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A SHORT SURVEY OF JAPANESE RADAR,
VOLUME I.

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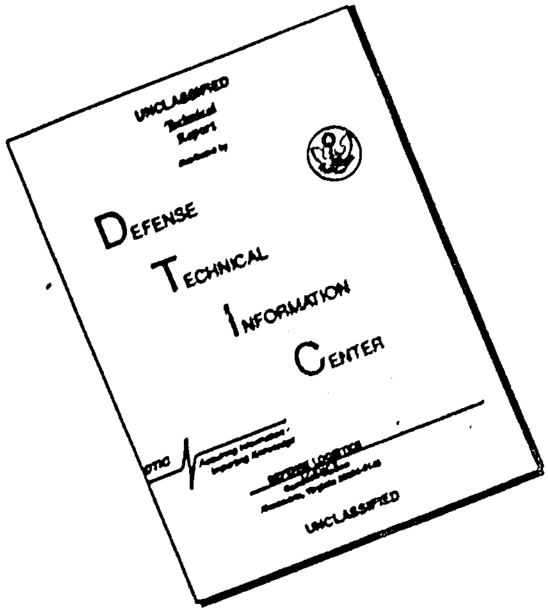

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A SHORT SURVEY OF JAPANESE RADAR

Volume I

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A SHORT SURVEY OF JAPANESE RADAR

FOREWORD

This study was initiated by the 2nd and 3rd Operations Analysis Sections at the suggestion of the Chief of Staff, Far East Air Forces, at the time plans were being made in early August 1945 for the occupation of Japan. It was thought that a small group of investigators arriving on the heels of the first occupation forces would be able to ascertain certain information which might be lost to later radar investigating groups. To a certain extent this has been true, since some equipment and records were inevitably destroyed by the advance of the occupying forces, and with the disbandment of the Japanese army and navy persons often best able to supply desired information became harder to locate for interrogation.

With the arrival in early October of the Air Technical Intelligence Group, conferences were held to coordinate their current and future studies with those of OAS. It was agreed that the latter should continue the broad survey they had begun, while the ATIG officers would make more exhaustive studies of those equipments or operations which seemed to have novelty or value to us from a military intelligence point of view.

ATIG, through the Technical Air Intelligence Unit assigned to them also supervised the collection of samples of all radar equipments and components which might be of interest to American students of the subject. Captain Lebbett, radio and radar officer of TAIU, has expedited the shipping of all such items by airplane carrier back to the United States.

The present report is designed to give a quick overall evaluation of Japanese radar, its history and its present stage of development. It is believed that, even as the writer, many persons who were associated with American radar in one or another of its phases will be interested in seeing what the enemy's equipment looked like and in learning something of its performance characteristics. The block diagrams of major equipments are for those interested in observing a little of the electronic techniques used by the Japanese. Research people will probably be disappointed since little is given on the details of Japanese fundamental electronic developments. For those wishing to study in more detail the design of typical successful Japanese radars, the circuit schematics of two of the latest army sets and two of the latest navy sets are reproduced in Appendices I and II.

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The present Survey is the product of many hands. Especial acknowledgement is due a number of the officers in the ATIG electronics section. Lt. Haller, in charge of radar studies, has supplied the technical information on a number of the sets, particularly those having to do with Radar Countermeasures. Lt. Fleming collected and made available material on the early army radar developments. Lts. Haller and Fleming are writing special reports on all phases of the RCM problem. Lt. Samuelson supervised the setting up of one of the Japanese navy's 10 centimeter No. 22 surface search sets, and furnished the pictures and some of the performance data shown here. He is writing a more detailed report on this set which TAIU is returning to the States. Lt. Alderman and Lt. Erickson have investigated the elaborate Tachi-28 multiple fighter control system and collected such of its equipment as is available. A report will be forthcoming on this. Lt. Alderman has also assisted Captain Featherstone in amplifying the basic report by Lt. Gian, S-2 of the 597th Signal Air Warning Bn, on the Tokyo fighter control center into a more comprehensive view of radar and ground observer reporting in the Japanese homeland. Major Hartsfield, ATIG radio officer, has been most helpful in assessing the numerous equipments and components examined, vacuum tubes in particular.

