadron commander, FUKUI put these principles into effect in June 1942 on SAGARA MARU (seaplane tender--former NYK type S high speed cargo ship), one of the first ships in the southwest area to be camouflaged. Colors used were black and light grey. FUKUI planned to use white instead of grey, but the captain objected on the grounds that white was the color of death and insisted on light grey instead. The pattern was the same both port and starboard. The squadron commander gave orders for ships sighting SAGARA MARU to submit reports, and it was said to be the best camouflage seen up to that time. Various army transports in the southwest area had haphazard camouflage, and many of them soon copied the camouflage design of SAGARA MARU. The ship remained camouflaged in this way until a general order was issued in June 1944 to camouflage according to the Number Two color plan.

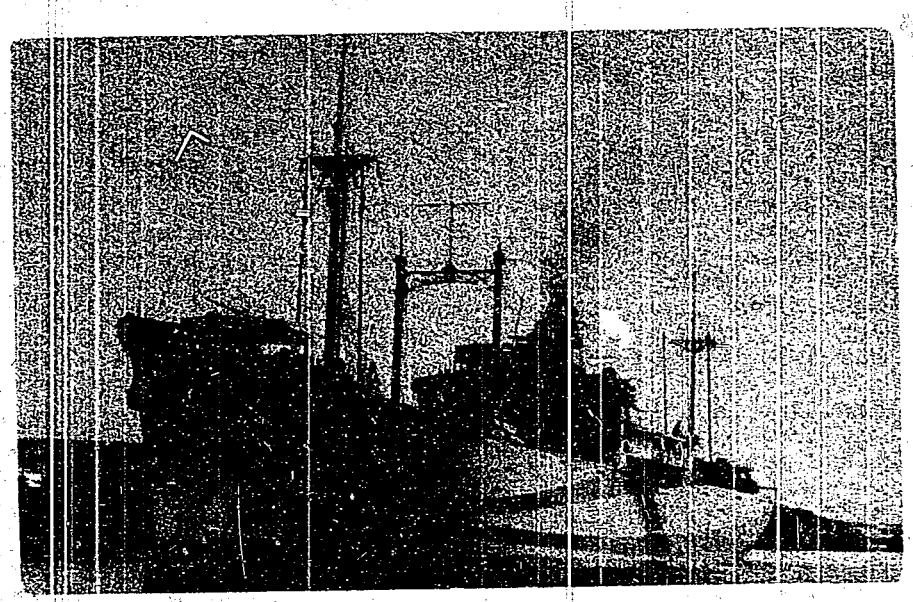


Figure 1
SAGARA MARU
(Bow View)

Figure 2
SAGARA MARU
(Aberm)

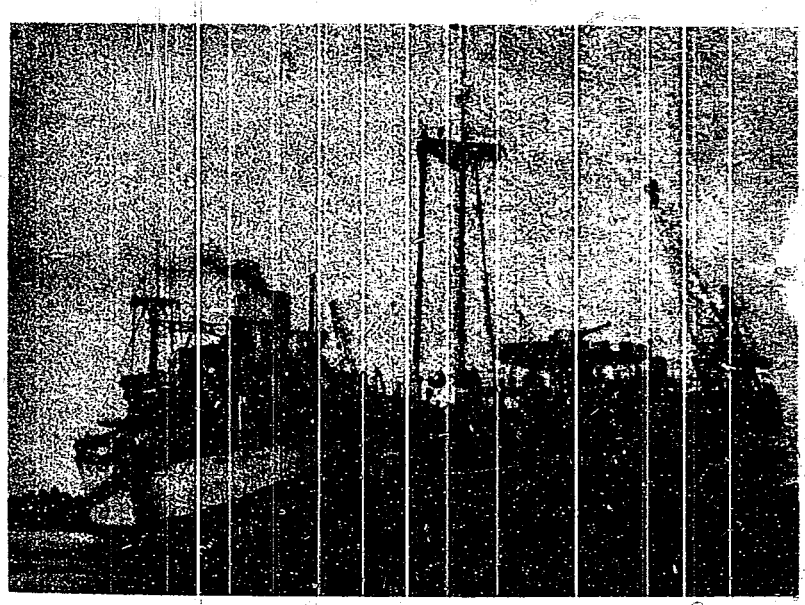


Figure 3
SAGARA MARU
(Stern View)

Other ships specially camouflaged by FUKUI are as follows:

1. KIYOZUMI MARU. This was done on much the same design as SAGARA MARU, except that the pattern differed slightly for port and starboard. The object of the pattern again was to make it impossible to judge the ship's heading when looking toward the bow. A dummy canvas funnel was added by the captain in spite of FUKUI's protests.

2. ISHIRO. An old slow tanker, the camouflage of the ship was designed about the end of 1943 at KURE to make the dark grey area resemble a modern fast tanker and so confuse the enemy as to her speed. The camouflage, designed to be seen from abeam to be effective, was a special case and was believed to have been left unchanged when the order for using the Number Two color system was issued.

3. AKITSUSHIMA. A seaplane tender, the forward third of the ship was painted with dazzle stripes in light green and black (or very blackish green).

4. ASAHI (OBB). A repair ship. Since her speed was only eight knots, a big bow wave was painted on to make it look as if she were fast. She had a dummy main battery of wood. The Malayans thought her a real Japanese battleship.

5. FUKUI also repainted in September 1942 two ships, AIKOKU MARU and HOKOKU MARU, whose camouflage had been designed at KURE. Their design was criticized in that the pattern was too small and that it was effective only if seen directly abeam. These faults, FUKUI asserted, were characteristic faults of all dazzle painting designed in Japan. HOKOKU MARU was in two colors, and AIKOKU MARU was in three: black, dark grey, and light grey. AIKOKU MARU also had a dummy canvas funnel.

The Japanese, realizing that all sorts of dazzle painting though they might be more or less effective in the daylight were extremely conspicuous at night under searchlights, never made widespread use of this technique.

Accordingly, Japanese ships in general were painted plain grey except for occasional examples of independent camouflage similar to those noted above. In March 1943, however, a special committee met at the Navigation School (KOKAI GAKKO) at YOKOSUKA as a research group on camouflage paint for merchant shipping. This committee took five ships of about 3000 tons, painted them with different colors and different patterns, and observed them under varying conditions: in daylight, at night, from the air, and from submarines. Their conclusion that camouflage against air observation was almost useless, led to emphasis on camouflage against submarines. The color decided on from the results of this experimentation was known as "standard color number two", a shade of olive green. (See paint sample, NavTechJap Equipment No. JE50-1222). It was considered particularly effective in waters near Japan, where foggy conditions prevail. This was the basic color used in camouflaging naval auxiliaries, merchant ships, and the sides of aircraft carriers. It was mixed in each case to match the standard color sample prepared by the Naval Technical Department and contained zinc white, chrome yellow, carbon black, and Prussian blue. Due to variations in color of the available chrome yellow, "standard color number two could not be described by a formula, but had to be mixed to match the standard color sample. This "number two color paint" was then used (with lighter shades of the same basic color) to paint all merchant vessels, according to the pattern shown in Figure 8.

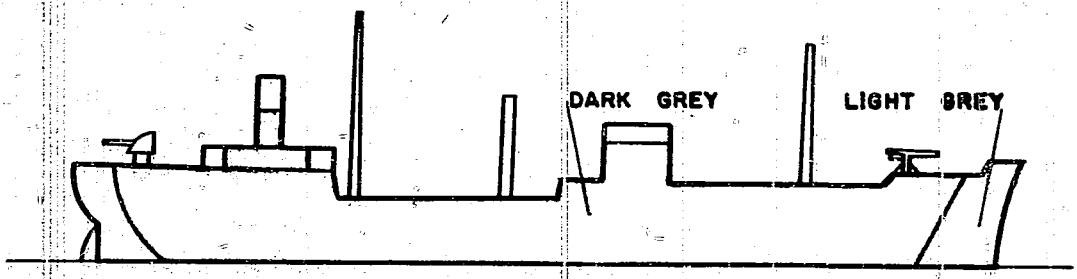


Figure 4
ISHIRO (SLOW TANKER)

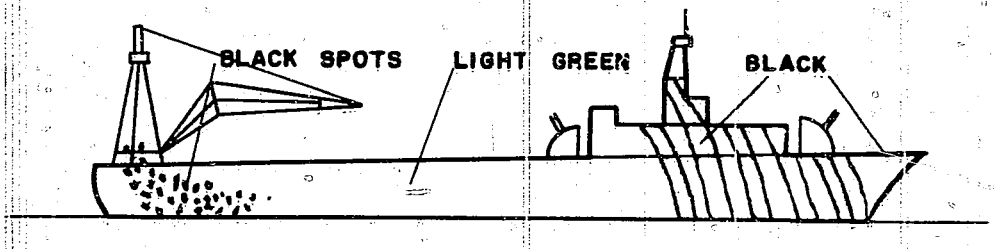


Figure 5
AKITSUSHIMA (SEAPLANE TENDER)

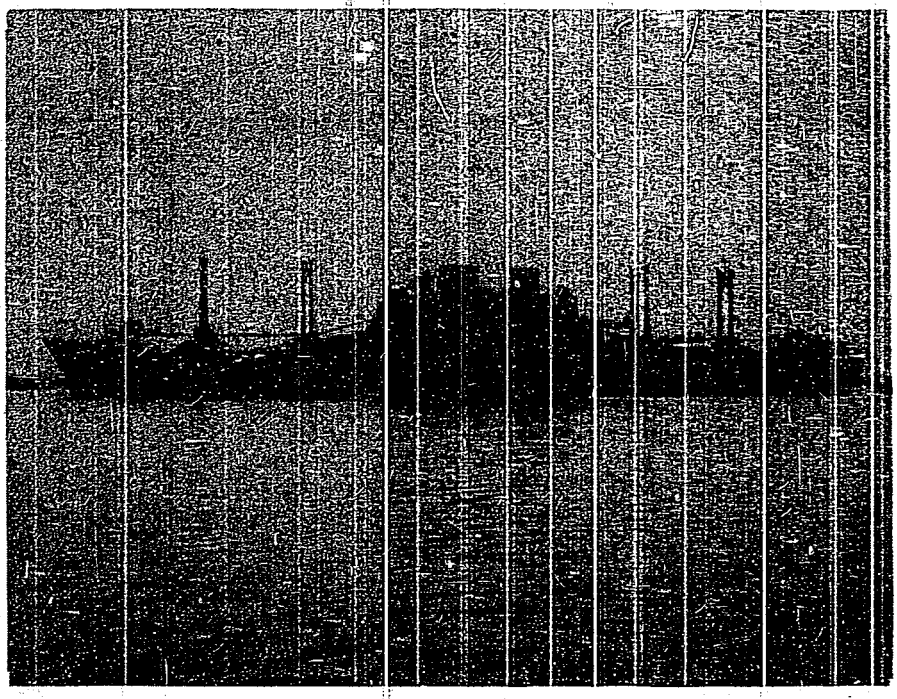


Figure 6
AIKOKU MARU

Figure 7
HOKOKU MARU

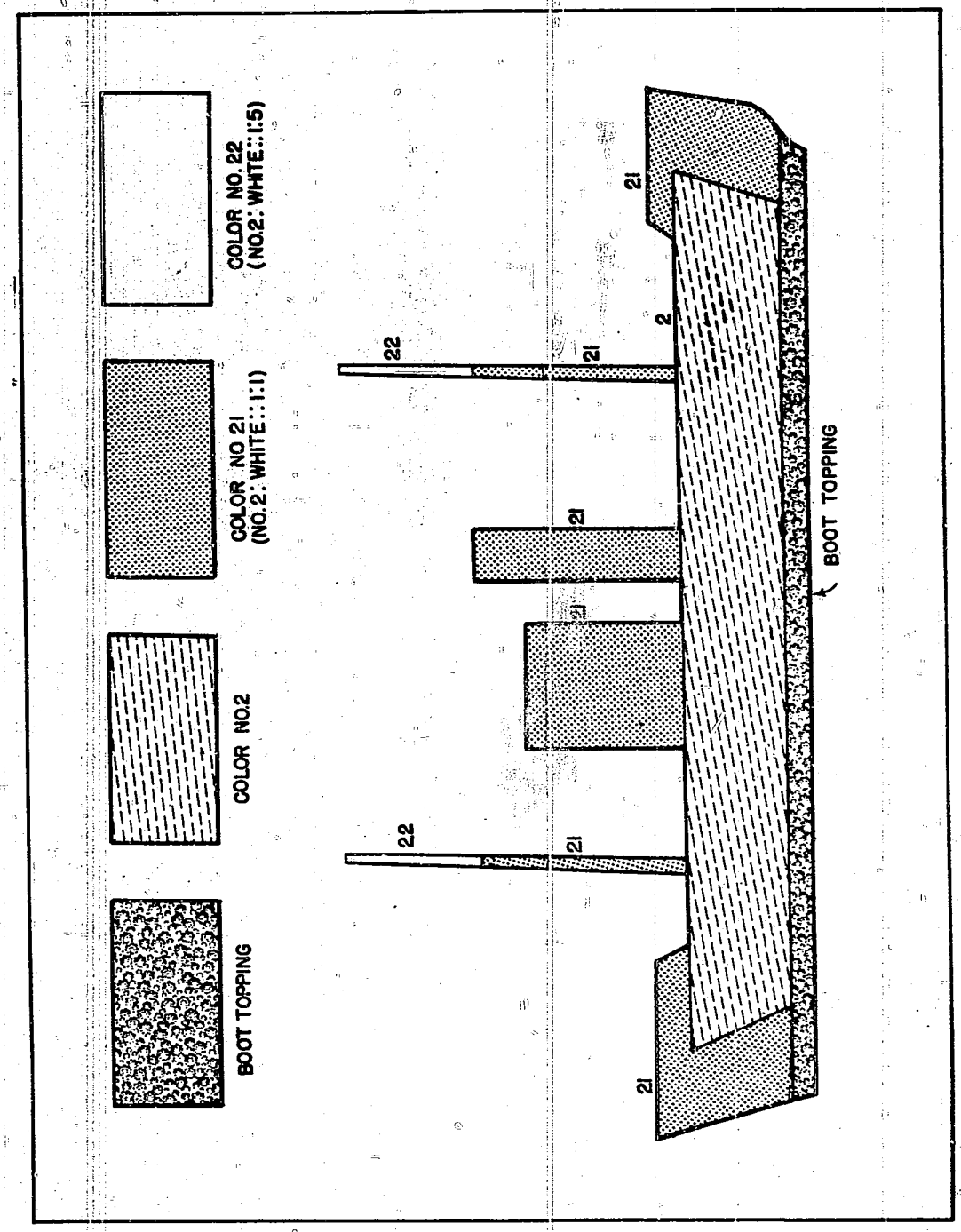


Figure 8
CAMOUFLAGE ON MERCHANT SHIP

This method of painting merchant shipping was used from the time of its adoption in July 1943 until the end of the war and was considered by the Japanese to be effective against submarines. The official order directing such camouflage was issued by the Maritime Transportation Bureau in the Department of Transportation and Communications, as follows:

* * * * *

Translation of Excerpts From Seized Document, NavTechJap No. ND50-5031
Instructions for Protection Of Shipping, and Related Notes
(SECRET)
Department of Transportation and Communication, Maritime Transportation Bureau

- - - - - - - - - - -

To all Merchant Shipping. No. 640

5 June 1944

From: Chief of the Maritime Transportation Bureau,
Department of Transportation and Communication.

To: Chairman of the Maritime Control Committee.
Owners of Vessels of more than 500 tons, gross tonnage.

Instructions for Protection of Shipping, No. 29.

Camouflage of vessels, based on Item 5 of the regulations for carrying out the protection of vessels in the South Sea Islands, and rules for the protection of vessels, shall be as follows:

1. Vessels which are to carry out camouflage:
All completed vessels of 500 gross tons or more, except for those operating only in the Inland Sea.

2. Date when camouflage is to be completed:
As soon as possible. For vessels sailing in a southerly direction, whenever opportunity affords.

3. Essential points of camouflage:

a. Repainting by the crews or scheduled crews of the vessel concerned.

b. Because of the results of recent tests, vessels which have an opportunity for repairs or docking will be repainted at the dock company.

c. Camouflaging with a No. 2 color system according to the sketch attached.

4. Method of obtaining paint:

To be purchased from commercial ship's stores companies in each area: (OTARU, TOKYO, YOKOHAMA, OSAKA, KOBE, MOJI, TAKAO).

NOTE: Special orders will be issued from the Naval Technical Department to the shipbuilders regarding ships at present under construction or to be built in the future.

* * * * *

Although plain silver grey was considered adequate for other combat types, special research was carried out on the camouflage or aircraft carriers. A

special committee composed of twenty naval officers met from March to July of 1944 for this purpose. Aviation and optical experts were included in the committee to express their views on how best to camouflage a carrier at sea. Models of carriers were presented by the committee to the Fourth Section (Ship Construction) of the Naval Technical Department, which decided on the patterns to be used. A translation of the report of the experiment follows:

* * * * *

Experiment on the Camouflage of Aircraft Carriers

Head of the Experimental Committee: President of the Naval Navigation School.

Place where experiment was made: The sea near YOKOSUKA.

Time of experiment: March-July 1944.

1. Object.

To camouflage aircraft carriers by painting so that they will be hard to spot from planes or so that they may be mistaken for another type vessel when observed from the air.

2. Method Used.

a. Experimentation with models.

Models about 1 meter long were floated alongside the side of FUJI (old BB belonging to the Navigation School). These were examined from the upper deck with inverted binoculars in order to produce long range visibility conditions. Two models were selected from the large number tested. (Diagram #1 of Fig. 9 illustrates the design used on these models: the straight lines design on the forward half of UNYO is from one model and the curved line design on the after half of UNYO is from the other.)

b. Experiment on the degree of brightness (of colors).

The degree of brightness of each color used in the paint camouflage was measured in the Optical Laboratory. A color was made up from various colors which had been put on a rotating disk and the degree of brightness of the color similar to the color produced by the disk was measured.

c. Experimentation with actual carriers.

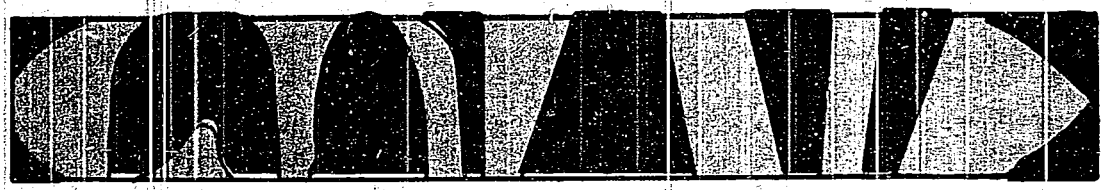
The aircraft carriers UNYO, TAIYO, CHITOSE, and UNRYU, painted in the manner shown in Figure 9, were observed and photographed from the air from various angles and altitudes.

(1) Diagram #1 (Figure

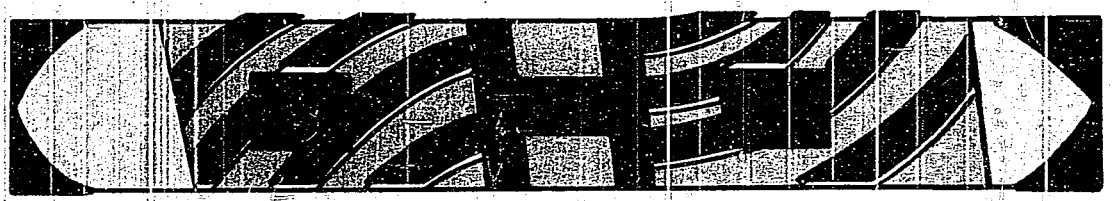
The purpose behind this design was the comparison of a straight line pattern with a curved line pattern.

Result: When observed from a great distance, the two patterns could not be distinguished one from the other. The color tone was too bright.

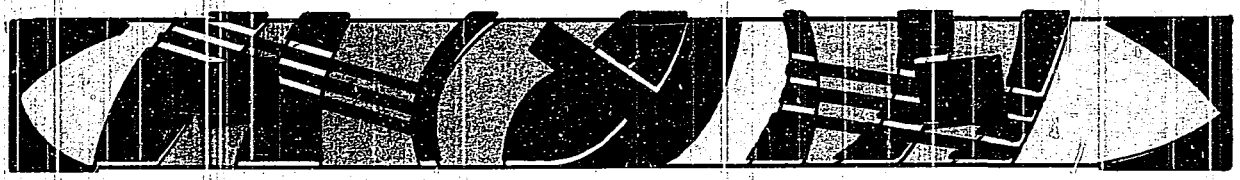
Figure 9
CAMOUFLAGE EXPERIMENTS FOR CARRIERS



NO. 1 UNYO

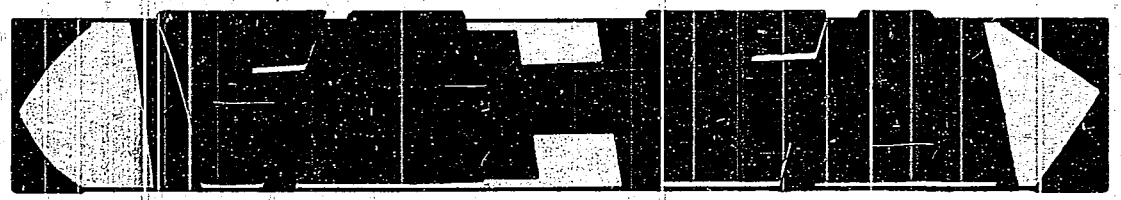


NO. 2 TAIYO

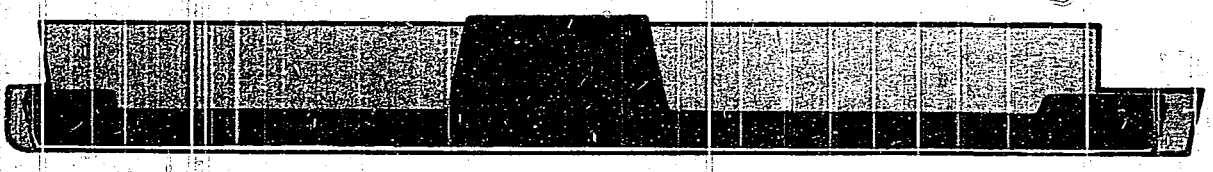


NO. 3 CHITOSE

NO. 4 UNRYU



NO. 5 UNYO



NO. 6 PROPTILE

(2) Diagram #2

The swirl design was used to attempt to throw off aiming (TN: to confuse planes, especially dive bombers, in their aim so that they could not gauge the center of the target).

Result: When observed from a distance, a mixed color, i.e. a merged color, was seen and this did not prove to be very effective.

(3) Diagram #3

It was hoped that this might be taken for a merchant ship.

Result: The design was too complicated (or fine). The color was a little too bright.

(4) Diagram #4

It was hoped this would be confused with a merchant ship.

Result: This was better than the experiments made prior to it. The color tone was better than any of the preceding ones.

(5) Diagram #5

Same as #4.

(6) Diagram #6

The purpose was to make it difficult for the carrier to be spotted by submarines and to cause confusion as to its course. Experiments were not made at this time because similar experiments in which submarines had been used for checking purposes had been made on other occasions.

3. Conclusion.

The paint camouflage was neither effective enough to prevent the carriers being spotted by planes nor effective enough to cause carriers to be mistaken for other ship types, but it was better than when no camouflage paint at all was applied to the flight deck. Diagrams #4 and #5 are considered good. (The effect caused by the camouflage was lessened when the carrier was against the sun. The flatness of the top deck was a decisive factor which caused the ship to be recognized as a carrier at a glance. When the design had been adopted, plans for painting were issued from the Naval Technical Department to the Navy Yard at YOKOSUKA.)

* * * * *

See blueprints appended to this report as Enclosures (A) and (B).

The sides of the carriers were painted with the Number Two color system, in a pattern which was intended to resemble the bridge and superstructure of a merchant vessel. Most of the flight deck patterns were also intended to resemble the top view of a merchant vessel. The flight deck was painted to try to alter its rectangular shape to the conventional pointed ship shape. A "bridge" and "stacks" were painted on, and the elevators were painted over to look like cargo hatches with painted cargo booms. The general plans for carrier camouflage decided on by this committee remained unchanged until the end of the war, although minor details varied from time to time with individual ships. The camouflage when completed was considered fairly effective against submarines, but of no use against observation from aircraft.

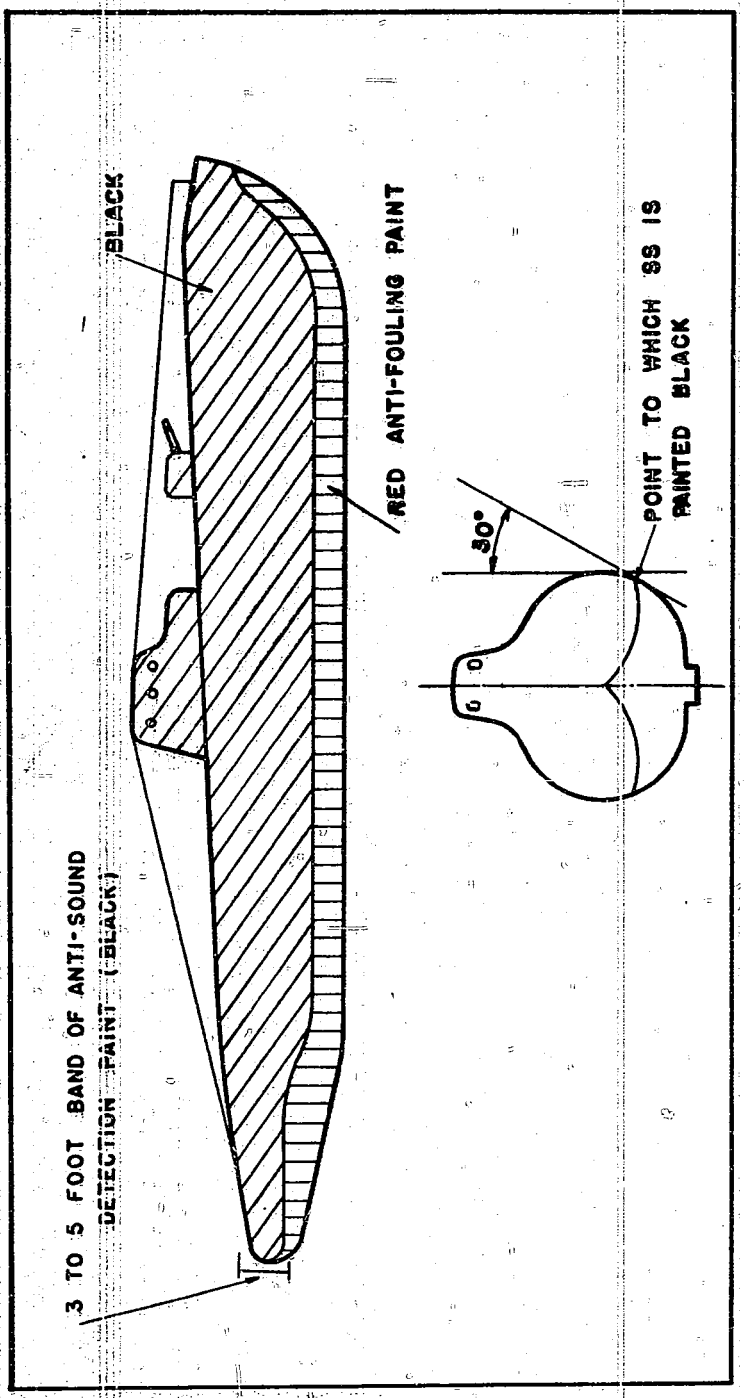


Figure 10
PAINTING OF SUBMARINES

Japanese submarines were painted black topside and on the hull down to the point of tangency of a line of sight thirty degrees from the vertical. (See FIG. 10.)

Below this point the bottom was painted with anti-fouling paint, red in color. A band of anti-sonar paint (black), three to five feet wide, went around the hull. (See NavTechJap Report, "Japanese Naval Vessels - Own Ship's Noise," Index No. S-43).

PART III - CAMOUFLAGE OF SHIPS IN PORT

One of the most eleborate uses of camouflage by the Japanese Navy was found in the attempts to conceal ships moored more or less permanently in the naval anchorages at KURE, YOKOSUKA, and SASEBO. The camouflaging of several carriers at KURE was carried out with particular care and thoroughness. Excellent photographic coverage of these ships is found in Photographic Interpretation Report 816 (Interpron Two), Shipping Report of KURE for 24-28 July 1945.

KATSURAGI, RYUHO, AMAGI, and KAIYO were all concealed in this manner at KURE at about the same time; JUNYO was similarly camouflaged at SASEBO. Concealment of the carriers was a high priority undertaking, and was said by Japanese officers to be the first instance of the use of this sort of camouflage by the Japanese Navy. The camouflage of KATSURAGI, besides being one of the most elaborate examples, also was among those least damaged by air attack. The camouflaging methods used are considered typical, and are described in detail as representing the best efforts of the Japanese toward camouflage of ships in port.

There were very good reasons for attempting this concealment in such an obvious place as KURE. Shortage of fuel was so acute as to make it not only impossible to move the carriers to some less conspicuous anchorage at more distant bombing range, but even to make it necessary for light and heat for the ship itself to be furnished by electricity from the shore. An anchorage having electric power in sufficient quantity therefore had to be selected.

KATSURAGI arrived in KURE about 15 February 1945. Shortly thereafter orders came from the Commander-in-Chief, Combined Fleet, to camouflage her. The work was begun about the first of March and took about two weeks. The result was as shown in Figures 11 and 12. On 19 March carrier planes from Task Force 58 struck KURE and KATSURAGI, together with AMAGI, RYUHO, and KAIYO, were moved close to shore. The order from the Commander-in-Chief, Combined Fleet, directed the carriers to be moored close to shore in water shallow enough to permit easy salvage in the event of heavy damage. When they had been moored in such a position, they were to be camouflaged. KATSURAGI accordingly was moored about 50 meters off the northeast side of MITSUKO Island, in 14 to 15 meters of water. AMAGI was moored off the southern end of the same island. The long narrow shape of the carriers was considered to be particularly well suited to camouflage intended: to make the carrier look like an extension of the island when seen from the air. No detailed instructions were given by superiors other than the general order to "carry out camouflage". The methods were devised by ship's officers, and the work was done by ship's company. KURE Naval District had no connection with the camouflaging, and no Navy Yard workers were used in the work. It was not planned to move the ships again once they had been camouflaged, and there was no provision for getting underway in case of heavy attack. The camouflage was constructed so that the anti-aircraft guns could be uncovered for firing.

The outboard (starboard) side of KATSURAGI was concealed with a bamboo screen hung down from the flight deck; similar screens covered the bow and stern. These screens were made of quarters of bamboo sticks hung lengthwise from a wire by means of a hole in the upper end. Green branches and other foliage, as well as straw mats, were then attached to this screen to make the concealment even more complete. Between the inboard (port) side and the shore

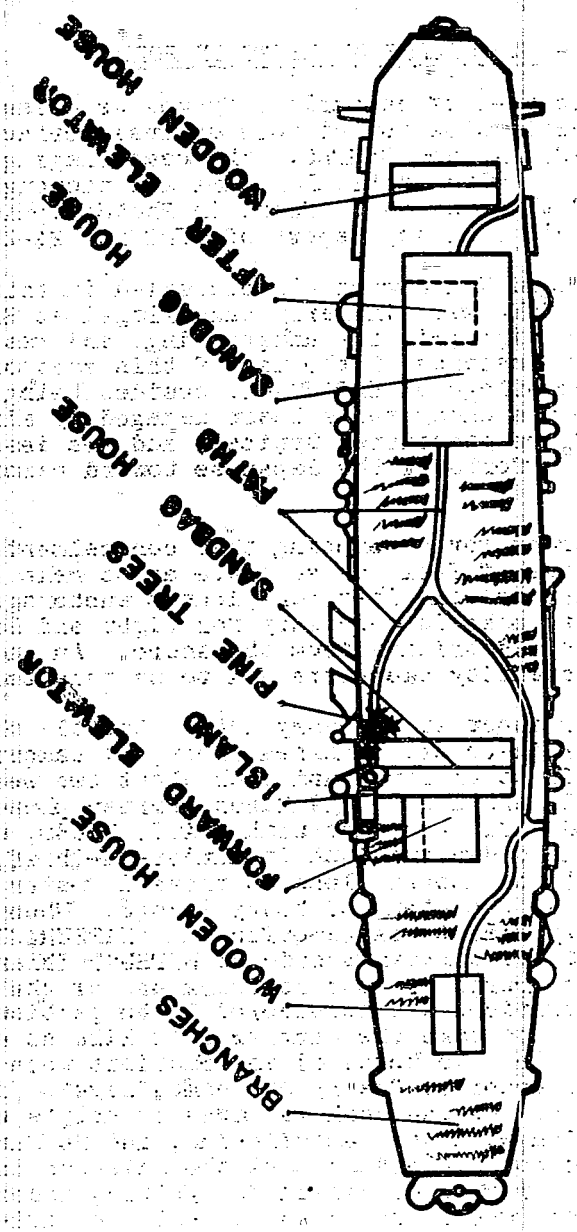


Figure 11

KAITSURAGI CAMOUFLAGED AS OF 19 MARCH 1945

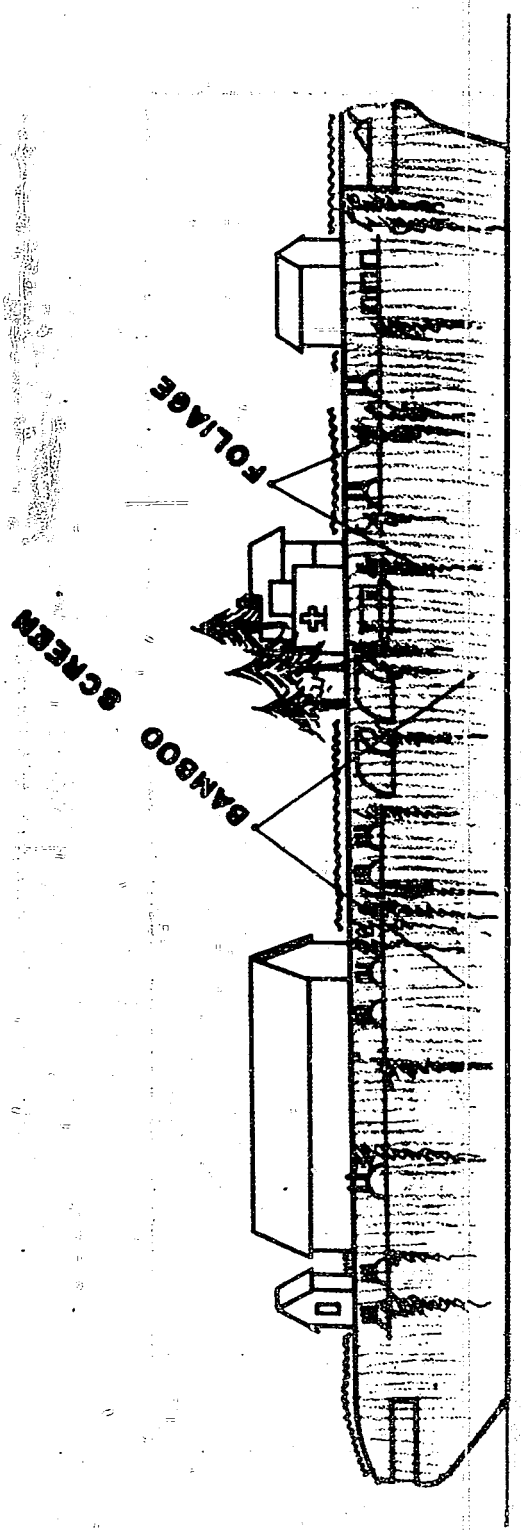


Figure 12
KATSURAGI (SIDE VIEW - STARBOARD) 19 MARCH 1945

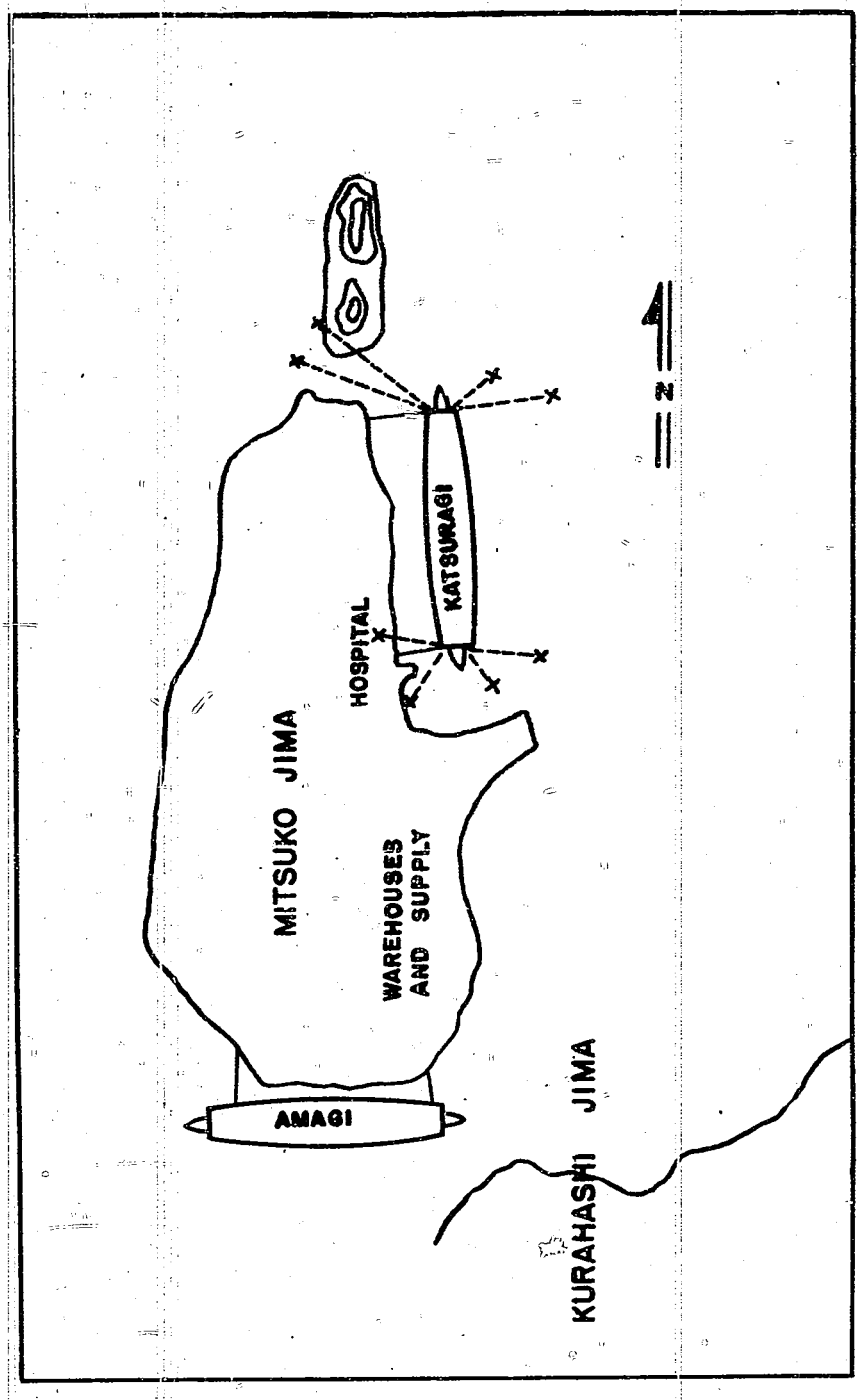


Figure 13
MOORING OF AMAGI AND KATSURAGI

was stretched a straw-rope net supported by wire rope. Tree branches and other foliage were attached to this also. The flight deck was higher than the land, so that the net sloped down at an angle; but no measures were taken to break up the shadow which the ship cast on the net and on the land. Other than the wire rope, no supports were used under the nets. A number of torpedo boats, which can be seen between the ship and the shore underneath the net in some aerial photographs, were there merely because of lack of a better base for concealment and had no connection whatsoever with the camouflage. Two torpedo boats were tied up some distance from the ship on the starboard side and nets were stretched between the ship and the boats. This was supposed, when seen from the air, to resemble two piers jutting out from the land.