Lt. (jg) Bill of the U.S. Strategic Bombing Survey and a former navy radar intelligence officer in the Pacific has contributed invaluable information on the state of our intelligence on Japanese installations prior to the surrender. Captain Pike and Lts. Wich and Johnson of Section 22, Office of the Chief Signal Officer, GHQ, have furnished pictures of several remote installations as well as certain data on equipment which would otherwise be missing.

Dr. T.H. Waterman of OAS assisted in interviews and gathering data in the earlier days. Captain Featherstone conducted numerous interviews, studied the operation of the more complicated army sets and wrote several of their descriptions. He is primarily responsible for the important Section VIII on the Japanese Air Defense System.

In a sense this book is merely a setting down of what the Japanese military and civilian people told us. There will be found numerous minor discrepancies therefore, although the general response was so consistent as to leave no doubt as to the near truth of the information given. The difficulty of interrogating in a decidedly foreign tongue, oftentimes through an interpreter unfamiliar with the technical terminology, was much more than offset by the obvious willingness of all ranks to tell us all that they could of their activities. Many volunteered information that we might not have otherwise easily discovered. Everywhere the Japanese displayed a desire to be as helpful as possible to our investigation.

This attitude of friendliness and cooperation was as surprising to us as it was agreeable; it made our task a much pleasanter one and at the same time more fruitful. Numerous inquiries as to the spring from which such universal cooperation arose so soon following the time when our B-29's were burning down 40 percent of Tokyo -- including the homes and entire possessions of many of our interpretees -- brought the same answer, "Our Emperor directed us to tell you everything."

Roger I. Wilkinson
Roger I. Wilkinson
Operations Analyst

Tokyo, Japan
20 November 1945

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A SHORT SURVEY OF JAPANESE RADAR

I - HISTORICAL AND GENERAL RÉSUMÉ

1. Early Development of Types A and B. Radar in Japan dates back to 1936 when credit is given to Professor K. Okabe of the University of Osaka for devising an electronic method for detecting the presence of passing aircraft.* At this time Professor Okabe was working under the famous Dr. Yagi, dean of science at the university. In his method, a radio transmitting station sends a continuous radio frequency signal with superposed audio modulation in as narrow a beam as convenient to a distant receiving station. If an object such as an airplane enters the transmission path the normal uniform signal or tone heard at the receiving station is disturbed, and instead of being steady comes in with a strong beat note. This is an application of the well known optical Doppler Effect.

According to Professor Yagi, the idea for this scheme arose following a trip he made to Germany before the first World War during which he became greatly interested in supersonic signalling. Upon his return he performed a number of experiments in this science which naturally led him and Professor Okabe to study the effects of the presence of foreign objects in radio fields. It was not until the middle 1930's however that Japanese military people became much interested in such detection problems. They then encouraged Professor Yagi and his assistants to apply their knowledge to the advancement of war techniques. Professor Okabe was a leader in the electrical engineering school at Osaka and was given the assignment. He proceeded forthwith to run many laboratory and field experiments on Doppler detection for the army and navy. The method had the great advantage of needing only very small amounts of power; it had the decided drawback, however, of not giving the definite location of the target along the line between the sending and the receiving stations. Professor Okabe and his assistants tried long and hard to solve this problem but unsuccessfully. In 1938 a large power output set was required to be used; in 1939 a much smaller set was adequate (3 watts) and was used experimentally and practically at Hankow. In 1940 a variety of sets with powers from 3 to 400 watts were built. The first Doppler system for aircraft warning was set up in 1941.