The carrier's island structure was concealed by means of a net hung over a wire to the mast. Anti-aircraft control, topside on the island structure, was covered with a small house. This was supposed to resemble a lookout station on the hill. Also, several fairly large pine trees were placed upright on and around this hill. The Japanese would have liked to utilize living trees planted in large boxes or some similar method, but time did not allow anything more complicated than cutting the trees and supporting them in an upright position.

The level surface of the flight deck was made to appear irregular by piles of straw-rope nets scattered around. To make it look like a field all bare spaces on the flight deck were covered with branches and foliage. Although no special means were used to secure this foliage no difficulty was experienced with the wind blowing it away. Three machine guns were removed from their mounts and put in emplacements built on the forward part of the flight deck to look like a machine gun emplacement ashore. Roads ran up to the ship and continued across the flight deck. At first these "roads" were merely bare intervals between the branches and leaves which covered the flight deck, but later they were more elaborately made with yellow sand of the same color as the roads ashore.

A variety of false structures were built on the flight deck. There were four dummy houses at first, two wooden ones (the forward one 3 by 5 meters, the after one, 12 by 50) and two made of straw bags filled with earth with a tent roof. Later, one wooden house was removed and an imitation scrap-metal pile, made of wooden boxes painted to look like rusty metal, was substituted. This was intended to correspond to a real scrap pile on the shore. In the final version of the camouflage there were also several small imitation houses amidships, made from small tents. The green foliage on the ship was renewed gradually, a little each day. A complete change required a period of about two weeks.

In the 24-28 July attacks, KATSURAGI received a bomb hit on the flight deck, port side amidships, which peeled up the flight deck leaving a large hole. This was covered with a net and camouflaged as before. The concealment of AMAGI was destroyed in the raids on 24 July.

On two occasions (about 10 April and about 15 June) pictures were taken of the camouflage by a seaplane from Saeki Air Group. No one from the carrier went aloft to inspect the camouflage. After study of these pictures, the Japanese concluded that the camouflage was quite effective. No special provision was made against infra-red reconnaissance, and that problem was not considered in the camouflage plan.

After these carriers had been camouflaged at KURE, other ships in the harbor (HYUGA, KUMA, NATORI, etc.) undertook similar camouflage, but it was on their own initiative and not the result of a specific order, as in the case of the carriers.

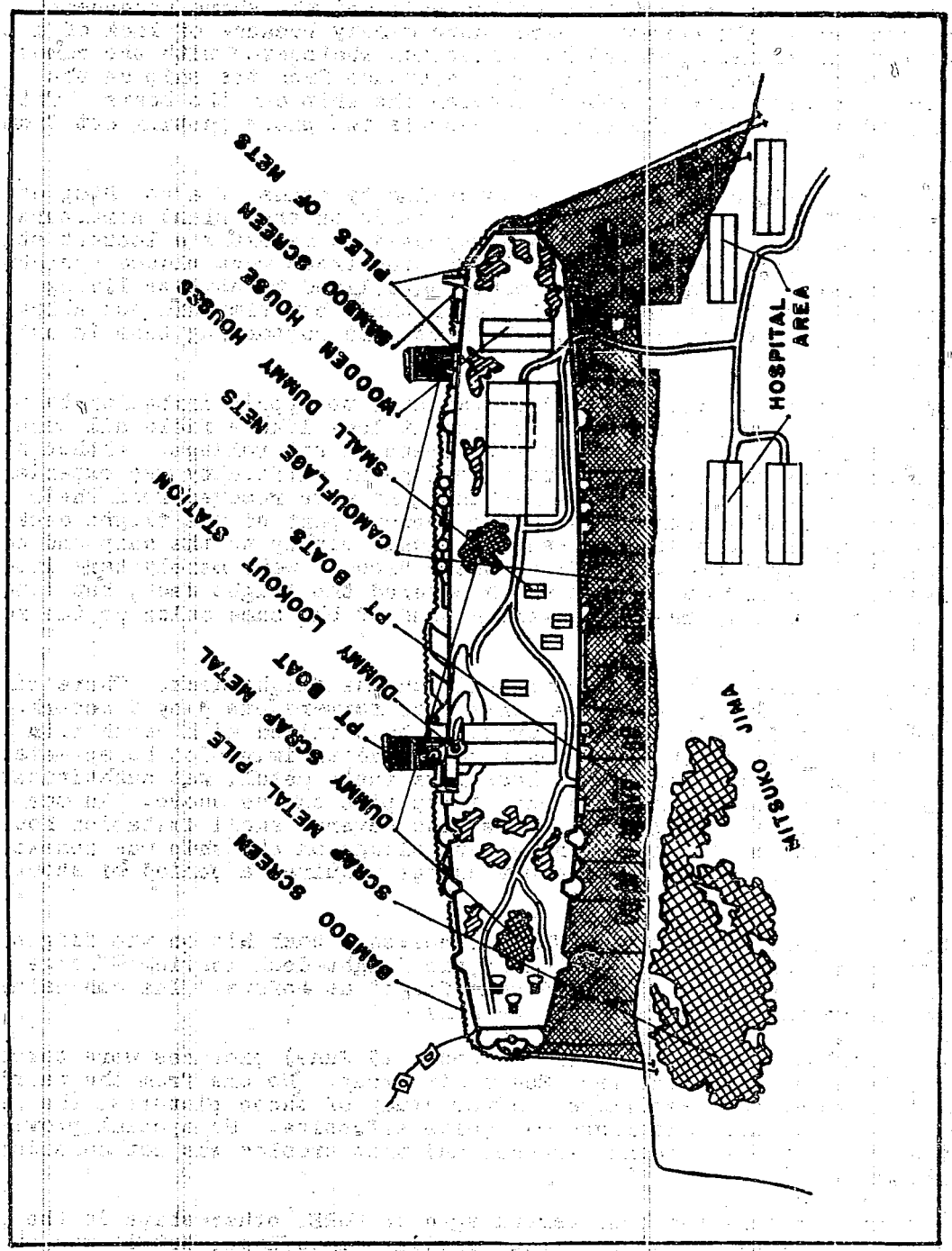


Figure 14 - RATSTRAGI CAMOUFLAGED AS OF 24-28 JULY 1945

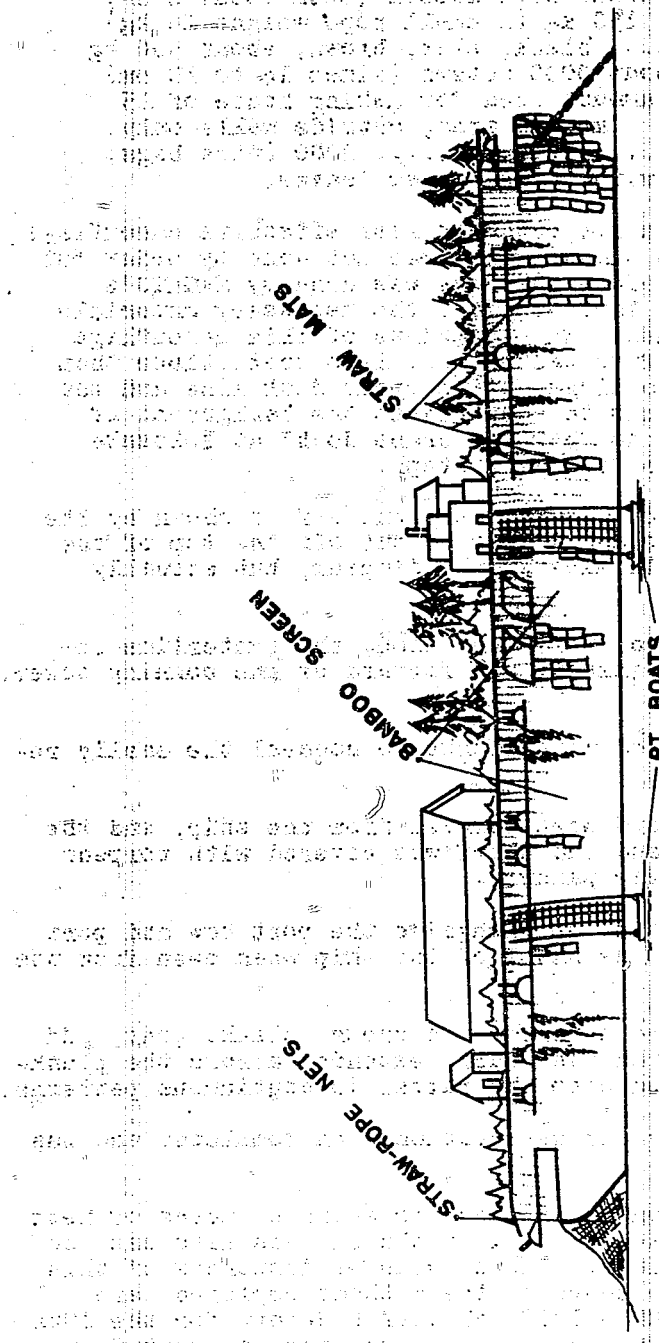


Figure 15

KATSURAGI (SIDE VIEW - STARBOARD) 24-28 JULY 1945

The following materials were used in the camouflage of KATSURAGI at KURE:

Straw	about 80 bundles
Bamboo	about 3000 sticks
Straw rope	about 1500 rolls (300 meters each)
Camouflage nets	about 8000 sheets (each about 2 m^2)
Miscellaneous cordage	150 kg (1 small rope weighs 20 kg)
Paints	black, blue, brown, about 500 kg
Wire rope	about 3000 meters (sizes 14 to 18 mm)
Wood	amount used for making house of 15 meters area, outside walls only.
Straw mats	2000 (rice bags)

Miscellaneous trees and branches with living green leaves.

Another example of equally large-scale but much less effective camouflage was found in NAGATO at YOKOSUKA. This camouflaging was not done by order but on the captain's own initiative. Therefore the work was done by NAGATO's ship's company, although Yokosuka Navy Yard supplied the necessary materials and helped by lending men to move cranes. No blueprints of this camouflage were made by Yokosuka Navy Yard. NAGATO's camouflage, less pretentious than that of the carriers, attempted only to disguise the upper deck line and the main batteries, and to make her difficult to see against the background of hills. The camouflage carried out at the "350-ton crane dock" at Yokosuka Navy yard in February 1945 included the following steps:

1. The top of the funnel and the mainmast were cut off as shown by the dotted lines in Fig. I6. It was planned also to cut off the top of the conning tower as shown by the chain line in the diagram, but actually there was not time to do so.

2. Bamboo screens, dazzle painted, were hung along the centerline between the conning tower and the mainmast, and forward of the conning tower, as shown in the diagram.

3. The main batteries were covered with planks to conceal the easily recognized guns and turrets.

4. Anti-aircraft guns to starboard were removed from the ship, and the space between the starboard side and the wharf was covered with torpedo nets, planks, and canvas, all dazzle painted.

5. Rafts, dazzle painted, were tied up alongside the port bow and port quarter at the waterline to alter the shape of the ship when seen from the air.

6. The upper decks and sides were covered with brown, black, grey, and white dazzle painting which began on the wharf, extended across the planking, across the ship, and continued onto the rafts, in continuous patterns.

This camouflage was tested by air observation when completed and was considered fairly good.

Small boats were sometimes concealed close to shore by means of nets to which strips of cloth were attached. This technique was also used to conceal small boats hauled up on land. Photographs of instances of this sort of camouflage, as well as close-ups of the methods employed, are shown in NavTechJap Document No. ND50-1217, "Research Report for the 10th Military Institute for 1944," forwarded to the Washington Document Center.

On all ships concealed in port by camouflage, only the two basic techniques (nets with canvas or foliage attached, or dazzle painted screens) seen to have been used, as illustrated by the examples shown.

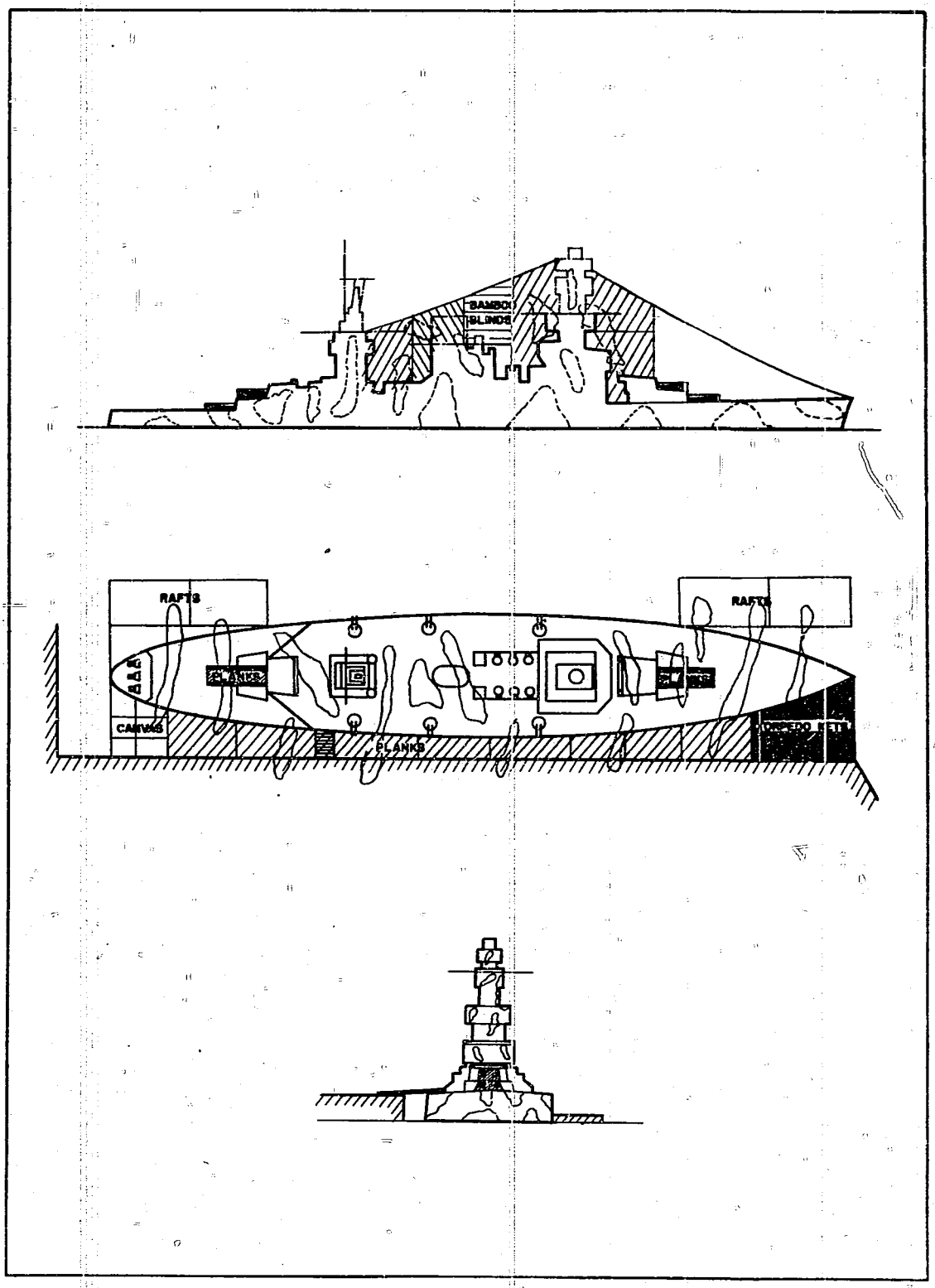


Figure 16
DIAGRAM OF NAGATO

PART IV - CAMOUFLAGE OF NAVAL SHORE INSTALLATIONS

The camouflage of shore installations was never given sufficient emphasis for a very successful or complete development. Lack of funds, failure to understand or cooperate with what was done in research on the part of some installations officers, and the natural difficulty in camouflaging major shore installations, such as airfields and drydocks, contributed to this lack of success.

Also, a large part of Japanese industrial area is located near landmarks, such as mountains, shore lines and rivers, which are impossible to conceal.

The theory evolved on the part of certain experts who worked more or less independently in some cases, seems similar to that of the United States Navy and is plausible enough. However, in practice, it often bordered on the ridiculous.

Generally, paint camouflage was felt to be ineffective, mud and grass or "attaching" type more effective, and concealment in caves obviously best. Smoke was used only in emergency cases and was considered effective only for the first raid in most cases.

Any apparent standardization of patterns or techniques was accidental. The object in most cases was to match the degree of brightness of the surrounding areas, placing less importance on color and pattern. Camouflage was the anti-bombing type, not anti-reconnaissance type, and patterns varied with the expected altitude of the raiders.

Camouflage to conceal damage was carried out to a slight extent. This was to absorb the attack, allowing the already damaged buildings to take as many bombs as possible. In other instances, obviously destroyed buildings were used to conceal and store material or vehicles on the supposition that the buildings would not be bombed again.

The following document, prepared by Lt. Comdr. MORI of the Naval Bureau of Installations, describes theory, methods and techniques of camouflage used, and materials in common use.

* * * * *

(Translation of Document)

CAMOUFLAGE OF NAVAL INSTALLATIONS
by Lt. Comdr. MORI, IJN
Naval Bureau of Installations

I. The Relation between Camouflage and Visual Distance.

A. The greatest visual distance.

The selection of the greatest visual distance varies according to the altitude of the air raid, speed of flight, time of aim, time of bomb release, etc. but in general in the daytime it is impossible to judge by eye from more than 10 kilometers visual distance (actual distance) with the result that accurate bombing is impossible if the visual distance is more than 10 kilometers. 4 to 20 kilometers may also be considered, depending on the circumstances.

In the case of a city or town, the standard visual distance is usually 10 kilometers as mentioned above, while in naval ports or in areas of military installations, 4 kilometers is about right. However, there is nothing definite or concrete in this connection, beyond doing what is best to complete the camouflage, as well as hiding installa-

tions completely by building them underground.

B. Types of camouflage.

Area Type	Visible Area to be Camouflaged				
	More Than 40,000 m^2	More than 10,000 m^2	More Than 2,000 m^2	More Than 500 m^2	Less Than 500 m^2
Dense Metropolitan Area	Topographical Camouflage	Technical Coloring	Broken Colors	Broken Colors or Single Color	Single Color
Urban Areas	Topographical Camouflage	Topographical or Technical Coloring	Broken Colors or Technical Coloring	Broken Colors	Single Color
Rural Areas	Topographical Camouflage	Topographical	Technical Coloring	Broken Colors	Single Color
Woodland	Topographical Camouflage	Topographical	Technical Coloring	Single Color	Single Color

NOTE: For particularly important things in special topography, 1/4 the visible area of this chart should be used as the limit.

Types of camouflage mentioned in the chart above are as follows:

1. Topographical Camouflage. Camouflage must be considered not only in connection with the distribution, shape, and color of buildings, etc., but also in relation to the surrounding shapes and the environment. For buildings already finished, methods such as planting trees, deceptive coloring, movable camouflage, and concealment underground are employed as necessity demands. In paint camouflage of buildings, technical coloring mentioned in 2. below may be done in conformity with the surroundings, and the planting of trees, etc. is needed to match the coloring.

2. Technical Coloring. Technical coloring concerns the use of two or three light and dark colors (black may be used instead of a dark color) which are predominant in the area where the buildings stand, and using these colors to paint the building so as to blend with the color of the surroundings, by altering the shape, outline, and shadow. It is best that the contrast of degree of brightness between the light and the dark color be more than double. The following is the unit of color used and the degree of contrast:

TABLE OF UNIT TO BE USED IN DISTRIBUTION OF COLOR (SQ. METERS)

Degree of Brightness of the Dark Color	Degree of Brightness of the Light Color		
	2 Times the Dark Color	3 Times the Dark Color	4 Times the Dark Color
3%	800	400	250
4%	600	300	220
5%	500	250	200

3. Broken Coloring. To break up shapes and alter them by means of brightness and darkness as in 2. above grey or black of the same brightness may be used) with the type and scale of the divisions according to the standards in 2.

4. Single Color Painting: Camouflage by means of painting with the average brightness of the area in which the buildings are located.

II. Movable and Stationary Camouflage.

A. Examples of movable camouflage.

1. Construction of a runway. Use roads already existing, and if both sides of the roads are grassland, camouflage each day's work on the runway by scattering grass over it, so that even when it is finished it looks as though it has not been touched.

2. Camouflage of aircraft, revetments, gun positions, etc. is best done in a forest. A camouflage net is spread among the trees and the actual camouflage is done under its concealment.

3. On building underground installations, such as the entrance to a tunnel, excavation is continued under a camouflage net. All rubble is carried out of the tunnel, far from the entrance, and covered with twigs, branches, leaves, etc.

4. In the foregoing case, people, animals, installations, machines, wheels, etc. should be covered with a camouflage net and trees and grass, etc., which are similar in color to the surrounding colors.

B. In short, movable camouflage implies a kind of camouflage which is given to workers, machines, work under construction, etc., in the course of constructing an installation, while stationary camouflage refers to camouflage given to protect things already built.

C. Movable camouflage is practical and can be used any time, and the construction it hides will remain undiscovered through frequent air reconnaissance, with the result that no air attacks ensue.

III. The Theory of Brightness, and Its Application to Camouflage.

A. Definition of brightness.

The elements of color are tone, purity, and brightness. Brightness of color means the amount of light which is reflected to the human eye. Brightness is expressed in percentage, with pure white as 100%.

B. Theory of brightness.

1. Elements of color are tone and brightness, yet when the visual distance is great, recognition of an installation depends chiefly upon the brightness of it in relation to the surroundings.

2. The following shows the relation between brightness and difficulty of recognition, and the characteristics of brightness.

a. The less the color tone of the thing being protected, the less the brightness when the tone is different from the surroundings, and the smaller the degree of contrast, the more difficult the recognition.

b. Where camouflage is concerned, too little brightness is better than too much. A single dark grey color is generally suitable.

c. When its brightness is great, an object stands out from its background; when brightness is small, it appears sunk. Therefore, in coloring a building to be protected in crowded urban areas or elsewhere, it is better to make it darker than the surroundings rather than lighter.

d. Even a color of less degree of brightness is less pronounced than the real light and shadow of the installation, so it is better to use camouflage nets or plant trees to destroy the shadow of an installation.

C. Examples of brightness.

Material	Brightness (%)	Material	Brightness (%)
Concrete	30 - 20	Brown Earth	10 - 6
Mortar	30 - 25	Black-Brown Earth	6 - 4
Granite	35 - 20	Black Earth	4 - 3
Andesite	13 - 9	Rice Paddies (Fall)	20 - 13
Cement Tile	25 - 15	Paddies (Spring Summer)	15 - 10
Grey Slate	40 - 20	Dry Fields	9 - 7
White Slate	40 - 25	Grassland	10 - 8
White Cement	70 - 55	Forest	8 - 4
Sheet Iron	30 - 10	Forest (Leaves)	20 - 15
Asphalt	12 - 8	Sod (Spring)	25 - 15
White Tile	80 - 50	Dead Grass (Brown)	15 - 10
Wood (old)	15	Dead Grass (Red)	10 - 5
Jap. Tile	10 - 8	Heavy Forest	4 - 2
Brick	20 - 8	Residences	10 - 5
Pavement	20 - 15	Thin Forest	9 - 6
Road	20 - 6	Dead Grass	20 - 10
Water Surface	20 - 5	Dead Grass Yellow	35 - 20
White Gravel	25 - 20	Residence Area	15 - 10
Dark Gravel	12 - 5		
Yellow Earth	25 - 20		
Yellow-Brown Earth	20 - 10		

D. Application of the Theory of Brightness.

Suggested particulars for carrying out camouflage on the theory of brightness mentioned above, are as follows:

1. In the daytime, with good light and short visual distance, it is difficult to camouflage installations effectively by protective coloring.

2. When the air observation distance is great, recognition of installations is chiefly by the difference in brightness between the installation and its surroundings, so it is important to equalize the brightness of the buildings, etc. to be protected with that of the environment and background.

3. When the buildings, etc. are comparatively small, single color camouflage closely resembling the color and brightness of the surroundings is required. When the buildings, etc. are comparatively large, it is necessary to camouflage by dividing into two or three light and dark colors which are predominant colors in the surroundings.

4. It is also necessary to obliterate or break up shadows by means of trees or camouflage nets, in addition to placing the installations in the shadow of hills and mountains.

5. It is necessary to keep airfields always in good repair and prevent turf from being destroyed, so that the bare earth will not show. In order to decrease brightness, it is better to scatter cinders, powdered coal, etc., or to grow clover, pigweed, etc. which are all quite low in brightness. The areas surrounding the airfield which have little connection with flying may be converted into cultivated land, or shrubs may be planted to fit in naturally with the surroundings.

In temperate or cold climates where the whole area is covered with dried grass in autumn and winter, so that there is considerable brightness, it is very effective to decrease the brightness of the airfield by burning off the grass in large straight line divisions in accordance with the shapes and topography and horizontal lines of the environment.

IV. "Attaching".

A. Definition.

"Attaching" means adding something to a building or another object to be protected, thereby altering its original shape or making its shadows disappear and in so doing making it similar to its surroundings.

In short, this comprises all camouflage other than protective coloring.

B. Methods of Construction.

1. When a runway cuts across roads, streams, or forests, it must be camouflaged to look as if there were no such crossing or cutting.

2. If the runway is not frequently used, it is necessary to build temporary, simple frame houses (the houses to be built with materials found at hand) similar to those which are seen nearby, with a view to making the enemy think it a small village not worth attacking.

3. Ditches along the runways should be made to appear irregular (not in straight lines) by planting trees here and there.

4. Aircraft revetments in a level field should be surrounded with plantings of trees and weeds to correspond to the topography and shape of the surroundings, or should be covered in whole or in part with camouflage nets.

5. Defensive positions (anti-aircraft emplacements, field guns, special fire positions, etc.) should be covered with camouflage nets or trees.

6. Each tank of a group of oil tanks situated above ground should be painted or covered with camouflage nets, bamboo, etc.; and if possible, it is best to cover the whole area where the tanks are situated with lumber, bamboo, etc.

C. Materials.

1. Camouflage nets.

Metal nets: burned, and wrapped (in tree bark, cloth, etc.) for greater durability.

Old fish nets: mesh of 5-10mm, with wrapping.

Straw rope nets: same, less durable.

Bamboo nets: bamboo laths, or round bamboo split in two, braided into squares, rectangles, or triangles.

Rattan nets.

Reed blinds: to be painted.

(Note: In addition, frames or blinds made of bamboo or wood are also effective as coverings.)

2. Lumber, tree branches, foliage, etc.

These are very effective materials for covering. Every effort should be made to use trees and grass which are suited to the climate, easily transplanted, and quick in growth. For this, broad-leaved evergreens, multi-leaved trees and creeping vines such as ivy may be used. Those which are quick in growth, fire-resistant, and strong enough to resist the drying of the sun and strong winds are the best.

The following trees are the most effective for camouflage:

a. Evergreen broad-leaved trees (oak, pasania, Japanese laurel, cinnamon, etc.)

b. Creeping vines, and other kinds of vines, tree ivy. In southern areas pumpkins are effective for covering.

Branches of trees which are discolored and yellow are not generally suitable for camouflage nets or wrapping, but pine trees which become brown when dead may be used. The brown needles will generally turn out none the less effective for the changing except where there is dark grey in the surroundings.

V. Dummy Installations and Lures.

A. General Theory.

Dummies are constructed at more than bombing distance from the real installation and are made similar in appearance. The object of the dummies is to fool the enemy and draw the attack so as to lessen actual damage. Consequently airbases, camps, gun batteries, and other important constructions may be built as genuine installations and camouflaged by every means possible, but if circumstances permit it is effective to build dummies and every effort should be used to construct them.

In order to confuse enemy night attacks, lights may be put up in suitable areas where no damage is feared (it may be possible to switch the lights on and off from a central controlling place). The kind, number, and brightness of the lights should be made to correspond to the real circumstances of the surroundings.

In the damage at airbases, it is of great effect to arrange damaged planes and wheels, etc., suitably, but it is necessary to remove these damaged planes, wheels, etc. occasionally, to keep the camouflage

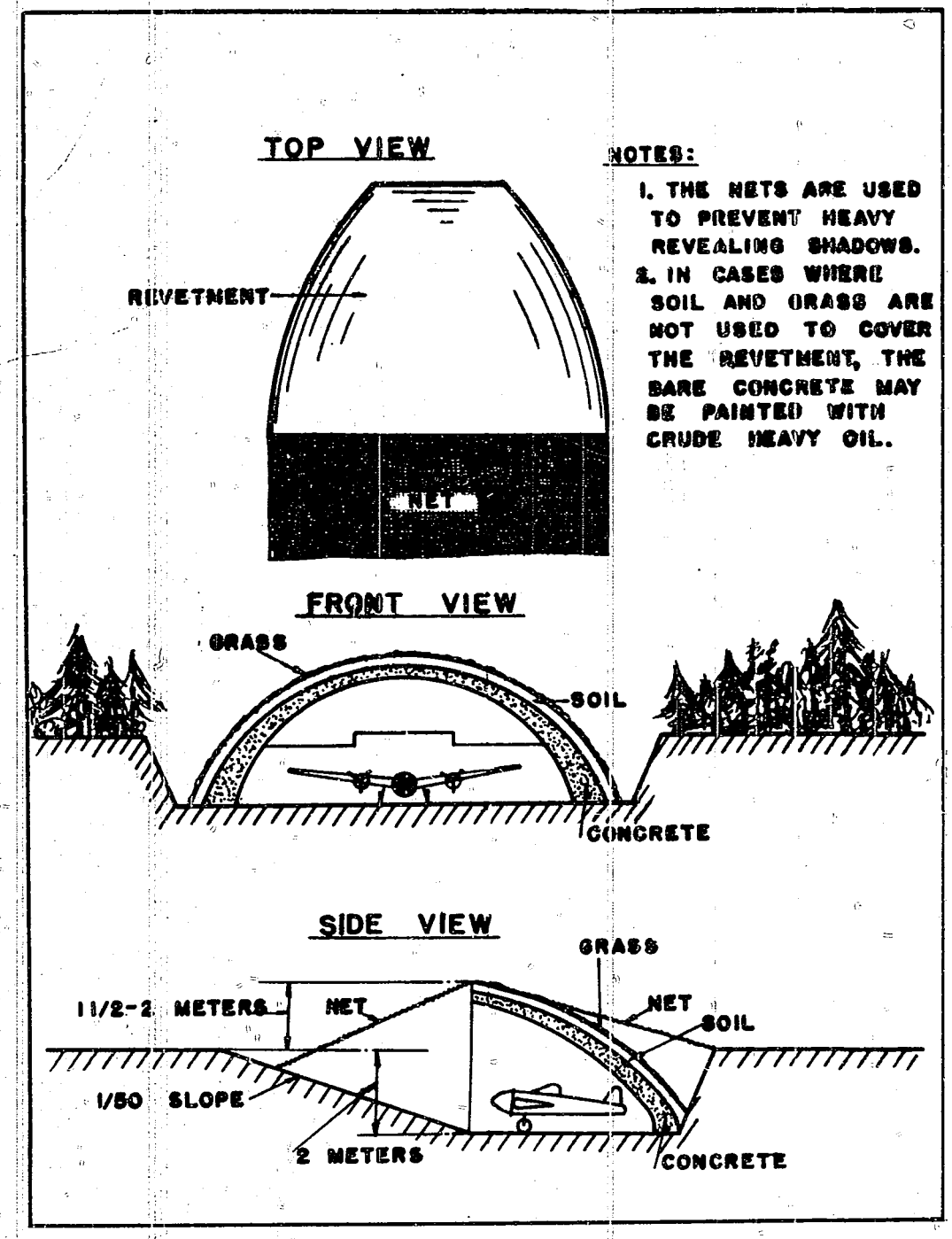


Figure 17
CAMOUFLAGE OF REVETMENTS

effective.

B. Examples.

1. Using levelled ground to look like a runway.

2. Use of wooden guns and sometimes dummy men in defensive installations and revetments.

3. Lures and genuine planes are placed together in a confusing way. On the surface on which the lures are placed heavy oil is spread so as to explode when the dummies are strafed. Sometimes the lures are placed in the revetments and the genuine planes are placed in the surrounding woods.

4. Making false roads of a high degree of brightness by scattering white sand.

C. Most dummies, lures, etc., are planned by the commander of the local forces (air force, defense force, etc.).

* * * * *

Commander MORI feels that runways are by far the most difficult subject to conceal because of their 90% brightness and size. Asphalt and especially heavy oil were used to cut down this brightness, while in Nanking, green paint was used for the same purpose. One of the best techniques was used on the MOHARA strip where 10 x 10 meter cement blocks formed the runway. In this case, grass was planted in bamboo tubes placed at the joints of the cement blocks. The grass spread over the runway hiding the field rather effectively. When strips were dazzle painted, camouflage was generally very poorly executed since, as mentioned previously, the work was directed by unqualified officers.

Aircraft usually were hidden in covered revetments, the covering varying from nets to bamboo screens, both of which were often covered in part with living branches. At ATSUGI airfield a superior type of revetment of concrete covered with sod was used. (See Fig. 17.) Gun positions on airfields and elsewhere were camouflaged with nets, branches and any available material.

Oil tanks and other circular tanks were hidden by "attaching" various materials to change the noticeable circular shape. This method was considered definitely the most effective. If only painting was to be used, the following method was employed: First, primary and secondary colors were selected after a careful study of the predominant colors in the surrounding landscape; these colors were then greyed down sufficiently to counteract the flat reflecting surface of the tanks. Wide stripes of the two colors were applied, 5 or 6 stripes being common. Roads occasionally were painted over tanks.

The following two documents were prepared by Professor HOSHINO of TOKYO Imperial University. They give Professor HOSHINO's theories on brightness, value, color, and summarize the research carried out by him.

* * * * *

FIRST DOCUMENT

Summary of Research

I. Fundamental Research.

A. To find the conditions of visible range.

1. Short distance experiments with the naked eye.

Object: 0.5-4cm. square, value 3.5-84%
Background: Value 3.5-84%
Distance: 1-400 meters (in the Imperial University)

Results:

a. Visibility depends upon the contrast of value (or more exactly, brightness) between the object and its background.

b. The hue has a little influence upon the visibility.

c. There is not a proportional relation between visual angle and contrast.

d. The visual angle (other conditions remaining unchanged) enlarges a little if the distance is increased.

e. The visibility increases as the brightness of the background increases.

f. Various shapes can be converted to squares on definite converting rates.

2. Middle distance experiments.

Object: 4-30cm square, value 4.5-82%, white, grey, and black plates.
Background: Value 4.5-82% plates.
Distance: 170-1400 meters on the straight road near SHINJUKU.

Results:

a. The relation between the contrast and visual angle is similarly extended on larger distance.

b. The enlarging rate of the minimum visual angle depends upon the turbidity of air and the distance.

c. It was found necessary to define the turbidity of air.

3. Long distance experiments with naked eye and binoculars.

Object: 30-270cm. square.
Distance: 1000-8900 meters on building roofs in TOKYO.
Objects: Value 3.5, 10, 20, 40, 80%, grey, yellow, green, blue, red, brown, indigo, yellow ochre, olive green.

Results:

a. The relation between visual angle, contrast and brightness extend similarly in the case of long distance.

b. Distance effects depend upon the turbidity of air, distance, and the height of the place of observation.

c. Hues have less influence with long distances.

4. Height effect experiments, with naked eye and telescope.

Object: 30-400cm square.
Distance: 8.5-14 km. on Mt. Fuji.
Height: 1500-3370 meters.

Results:

a. Distance effect decreases as the height increases.

b. Turbidity decreases as the height increases.