It is vehemently claimed by the Japanese that their studies of Doppler detection were conceived quite independently of the suggestions made by Dr. C. W. Rice of the General Electric Company whose papers on the subject appeared in American journals in 1936. Be that as it may, all Japanese radar research and development engineers are familiar with Dr. Rice's writings.

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*The term radar first appeared in Japanese papers near the end of 1944. The Japanese were under the impression that we used it only to describe the PPI search type of set found in B-29s. Instead of radar, they call early warning sets Detectors; searchlight and AA fire control sets are known as Locators.

It was not until 1940 that the idea of pulsed radar arose strongly enough for researches on this technique to be initiated. Its advantages were quickly so manifest that the chief effort was thereafter devoted to developing this method.

The Japanese classify their radars under the two generic headings:

Type A - Continuous Wave or Doppler Systems.
Type B - Impulse Systems.

Unlike American practise, both systems were installed side by side in the army early warning nets surrounding Japan, and facilities were provided at the information centers for simultaneously displaying the information from both. The Japanese navy also developed a Type A system but never put it into actual operation.

Type A radars (or Detectors as all early warning devices are called in Japan) operating in the 40-80 megacycle band were found to give indications of the passage of aircraft across a fixed line in mountainous places where pulsed types were unsuccessful. They were also operable over much greater distances. The longest Type A line of detection used was from Formosa to Shanghai, a distance of over 400 miles. The locations of the chains of Type A stations protecting the Japanese homeland are shown on the map of army early warning stations given in Section VIII of this Survey.

In 1937 the navy research laboratory was experimenting with frequency modulated continuous wave radar, on the same principle as is used in the present American and Japanese low altitude altimeters. In that year a large fleet parade was held in Tokyo Bay, and ranges were obtained up to 5 kilometers. This was considered unsatisfactory and these experiments were abandoned.

2. Nomenclature. Before continuing with a discussion of later developments which will inevitably revolve about particular sets it will be well to describe briefly the systems of radar nomenclature used by the Japanese army and navy. Japanese radar nomenclature is about as confusing and difficult for the layman to remember as that used in the United States. Over a period of years our radar intelligence people laboriously built up a background of Japanese navy sets which in general listed for each the four items, Mark ___, Model ___, Modification ___, Type ___. Apparently this was too much for even the Japanese to keep straight since officers and men in their service usually referred to their equipment by either shortened numbers or by nicknames. For instance the navy's 10 cm surface search sets Mark II Model 2, Modifications 1 to 4 were all called simply No. 22, while the night fighter's Prototype 19 Air Mark 2 Model 11 was generally called Gyoku-3. (Shades of our "Mickey" and "H2X" expressions!)

The official designation system used by the Navy Technical Department was based on employing the following as the tens digit in the number assigned to any equipment:

1 - Land Based Search
2 - Shipborne Search
3 - Shipborne Fire Control
4 - Antiaircraft Fire Control
5 - Panoramic Indication
6 - Guiding Type (GCI)

The second digit was supposed to be selected according to:

1 - Fixed (e.g., 61 = Fixed Type Guiding or GCI Set)
2 - Mobile (e.g., 12 = Land Based Search Set on a Trailer)
3 - Portable (e.g., 13 = Land Based Search Set, Light Weight)

except that in the 2-Shipborne series, the second digit refers to a wavelength code and not to degree of mobility. Navy people readily admitted this was far from a perfect system of numbering.

Unofficially, the navy research laboratory gave each set a name or number as met their whim. For instance in the airborne set FD-1, the F stands for "fly" or the German Flutzeig, and the D for decimeter wavelength. No. 1 was the first one of the series built on the same fundamental designs. The unusual name Gyoku-3 arose from the Japanese word Gyoku-sai meaning "all suicide", which may have had considerable appropriateness since this was to have been a night fighter radar. The letter K added to certain sets' numbers does not refer to the year 1943 as was once suggested in American intelligence, but stands for Kantau which means Simple or Simplified.