5. Moving effect experiments, with naked eye and aiming apparatus.

Object: 100-400 x 4cm. square
Distance: 500-20,000 meters.
Height: 500-5000 meters.

Results:

a. Moving effect depends upon the angular velocity of the sight lines.

b. Moving effect is not so large as supposed.

B. To find a practical coefficient.

1. Model experiments.

Object: Model buildings about the size of 1-10cm.
Background: City street, field, wooded districts.
Scale: 1/500, 1/1000.
Results: We found the relation between experiments and calculation.

2. Practical experiments.

Object: Some real buildings near TOKYO.
Background: Some districts near TOKYO.
Results: We found practical coefficient of knowledge in various districts.

II. Practical Research.

A. To find the aiming condition of bombing.

Results: When we consider the point where the aiming is begun as the standard distance for camouflage, we find the following table for various heights. (Table omitted.)

B. To find the effective area for various shapes.

Results: Effective area A is calculated by the following formula:

$$A = l\,(b \sin\theta + h \cos\theta)$$

where θ is aiming angle
b is breadth of building
h is height of building
l is length of building

C. To find brightness of backgrounds.

Results: We measure the natural brightness at various times and in varying weather.

D. To measure the value of various districts.

Results: Mean values of various materials and districts are as follows:

Districts:	city streets	5%
	fields	7%
	woods	3%
Materials:	asbestos slate	40%
	cement concrete	20%
	asphalt	10%
	roof tile	8-12%
	red brick	8-14%
Painting:	white	80%
	yellow	60-80%
	green	20-40%
	brown	6-8%
	dark green	6-10%
	coal tar	2-3%

E. To find the method of camouflage to be used.

1. We define the type of camouflage as follows:

- Dazzle painting
  1. single color
  2. light and dark color (colorless, colored)
  3. multiple color
- Covered camouflage
  1. partial covering
  2. complete covering
  3. covering by wood
- Deforming camouflage
- Burial camouflage

We could not perform experiments on infra-red because the military office did not give us much in the way of facilities for research. We did not claim to conceal anything from a precise infra-red reconnaissance photograph, because we could not expect much success unless we used expensive materials for concealment, and in Japan we could not hope to get such materials for camouflage. If we had had a chance to make experiments with infra-red, it would have affected our camouflage.

Naval installations we advised as to camouflage:

1. Barracks of Mie Air Squadron.
2. Barracks of Katori Air Squadron.
3. Barracks of SHANGHAI.
4. MURORAN SEIKOSHO (steel factory at MURORAN, Hokkaido).
5. Kawanishi Airplane Factories near KOBE (KONAN, TAKARAZUKA, NARUO).

Some of the better camouflaged factories:

1. HITACHI SEISAKUSHO at Kameari, TOKYO.
2. CHUOKOGYO NANBU KOJO at Kokubunji, TOKYO.
3. NIHON SHIMPU at Kaneko, TOKYO.
4. MITSUBISHI JUKO TOKYO KIKI, at MARUKO.
5. KANTO KOGYO, near UTSUNOMIYA.

These are too large to conceal perfectly, but as they are separated some distance from large city centers, they would have a chance to escape precision bombing. The perfect camouflage can exist only when situations, block plans, shapes, and materials of buildings are considered from the standpoint of camouflage. We must utilize most effectively the topography of the country. We consider the fundamental conditions of effective

camouflage to be as follows: (1) scattering, (2) utilization of woods, villages, hills or other topographical features, (3) correspondence of the brightness of material to the environment.

* * * * *

SECOND DOCUMENT

Degree of Brightness and Standard Color Table for Camouflage

1. FOREWORD

There were few techniques used in camouflage of the past which had a scientific basis. The so-called three color camouflage method and the buda or blue single color method of camouflage was used. The methods of camouflage should vary with the background, the distance of the object from the point of observation (for example 10 kilometers is considered a good distance for objects which are to be hidden from aircraft) and the size of the object. Moreover if shadows are not taken into account, it is impossible to carry out the camouflage of geometric objects. Color camouflage of the past merely made use of the actual color of the object and was nothing more than an imitation of the examples of foreign nations. Even if the color of the background was considered, the color of the object itself was the only color which was used. No thought was given to the color of the object from the standpoint of the average value of the minute shadow peculiar to natural objects. Moreover even if camouflage experts (of the old school) take into consideration long distances and color in the relationships to its various characteristics, they still don't pay any attention to the fact that the potentiality of an object's being or not being discovered depends on its degree of brightness (in the brightness which the color itself has). This book points out the standard color for camouflage and also contains notes on the methods of camouflage which should be applied.

2. DEGREE OF BRIGHTNESS

All colors have their own particular brightness and the difference between their brightness is an important element in the recognition of objects. In order to make an object difficult to see it is absolutely necessary that its brightness be made to conform with its background. To deal only vaguely with the degree of brightness as was done formerly is unsatisfactory and I propose to make up a standard numerical table on the subject called "degree of brightness" pointing out in round numbers the degree of brightness of all colors which should be used in camouflage. By using this table it is convenient to measure the degree of brightness of a similar color in actual practice.

Degree of brightness is the percentage of brightness in a basic color, taking pure white as 100%. Moreover a light color has a large degree of brightness and a dark color a small degree of brightness.

As far as grades of brightness are concerned, one cannot see visually as an equal difference the things which are numerically equally different and one sees the things of an equal ratio as being of an equal ratio. Consequently one should separate brightness of equal ratio (equal logarithm).

In order to measure the comparative brightness of a common color I have made up for you in this book under the "degree of brightness table for grey" the degrees of brightness of grey in 10 equally graded steps from 80% to 3.5%. Moreover Table I is a chart which points out in round numbers the degree of brightness of all natural materials.

TABLE I

DEGREE OF BRIGHTNESS OF THE COLORS OF MATERIALS WHICH ARE CONTAINED IN A TARGET AREA

	Name of Material	Color, based on Ostwald 24 divisions*	Degree of brightness in percentage
Urban areas	Roof tile	--	8 - 10
	Brown colored roof	3 - 6	5 - 7
	Roof painted blackish-green	22 - 23	6 - 8
	Galvanized iron	--	10 - 30
	Concrete	--	18 - 25
	Slate	--	25 - 40
	Asphalt	--	8 - 12
	Trees	23 - 24	4 - 8
	Grass land	23 - 24	8 - 10
	Dried grass	2	10 - 18
	Dead leaves	2 - 8	8 - 30
	Imitation stone	--	20 - 30
	Granite	--	20 - 35
	Cream tile	2	50 - 70
	White tile	--	50 - 80
	White mortar	--	40 - 60
	Boulders	1 - 2	12 - 16
	Brick	3 - 5	8 - 20
	Andesite	2 - 4	9 - 13
	Black earth	3 - 4	3 - 4
	Brown earth	3	6 - 8
	Gravel	--	7 - 12
Rural areas	Grass land	24	8 - 10
	Fields	23 - 24	7 - 9
	Rice-paddies (spring, summer, and autumn)	24 - 1	9 - 13
	Dead grass	1 - 2	10 - 20
	Woodland (thick)	23	2 - 4
	Woodland (medium)	23 - 24	4 - 6
	Woodland (thin)	24	6 - 9
	Yellow-brown earth	2 - 3	10 - 20
	Brown earth	3 - 4	6 - 10
	Black brown earth	3 - 4	4 - 6
	Roads	2 - 3	6 - 20
	Dead leaves (yellow)	1 - 2	20 - 35
	Dead leaves (brown)	2 - 3	10 - 15
	Dead leaves (red)	4 - 6	5 - 10

*Color wheel (apparently similar to Munsell System):

3. CAMOUFLAGE COLORS.

To arrive at the coloration to be used in camouflage, one should select the representative light and dark colors from among the principal colors contained in the natural materials which make up the incinity, (sometimes three colors are used) and using these colors we make up the camouflage color. Even in the cases where the surroundings are paddies or grass land or other cases where green is used, if in practice a color of a yellow green nature is used, it will last longer than an object painted green. Moreover, it is better since it fits in even with the yellow leaves of autumn and winter and even in the cases where grey is used, if a little yellow is added to the grey, it comes close to the color of natural objects. In the cases where the color of the earth in rural dress, etc., is bright, dark yellow (degree of brightness 10-14) can be added.

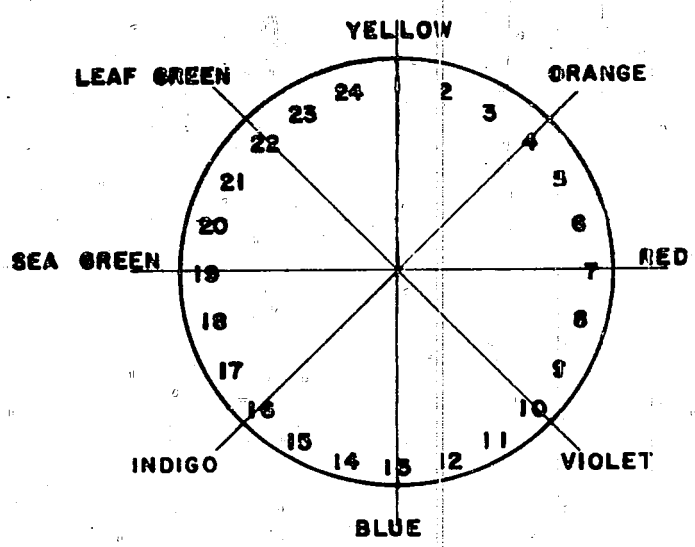


Figure 18

COLOR WHEEL (APPARENTLY SIMILAR TO MUNSELL SYSTEM)

TABLE II

STANDARD TABLE FOR CAMOUFLAGE COLOR

Camouflage Color	Urban Area, Factory Area.	Rural Area	Wooded Area
Bright color	Grey, yellow, brown, or yellow green (degree of brightness 8-14)	Yellow green and yellow (degree of brightness 7-13)	Yellow green (degree of brightness 4-6)
Dark color	Black (degree of brightness 3-4)	Brown & black (degree of brightness 3-4)	Black (degree of brightness 2-3)
Average color	Blackish grey (degree of brightness 5-6)	Yellow green (degree of brightness 6-7)	Dark green (degree of brightness 3-4)

In the cases where the area to be camouflaged is below the standard size (in the urban area, a total area of below 2000 square meters; in rural areas, below 500 square meters) it is not necessary to use color, but it would be well to paint objects with a grey which corresponds to the brightness of the area.

The design with which to paint the color used should be decided in accordance with the surroundings of the project to be painted. Generally, in an area which contains city streets or in rural areas there are many cases in which straight line patterns are suitable. One should use curved lines designs in wooded areas.

The unit of division depends upon the contrast of the degree of brightness of the colors to be used and in general it is desirable that it be done according to the following standards:

TABLE III

STANDARD TABLE OF UNIT TO BE USED FOR DISTRIBUTION OF COLOR
(UNIT IS SQUARE METERS)

Degree of Brightness of a Dark Color	Degree of Brightness of a Light Color		
	2 Times Dark Color	3 Times Dark Color	4 Times Dark Color
3%	800	400	250
4%	600	300	220
5%	500	250	200

4. METHODS OF MEASURING DEGREES OF BRIGHTNESS.

To try to measure the degree of brightness by using the table of degree of brightness, put a copy of the object to be measured side by side with the table, and put both of the objects under the same illumination condition and compare their degree of reflection. If you use the degree of brightness table which is closest to the color hue, it is easy to measure. It is easy to compare them by getting a feeling of distance and a feeling for color by closing one eye and squinting. In the cases of leaves and grass land, it is better to carry out the experiment on a bright day in ordinary light. Get close to the points which are to be camouflaged.

* * * * *

PART V - CAMOUFLAGE AGAINST INFRA-RED RECONNAISSANCE.

This problem was attacked not only through investigation of camouflage research and interrogation of camouflage experts, but also through investigation and interrogation concerning infra-red research. Experts in both fields said that no research was ever done on camouflaging against infra-red reconnaissance and no special materials or techniques were developed. They understood the principles involved in infra-red reconnaissance and some said they might eventually have done research on camouflaging against it, but that they did not have the time.

The photographs that follow are models produced and studied in Professor HOSHINO's laboratory at the Imperial University. The actual aerial photographs were selected for their similarity to the solutions worked out on the models. The comments accompanying the photographs are the result of a discussion with Professor HOSHINO of the relative merits of the actual examples in relation to the techniques he developed.

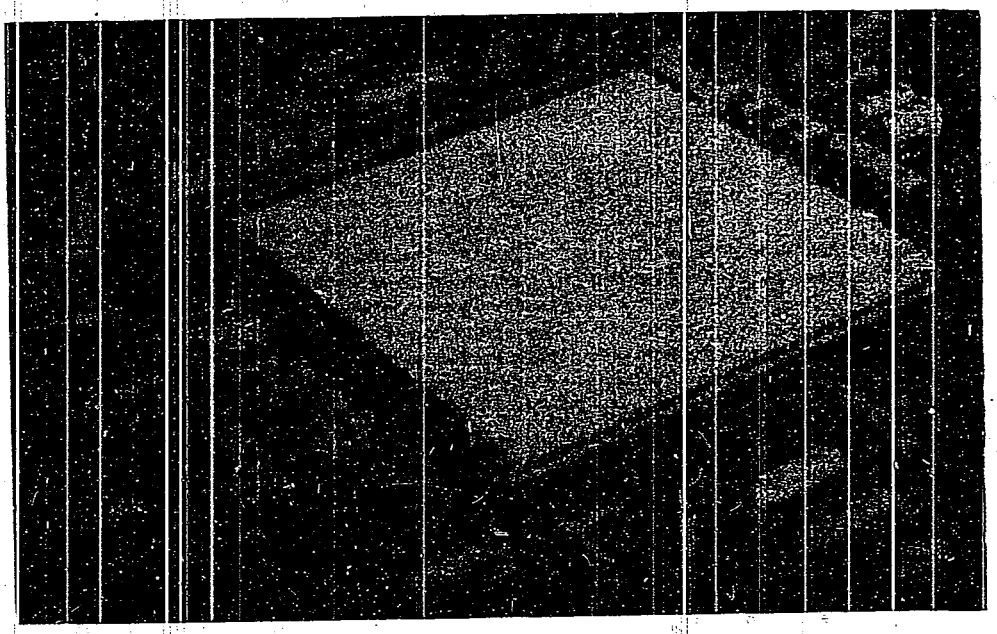


Figure 19
HYPOTHETICAL PROBLEM, URBAN FACTORY

Figure 20
SOLUTION, URBAN FACTORY

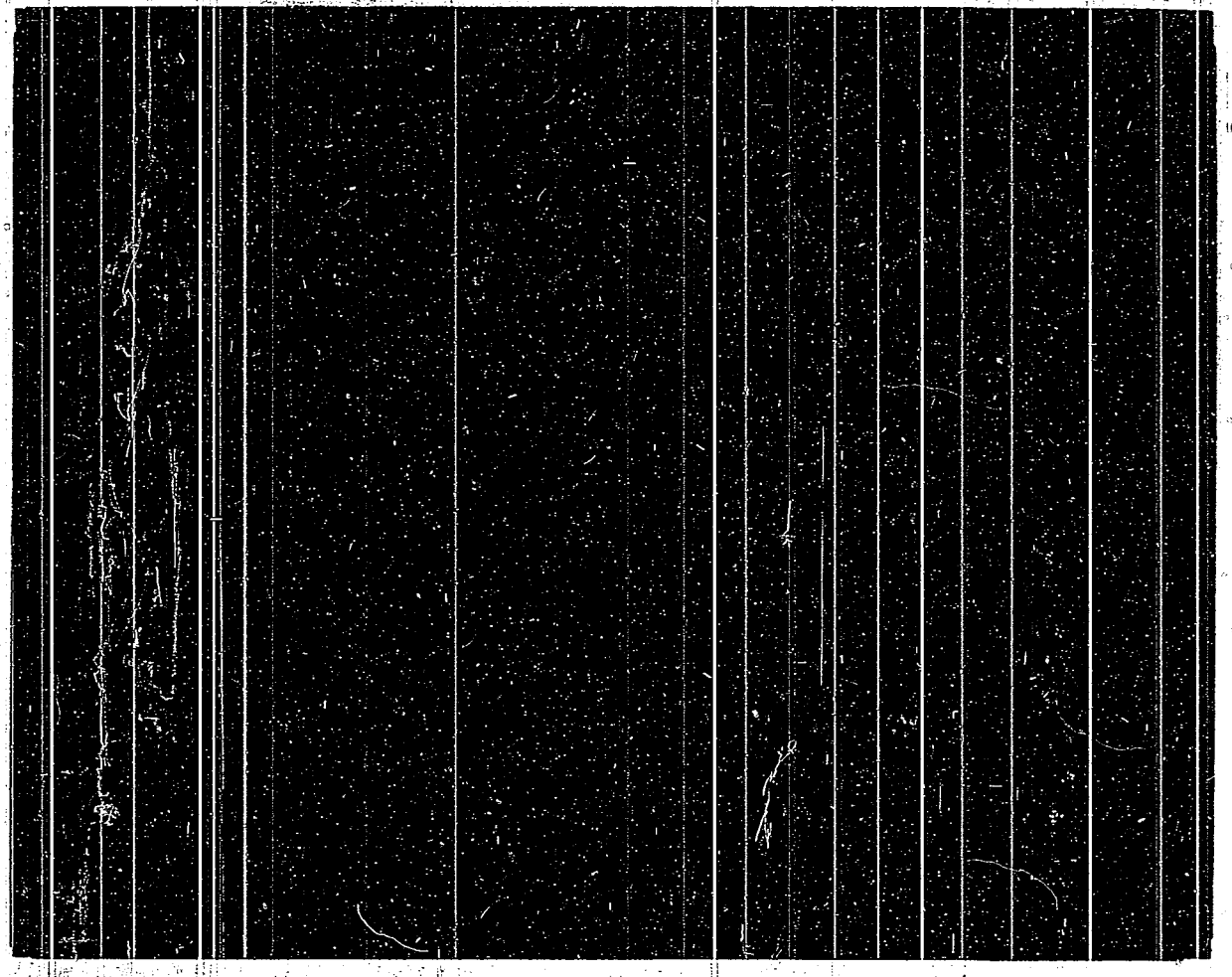


Figure 21
EXAMPLE, KARATSU, KYUSHU

Professor HOSHINO feels that the shapes in this pattern are too large as well as being considerably too dark. The two long buildings toned down successfully in lower right corner are less noticeable in the photograph at least.