The Japanese Army also had a fairly logical set designation system; the numbers were assigned during development and usually stayed with the set. The type number of each equipment was preceded by one of the following words, in which the prefix "TA" comes from Tama Institute:

Tachi, meaning land based; (chi = land).
Tase, meaning shipborne; (se = sea).
Taki, meaning airborne; (ki = air).

In Section IV of this Survey, which shows the block diagrams of the principal army sets, the Tachi-Tase-Taki nomenclature is used throughout. In Section V which contains the corresponding information for navy sets both the Mark-Model-Modification-Type and the shortened designations are given.

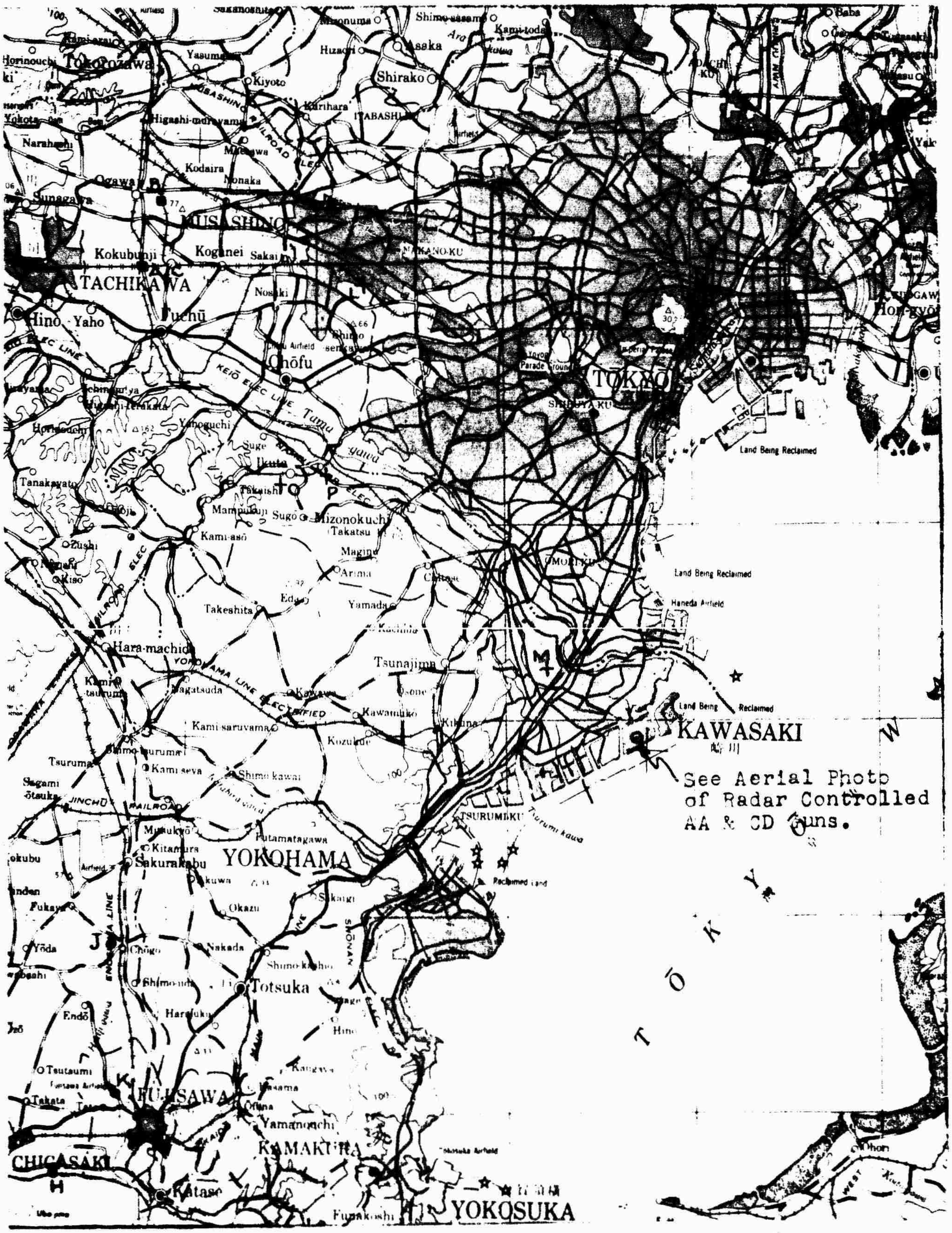
3. Locations of Important Radar Units. In the present and in the following sections, a number of research institutes, schools and manufacturing companies located for the most part in the vicinity of Tokyo are referred to. The map of Fig. 1 is included, with a key, to help the reader fix their locations.

4. Development of Army Radars. In 1940 a Japanese Technical Commission spent several months in Germany, and returned with reports of

FIG. 1

LOCATION OF RADAR LABORATORIES, SCHOOLS, MANUFACTURERS

IN TOKYO AREA



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KEY TO INSTALLATIONS - TOKYO AREA MAP

Army Installations:

A - Tama Research Institute - Kunatachi
B - Radar School (Dempa Heiki Renshubu) - Kodaira
C - Branch School (Dempa Heiki Renshubu) - Kunatachi
D - Tokyo Fighter Control Center
E - Projected GCI Center - Matsudo

Navy Installations:

F - 2d Naval Research Institute - Kanazawa
G - 2d Naval Research Institute Branch - Meguro Park
H - 2d Naval Research Institute Test Area - Hiratsuka (Chigasaki)
I - 2d Naval Research Institute Test Area - Tsukishima
J - Navy Radar School, Ground, Sea, - Chogo
K - Navy Radar School, Airborne - Fujisawa Air Station

Manufacturing Enterprises:

L - Nihon Musen Co. - Radar Mfg - Mitaka
M - Tokyo Shibaura Co. - Radar Mfg - Kawasaki
N - Sumitomo Communications Industries - Mita Plant
O - Sumitomo Communications Industries - Ikuta Laboratory
P - Sumitomo Communications Industries - Radio Mfg - Kawasaki

pulsed radars being built in England. This gave new impetus to forward looking officers in the Japanese army and navy to make further studies of its possibilities. Accordingly the first researches in the army's search radars were begun in 1941.

As a general rule the Japanese search radars were designed for simplicity of operation and presentation; a single A-scope showing range was the usual case. Bearing was only roughly obtainable through guessing at what point the maximum signal was received. The height finding radars Tachi-20 and -35 perforce had more elaborate displays. Resort to pip matching on an azimuth and elevation scope was the usual procedure.

To coordinate the various projects which were beginning to spring up in the army's radar investigations, a research group called the Tama Research Institute was formed in 1943 under the leadership of Lt. Gen. Suda. The Institute headquarters was located near Tachikawa where much aeronautical research of all kinds was going on. The Institute was responsible also for army radar training until the last few months of the war. From the name Tama comes the "Ta" designation attached to many of the army radar sets. Details of the Institute's organization and projects will be found in Section II of this Survey.

4.1. Army Search Radars. The first army set to be built was the rough prototype of what is now known as Tachi-6. This is the large fixed installation used for primary early warning, and corresponds somewhat to the American SCR-270. Frequencies assigned vary from 68 to 80 megacycles. It made use of one transmitter looking either in all directions or over quite a wide fixed arc, with a series of receivers each looking over a much narrower but movable angle. The first Tachi-6's were produced in 1942 with powers ranging from 10 to 50 kw peak. Initial installation was made at Choshi, 100 km east of Tokyo.

Portable sets were needed to supplement the ponderous Tachi-6 equipment which was ill adapted to use outside of the home or mandated islands. Accordingly the mobile Tachi-7, operating at 100 MC/S, was developed in the same year. It was ready for service in 1943 and most of the 60 sets manufactured were sent overseas where mobility and ease of handling were of great importance.