Figure 22
PROBLEM - LARGE FACTORY ON EDGE OF CITY

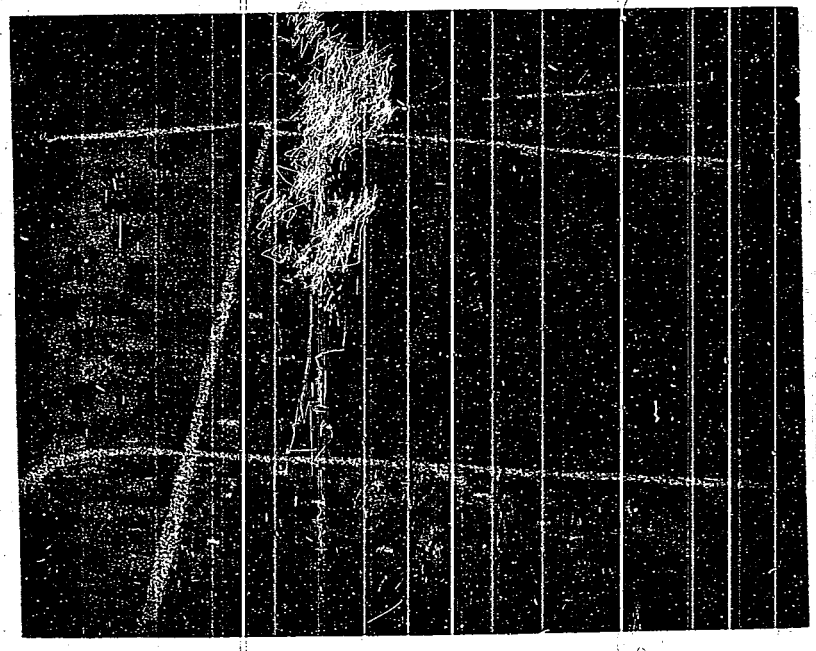


Figure 23
SOLUTION - LARGE FACTORY

In this instance, the value or degree of brightness is well matched in the actual solution, and the general effect of the job is good. However, the shapes are poorly planned and do not follow the general effect of the hypothetical solution.

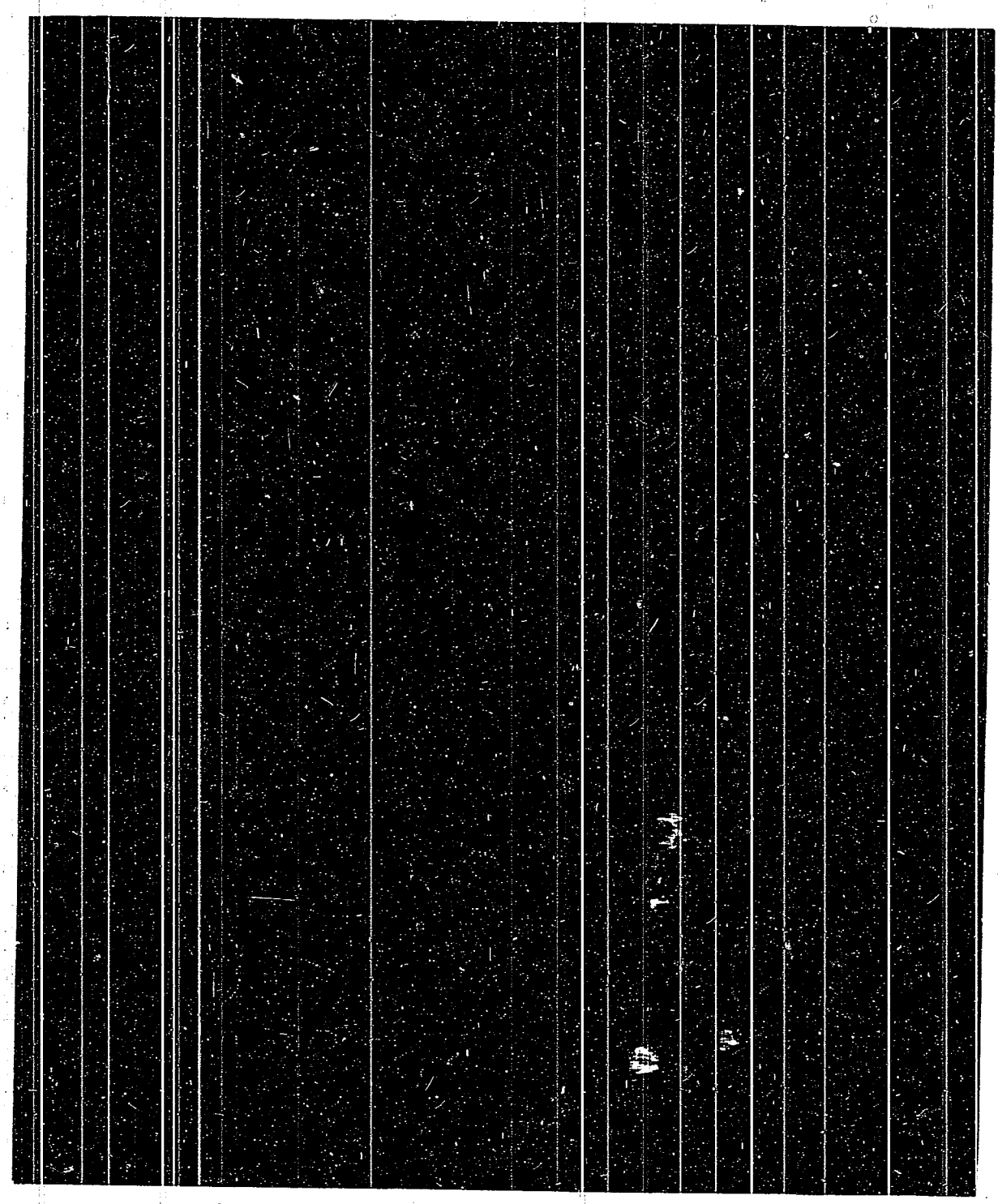


Figure 24

ACTUAL EXAMPLE NEAR MIHARA

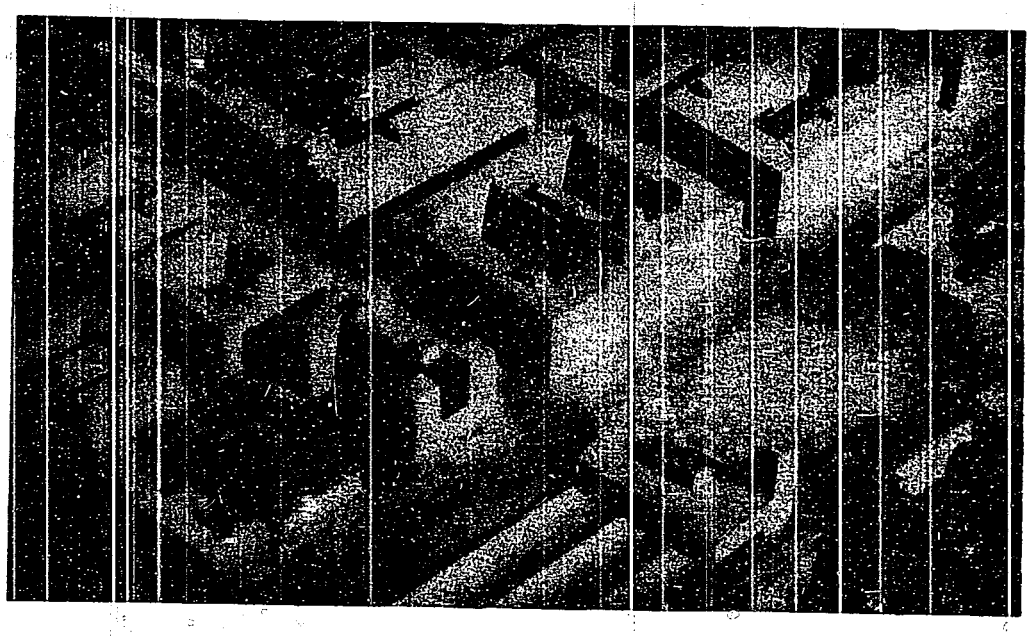


Figure 25
HYPOTHETICAL PROBLEM, CITY BUILDINGS

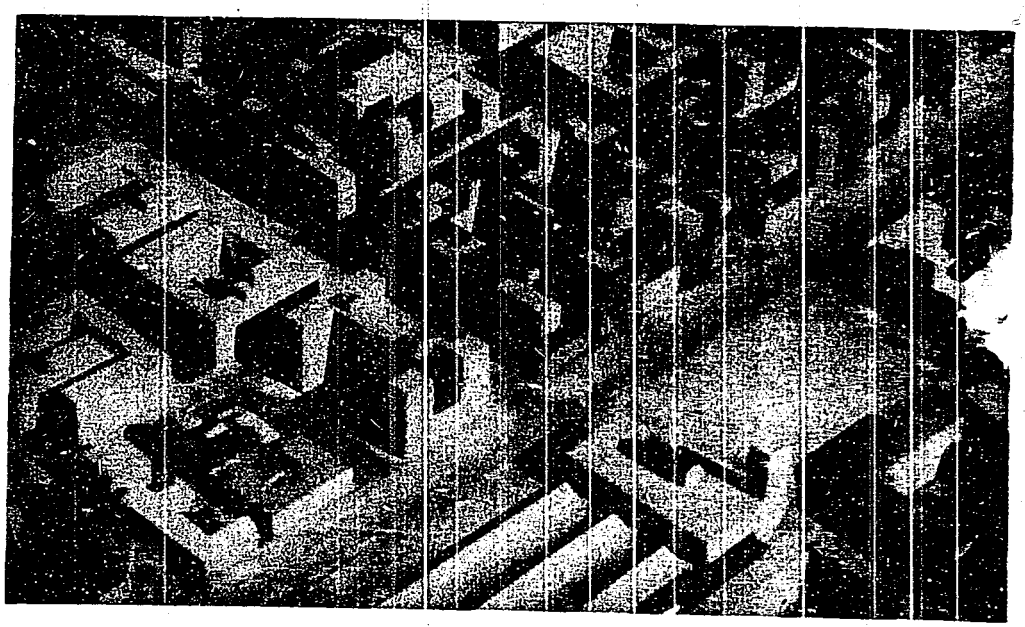


Figure 26
SOLUTION, CITY BUILDINGS

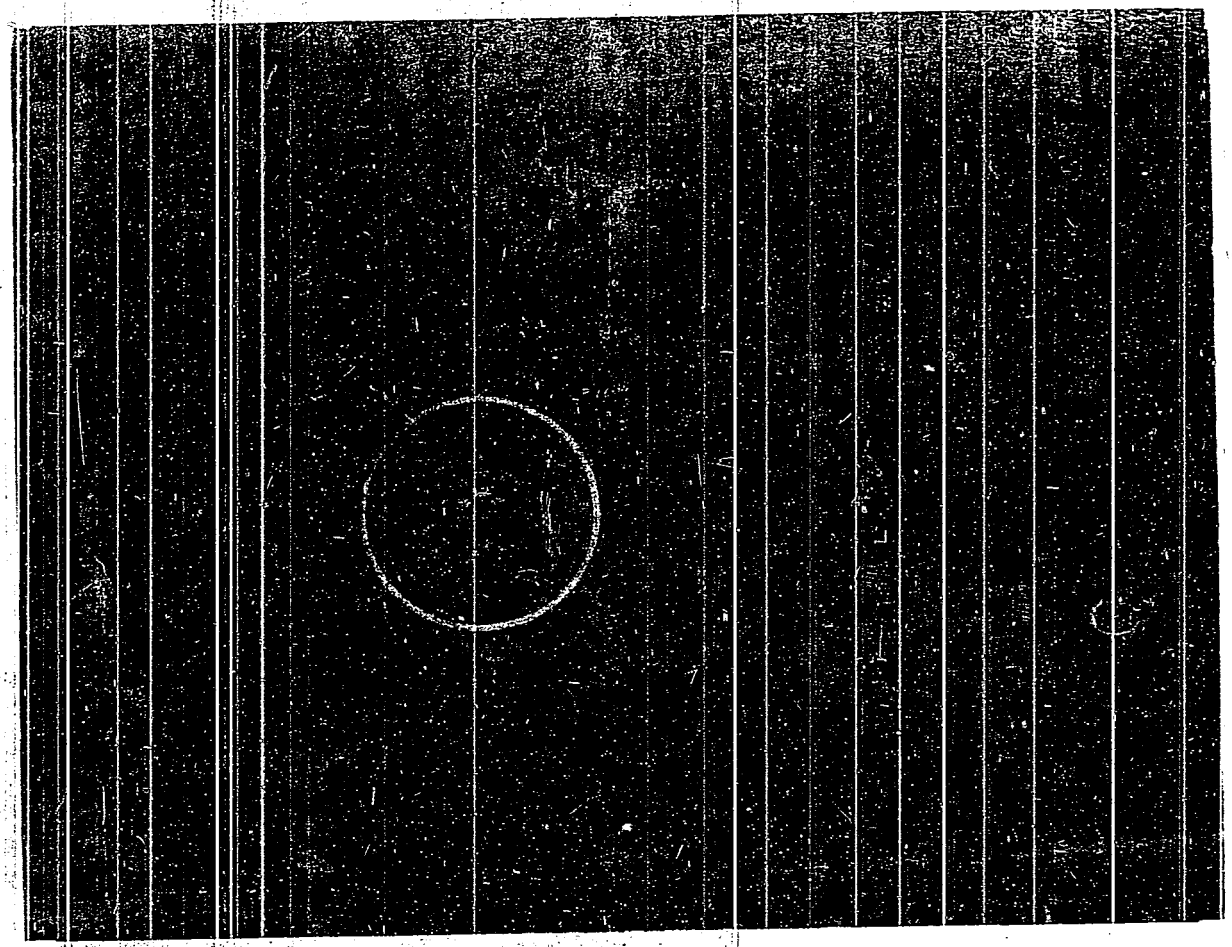


Figure 27

ACTUAL EXAMPLE, SAGA, KYUSHU

In this case, the shape of patterns is too regular and the value difference too great. The general effect seems to call attention to the target.