A still lighter set was needed for portable service. For this, work on Tachi-18 was begun early in 1943 and a 100 MC/S set weighing 4 tons was completed at the end of the year. These sets were mainly retained in Japan where they provided a standby for Tachi-6 or assisted in reading through allied jamming signals.

Tachi-6, like our own SCR-270, gave only the barest information on airplane heights. Tachi-20, installed at Choshi in March 1945, and Tachi-35 at Matsuda in May were the army's current attempt to answer the height problem. (Details of these sets will be found in Section IV.)

In late 1942 the army began studies for a radar to be installed on transports and other large ships for protection against Allied submarines. This led to the building of the 15.7 centimeter Tase-2 set by Nihon Musen. In February 1943 installations were made on two ships, but the set did not have sufficient power to give satisfactory range so it was earmarked for use on land. A second marine set, Tase-10, operating at 150 MC/S was produced in December 1944. This was expressly designed for use on transport submarines. However upon its completion, Japan had left only one submarine of size suitable for its installation. And this installation proved abortive when the submarine's power supply was found inadequate.

The first army airborne set, Taki-1, was built by Nihon Musen in 1943 with only 6 months elapsing from drawing board to installation. It operated at 200 MC/S with 10 kw peak output. Presentation was on a simple A-scope with a scale laid off by range marker pips. A certain amount of directional searching was obtainable by switching transmitter and receiver to any one of three antennas, a nose Yagi, and a doublet on either side of the fuselage. This was considered quite satisfactory for sea search and more than 1000 sets were built. Smaller and lighter editions came out from time to time.

It was appreciated that greater definition in the scope presentation than that given by Taki-1 was much to be desired. Accordingly in August 1943 research was started on a centimeter wavelength airborne radar, called Taki-14. The first set operating at 27 centimeters with a triode transmitting tube was completed in August 1944 under the direction of Major Uozumi of Tama Research Institute. The antenna was a Yagi array with a paraboloid reflector. The set when installed on a heavy bomber gave ranges of only 25-30 km which was thought not nearly good enough. By a series of experiments on the transmission lines and the antenna, the ranges were stepped up to 40-50 km by February 1945. Production was made very difficult by the B-29 bombings of the plant doing the manufacturing, so that no sets were actually installed and in use by the end of the war in August. Continued experiments during this period involving the use of cavity tuning had brought the range up to 70-80 km.

Parallelling the development of Taki-14 at 27 centimeters, were studies at Tama Institute using the identical equipment with the radio frequency circuits altered to accommodate 10 centimeter transmitting tubes thus producing Taki-24. At the same time, a 5 centimeter set called Taki-34 was under development at the Ikuta Research Laboratory of the Sumitomo Communications Industries. A magnetron was used for transmitting and a velocity modulated tube for the local oscillator.* A PPI presentation with sweep corresponding to the position of the paraboloid antenna was used with magnetic deflection coils on the scope; this was developed after seeing the construction used on B-29s which had crashed over Japan. This set was turned

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*Samples of these tubes are being returned to the U.S. by the Office of the Chief Signal Officer, GHQ, U.S. Army Forces Pacific.

over to Tama engineers in July 1945; it was never test flown, but experiments from a high point of land at Ajiro on the Peninsula south of Tokyo showed the disappointing ranges of only 12-15 km on nearby mountains. The set and all circuits and data on it were destroyed by its builders on 14 August, one day before the end of the war.

4.2. Locator-Type Radars. In 1942 one officer and two civilian engineers went to Singapore and Corregidor to inspect captured English and American radars. At Singapore they found the equipment pretty well demolished; however according to Japanese accounts they discovered one complete set of drawings and specifications for a searchlight or fire control radar. At Corregidor several SCR-268's were captured, one of which was in complete operating order. Some of these were shipped back to Japan and the Sumitomo and Tokyo Shibaura companies were immediately put to work making modified Japanese copies of them.