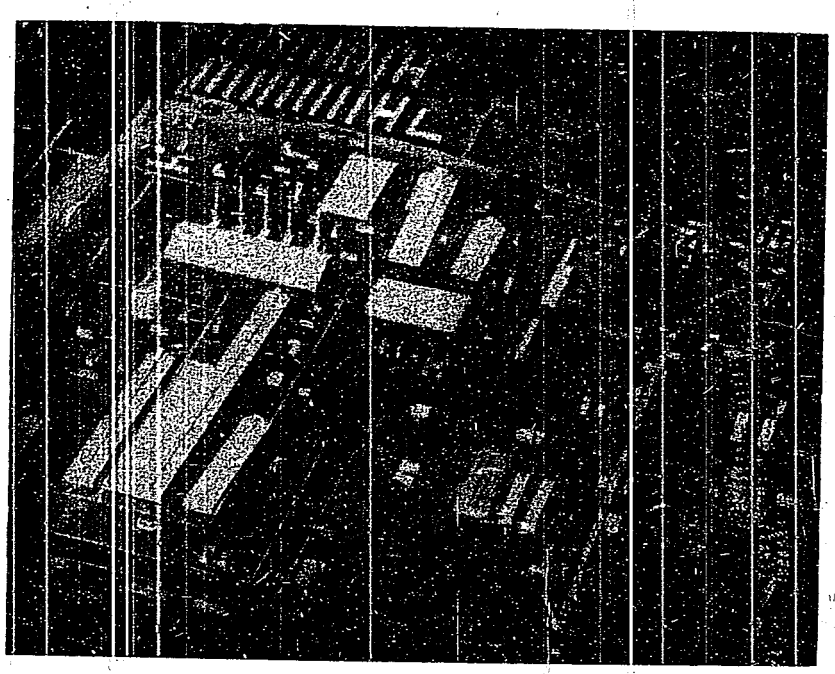


Figure 28
HYPOTHETICAL PROBLEM, STEEL PLANT

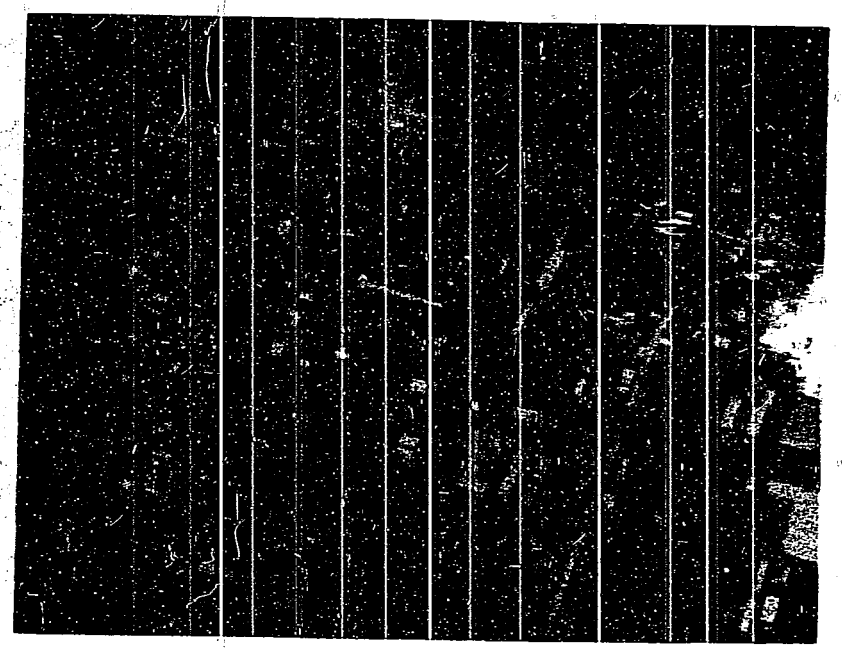


Figure 29
SOLUTION, STEEL PLANT

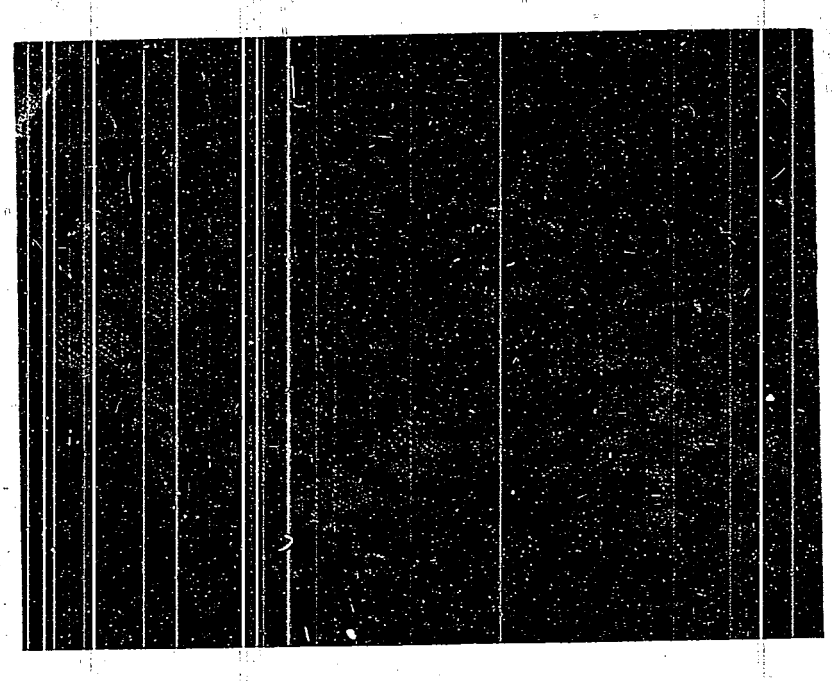


Figure 30
SYMMETRICAL ARRANGEMENT AND IRREGULAR DISPERSAL

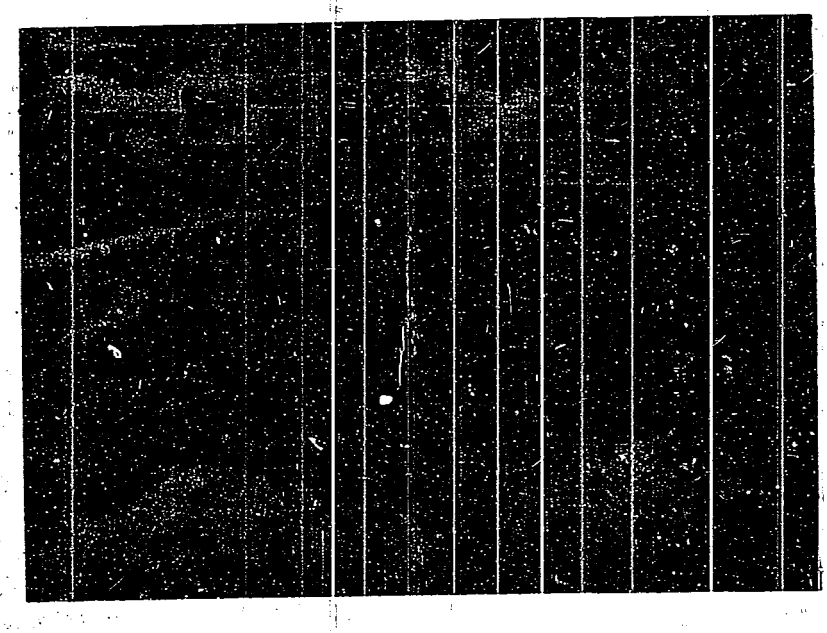


Figure 31
REGULAR AND IRREGULAR ARRANGEMENTS

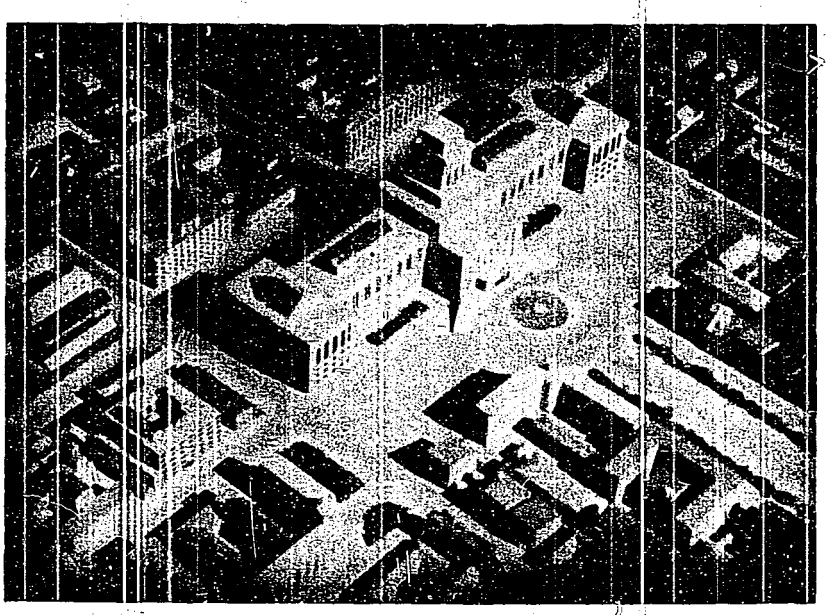


Figure 32
PROBLEM, MUNICIPAL BUILDING

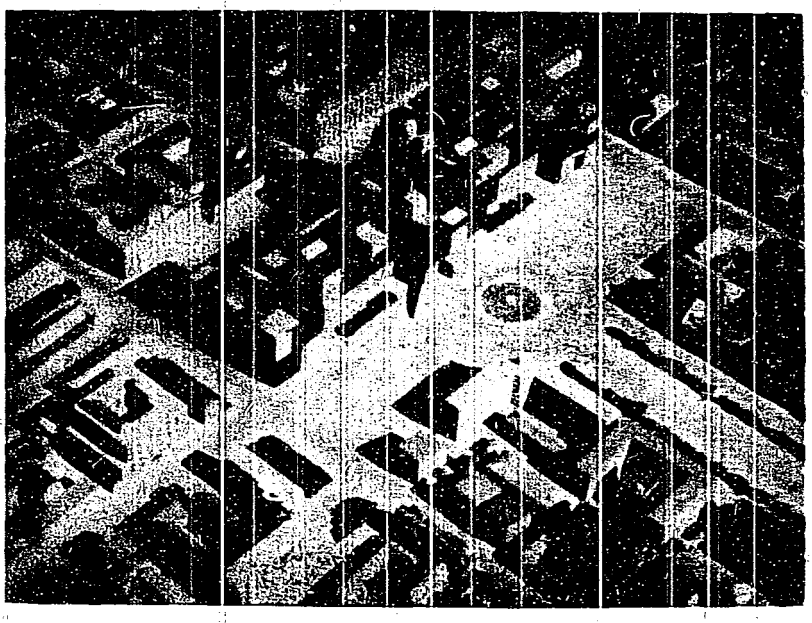


Figure 33
SOLUTION, MUNICIPAL BUILDING

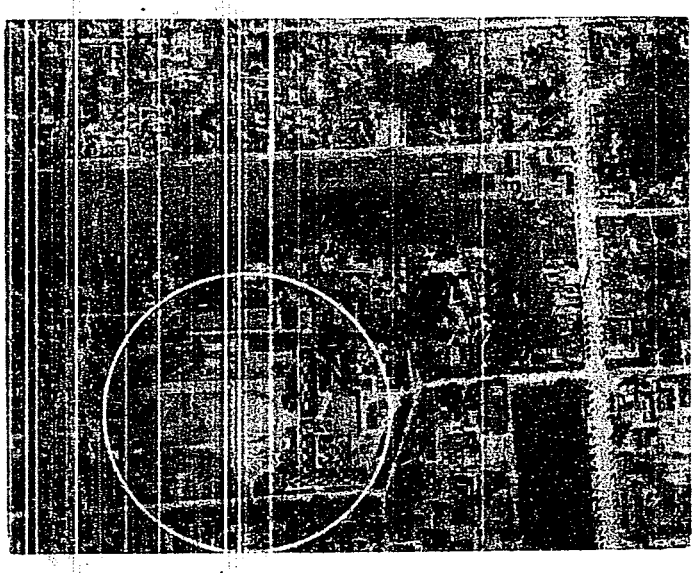


Figure 34

EXAMPLE, SAGA, KYUSHU

Here, due to lack of understanding or proper supervision, the pattern is too regular and is not successful. This particular case, as well as the hypothetical example (Figure 35) is hardly a successful job until the open court area, which is a prominent landmark, is broken up or concealed. However, because of the lack of funds and materials, the Japanese did not use this technique.

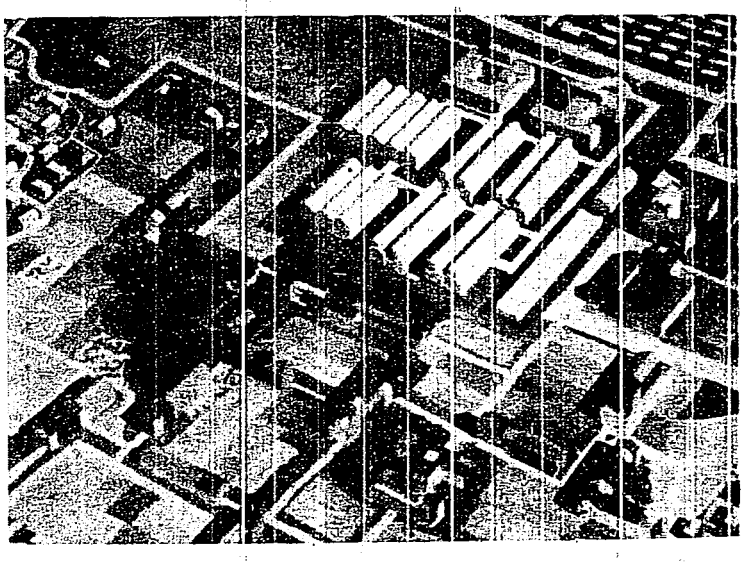


Figure 35

DISPERSED AND CENTRALIZED FACTORIES

In addition to typical tone-down and disruptive painting, this model shows how, by intelligent planning of factory layout, camouflage can be done well, with little effort. Traffic and flow of work is not hindered and dispersed arrangement lessens damage one bomb can do. Few such factories were observed.

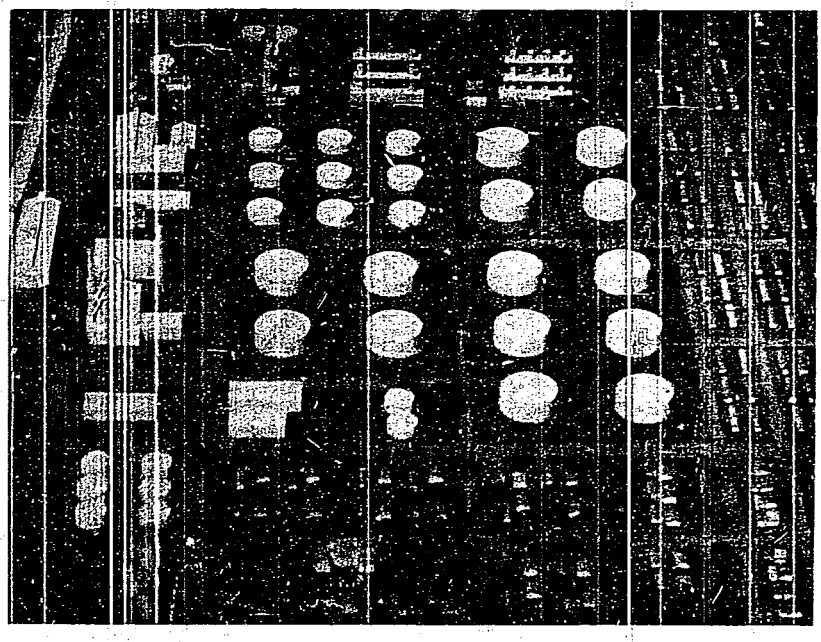


Figure 36
HYPOTHETICAL PROBLEM, REFINERY AND OIL STORAGE

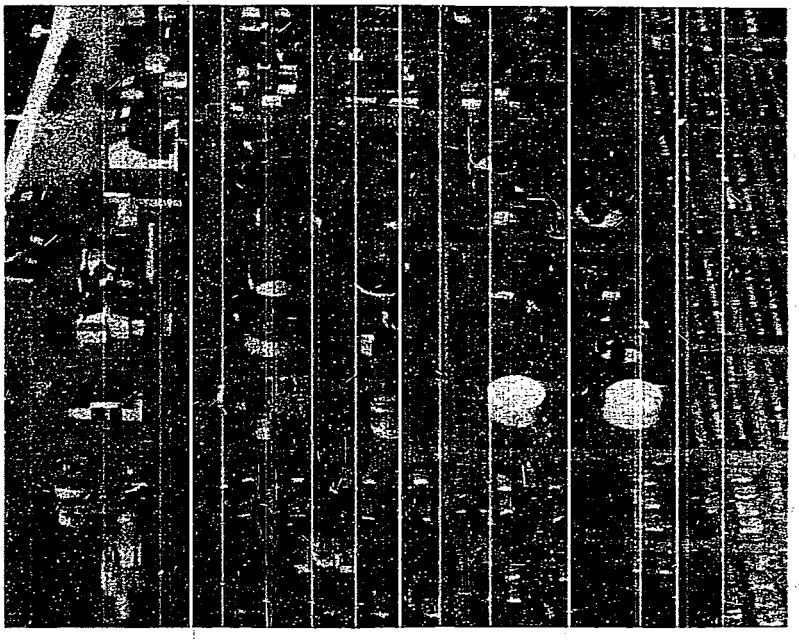


Figure 37
SOLUTION, REFINERY AND OIL STORAGE

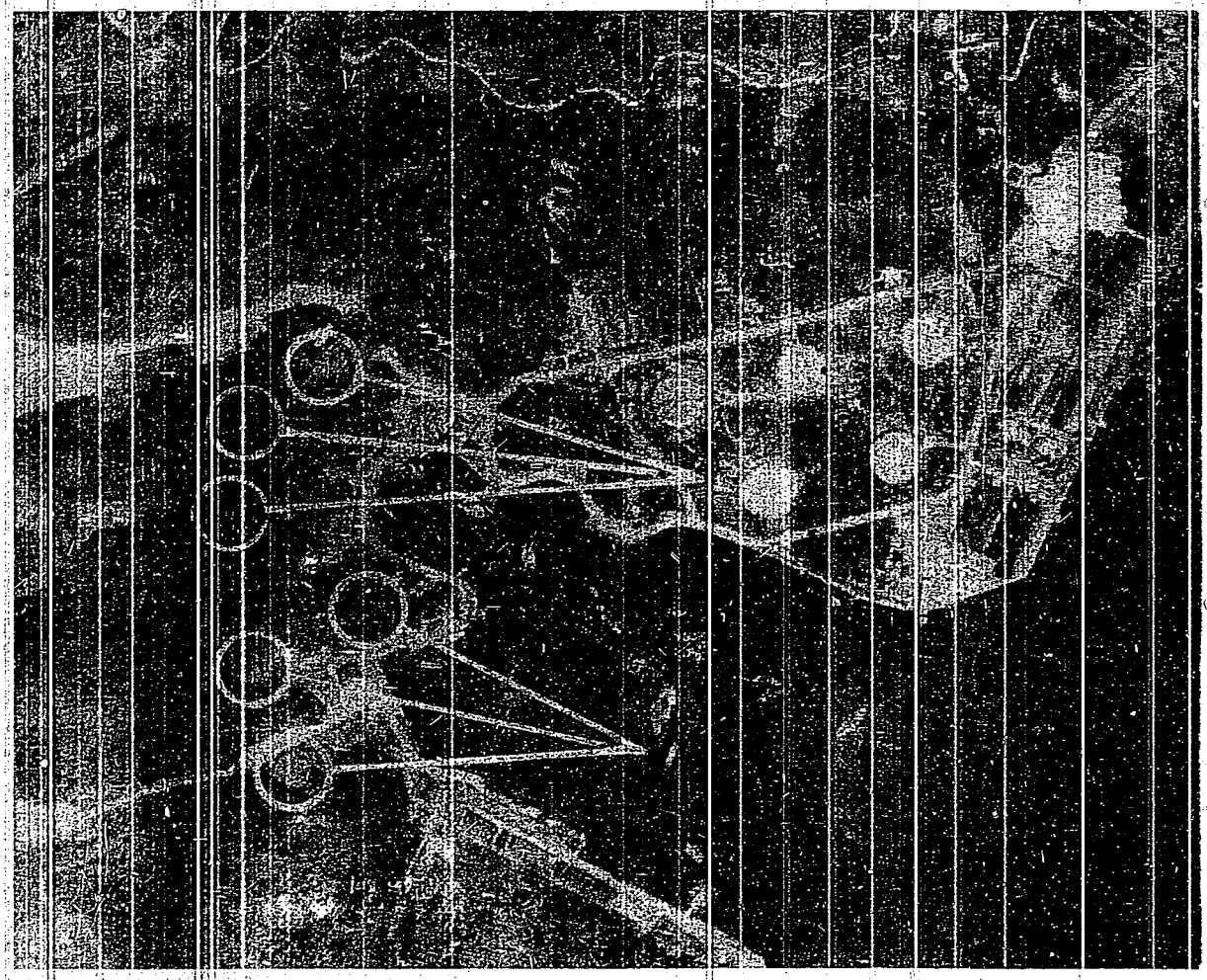


Figure 38

EXAMPLE, SASEBO, KYUSHU

No good example of the Figure 37 technique was available. In this case (Figure 38) Group 1 is toned down with paint to match value of surroundings. Group 2 appears to be buried tanks, their location given away by the appearance of the ground surface.