Tachi-1 and Tachi-2, the first two locators designed by the army show strong indications of British SLC influence. Both are 200 megacycle sets, Tachi-1 having separately mounted transmitting and receiving antennas, while Tachi-2 has them together on the same mobile trailer mount. A phasing ring is used in both cases to give the receiver lobe generated by the four Yagi antennas a rotary movement. A mechanical distributor is used to switch the received signal at appropriate moments to the azimuth and elevation scopes. Tachi-3, which became the army's chief fixed position fire control reliance (150 were produced), was patterned after the British GL Mark II equipment. It was rated at 50 kw at 78 megacycles, and had a claimed range of 40 km. Color disks were used for pip matching in both azimuth and elevation. It may be noted here that the Japanese navy acquired a Tachi-3 for experiment and comparison with navy fire control sets at their Chigasaki field laboratory. They found that it had greater range than their own S-3 and S-24 equipments, but that its bearing and elevation accuracies were not as good; consequently they considered their navy sets superior for searchlight and fire control purposes.

Figure 2 shows a typical army AA defense layout at Kawasaki, 10 miles below Tokyo, guarding the southern approaches to the capital. (See location on map of Fig. 1.) Six 120 MM guns arranged in the characteristic circular positions, and six 88 MM guns in a semi-circular design, are controlled by a Tachi-2 and a Tachi-3 set. Tachi-2 is camouflaged by a barn which rolls back on railroad tracks when the set is to be used. (See detail in Section IV.)

Tachi-4 was a mobile locator built to replace Tachi-2 which proved unsatisfactory in operation; the transmitter and receiver were combined to simplify the assembly. Finally Tachi-31 was built from modifications of Tachi-4; this set uses all four Yagis for transmitting and receiving, thereby giving greater range and directional definition. Tachi-31 was to become the standard 200 megacycle radio locator for the army.