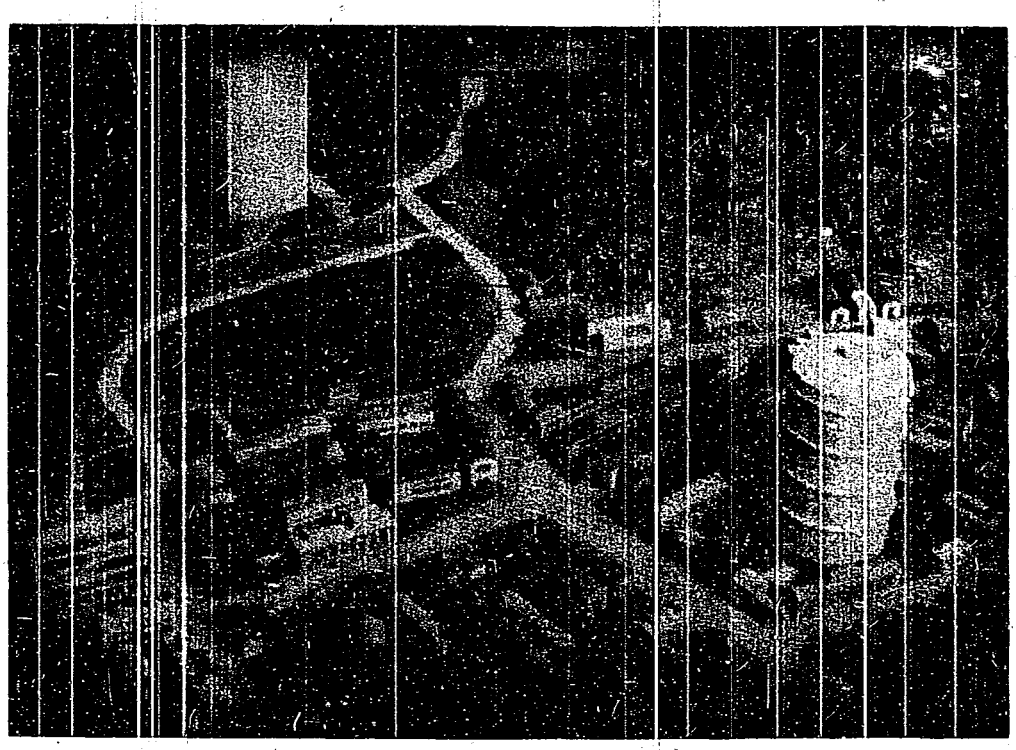


Figure 39
HYPOTHETICAL PROBLEM, GASOMETERS

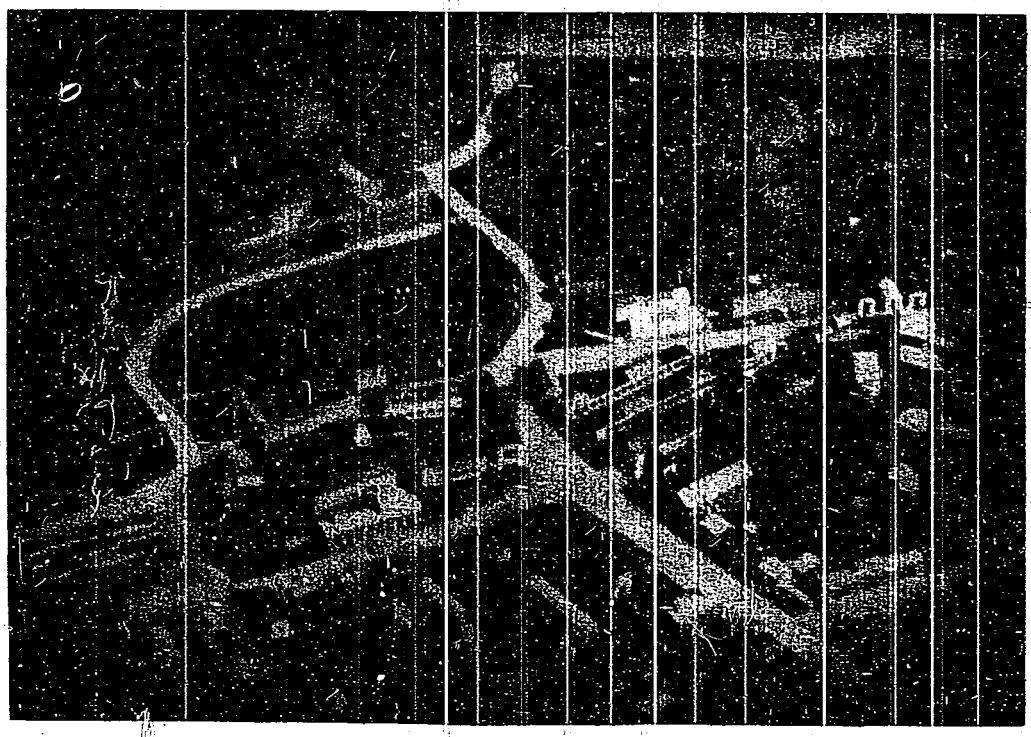


Figure 40
SOLUTION, GASOMETERS

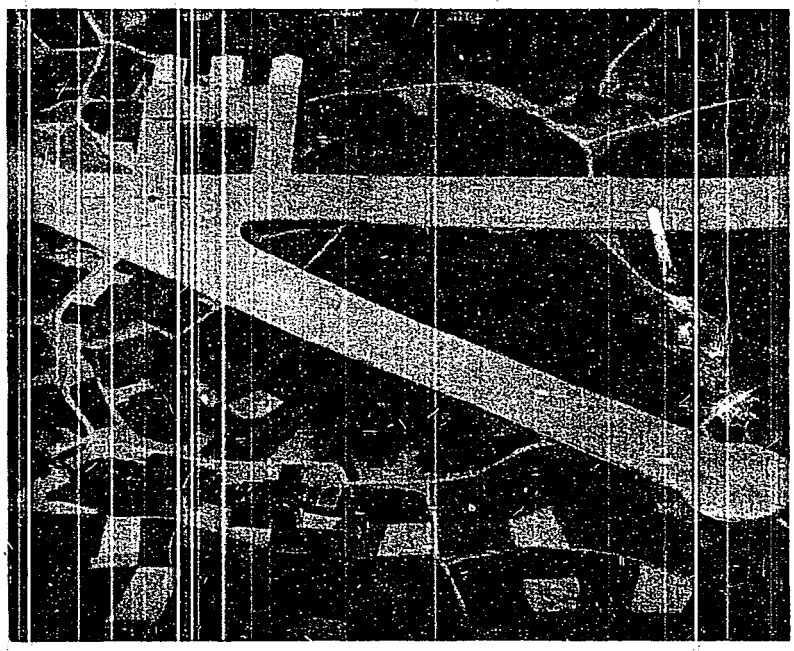


Figure 41
HYPOTHETICAL PROBLEM, AIR STRIP

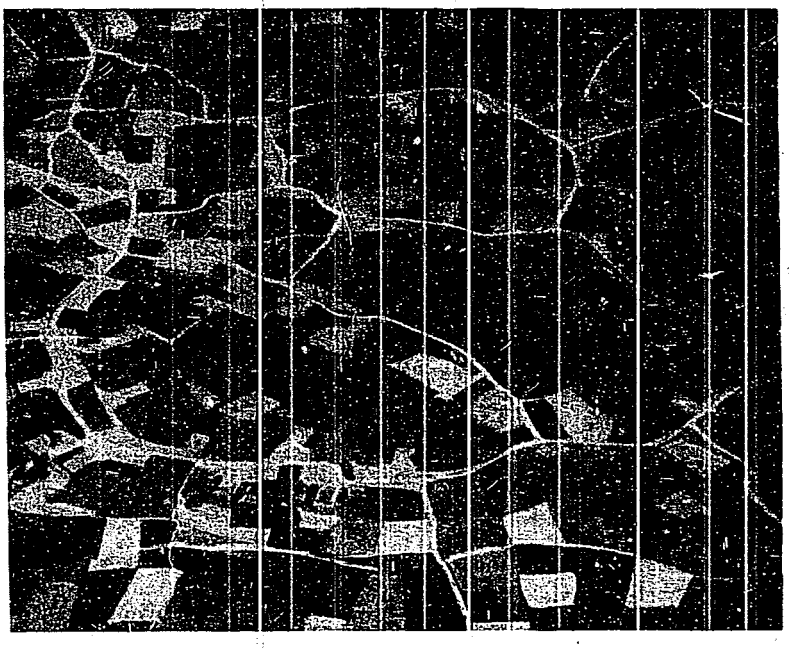


Figure 42
SOLUTION, AIRSTRIP

Figures 41 and 42 show how a hypothetical case can be exaggerated in its effectiveness, giving the impression that a job can be more effective than is actually the case.

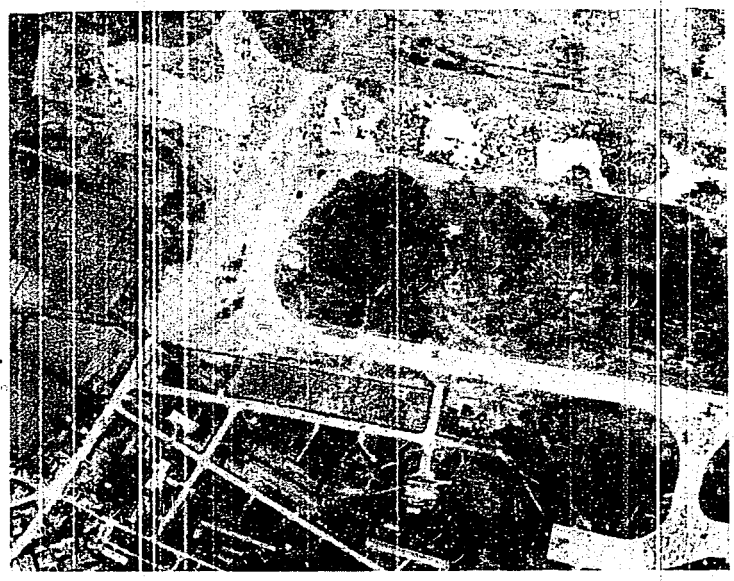


Figure 43
EXAMPLE, SONE AIRFIELD, KYUSHU
Poorly done disruption. Emphasizes strip more than it conceals it.

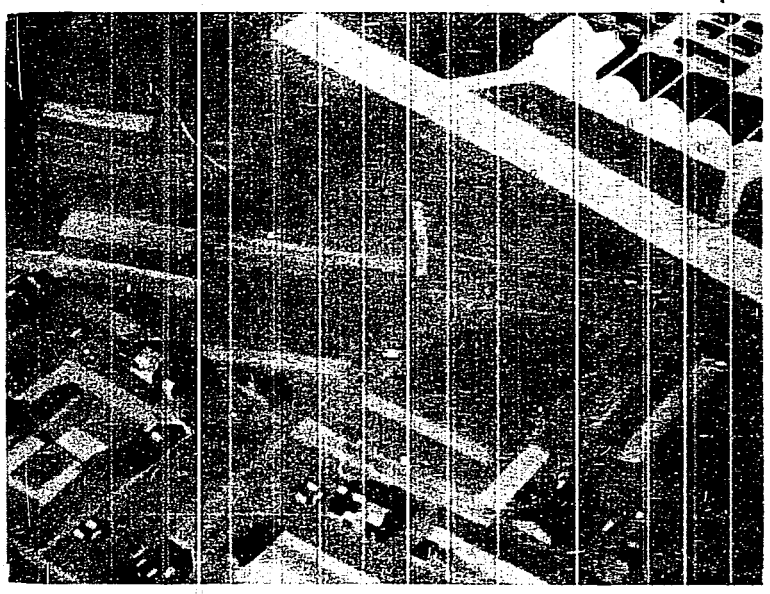


Figure 44
HYPOTHETICAL PROBLEM, AIRBASE

Figure 45
ACTUAL EXAMPLE, NITTAGAHARA AIRFIELD, KYUSHU

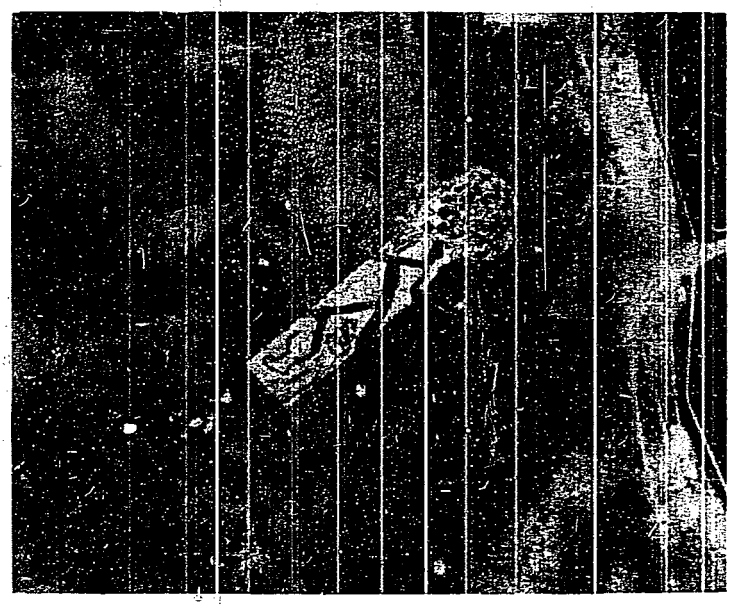


Figure 46
ACTUAL EXAMPLE, METABARU AIRDROME, KYUSHU
This example shows how bad camouflage can be. The strip was fairly well hidden until camouflage was applied.

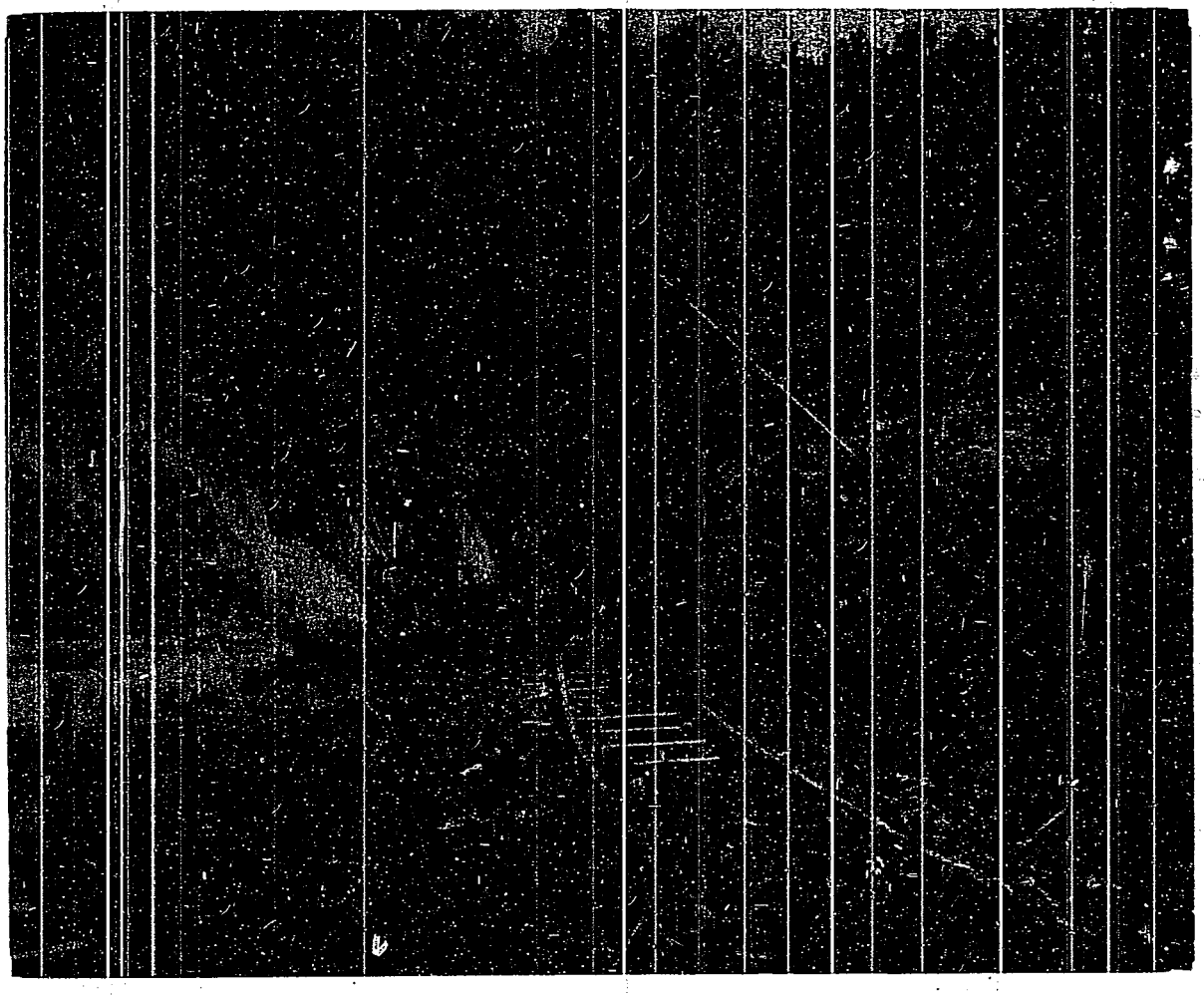


Figure 47

UNDERGROUND SUBMARINE FACTORY, MISAKI, HONSHU

This entire plant is underground with only three or four railways showing from the air. These were hidden by nets supported on poles, during the time when the factory was in operation.

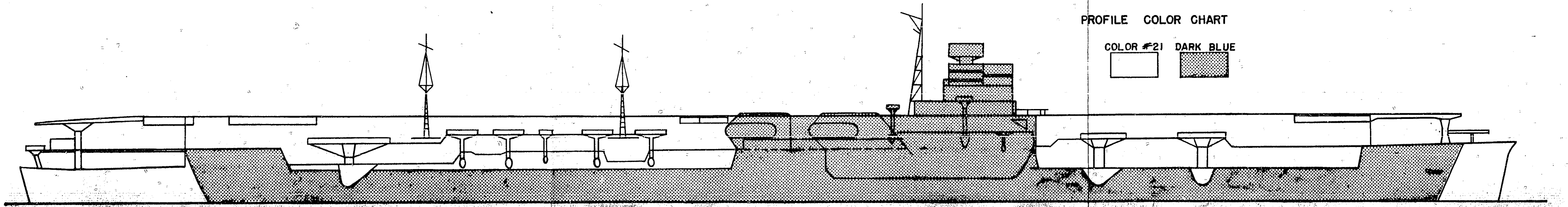
X-32

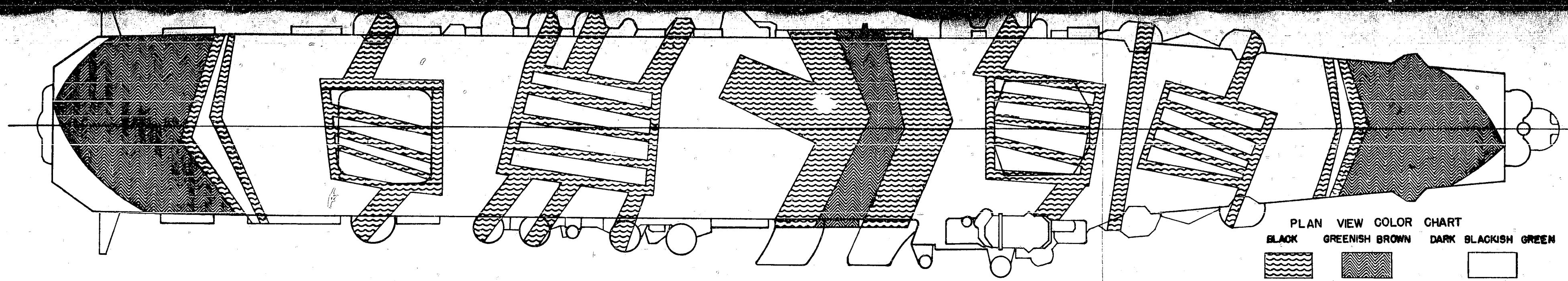
ENCLOSURE (A)

RESTRICTED

PROFILE COLOR CHART

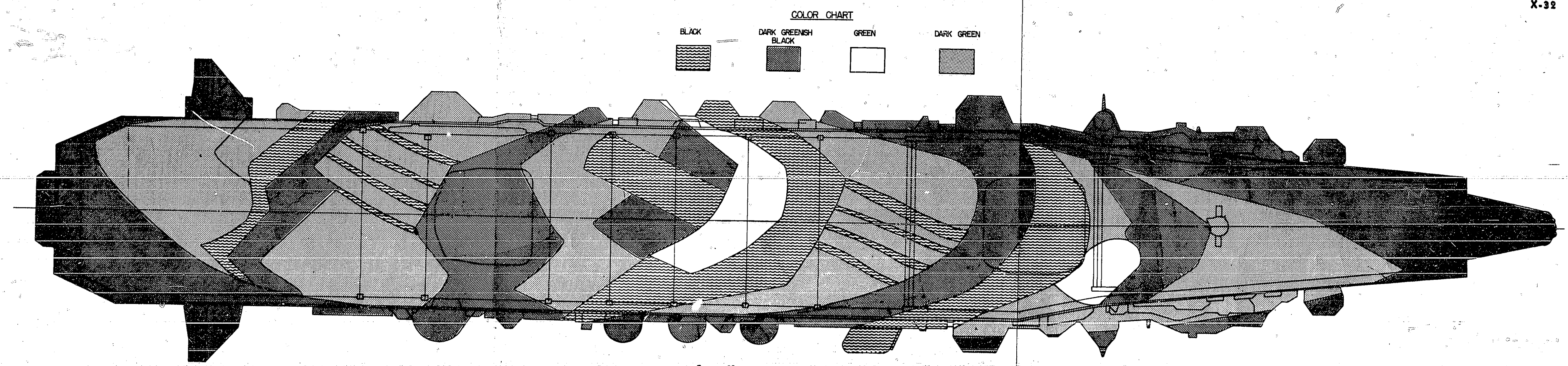
COLOR #21 DARK BLUE





Camouflage Plan for CV [redacted]

ENCLOSURE (B)



Camouflage Plan for CVL CHITOSE