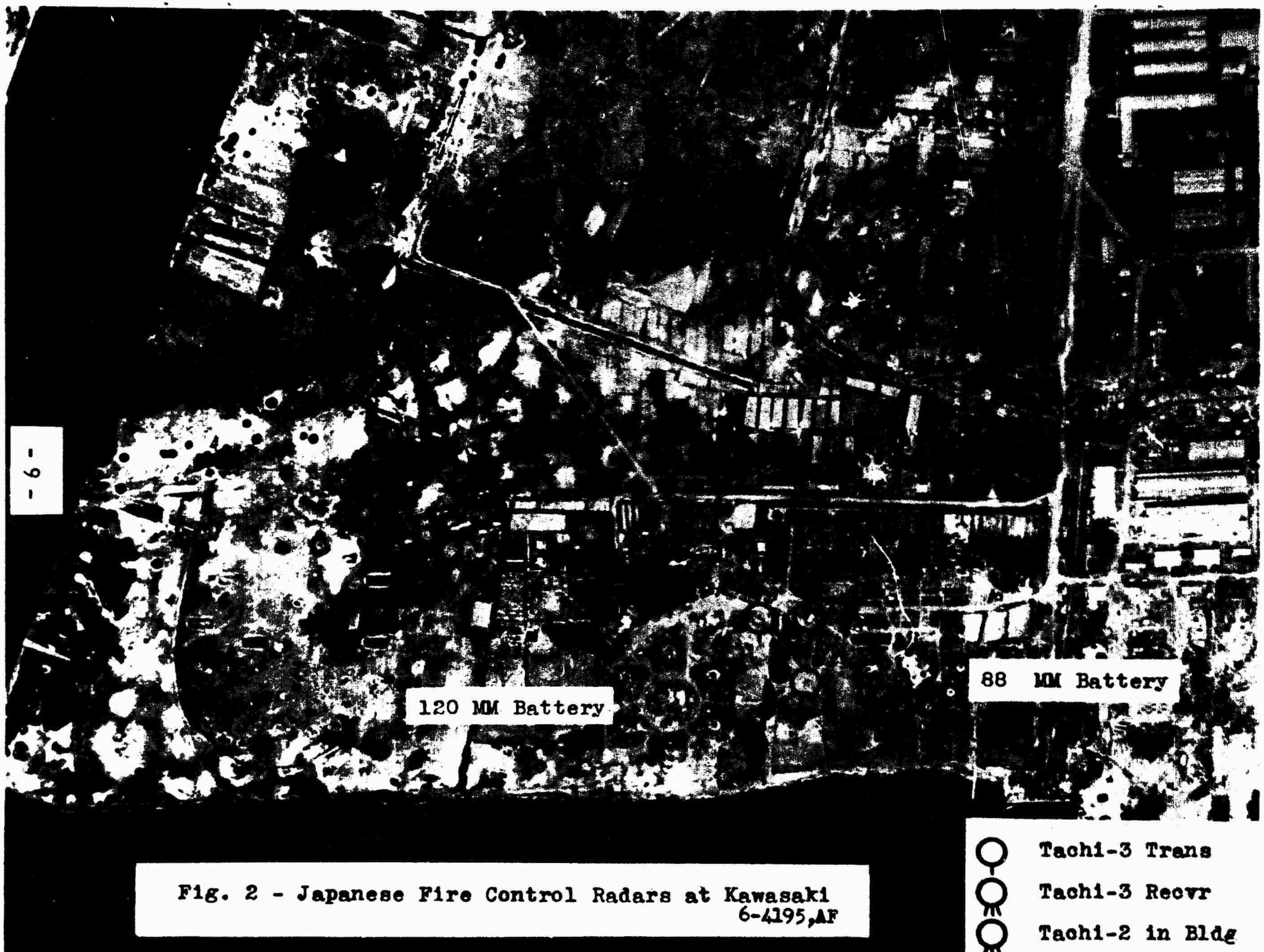

Fig. 2 - Japanese Fire Control Radars at Kawasaki
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At the same time that the 200 megacycle development above was going on, slow progress was being made on building an exact copy of the German Small Wurzburg (Tachi-24), which would operate at a 50 centimeter wavelength and give a much improved azimuth and elevation accuracy (in the order of ± 1/8°). Plans for this set and the major components had been brought from Germany by submarine in January 1944. Re-engineering to Japanese specifications and parts required several months, and the first of three sets to be made by Nihon Musen as models for Sumitomo and Shibaura to copy was just nearing completion in August 1945.

In all of the above fire control sets the data are sent to the gun directors by means of selsyns.

The army was just beginning to produce a "locator" for use on aircraft as the war ended. This was Taki-2, an 80 cm set, with a single Yagi transmitting antenna, and four similar receiving antennas switched in rotation for azimuth and elevation estimating. It does not seem likely that this set would have given sufficient directional accuracy for much success as a night fighter.

4.3 ARMY Leading Radar (GCI). The Japanese were trying hard to solve the problem of Ground Controlled Interception as the war ended. For this they had built a ground interrogator, Tachi-13, transmitting at 184 MC/S and receiving at 175 MC/S. This was to work with the transpondor Taki-15 installed in the plane to both identify and fix the position of the night fighter. Display was on two A scopes, one giving range, the other bearing by means of pip matching. This would have been quite similar to using the American RC-184 for guiding an interceptor, something which could be done only with exceedingly skilled plotters and controllers. Presumably the 200 megacycle Tachi-31 or the Wurzburg, Tachi-24, would have been used for fixing the position of the enemy plane at any moment.

In order to handle more than one air interception at one time, a scheme called Tachi-28 was in process of building, by means of which as many as 30 friendly planes could (theoretically) be guided simultaneously. The idea employed here of using two Direction Finding stations to report automatically and continuously the positions of each of the friendly planes to a central station is ingenious and perhaps deserves some consideration by American students of air defense.

The transpondor used with Tachi-13 above is really an IFF set and would ordinarily be used with the Tachi-13 or -17 on the ground as the interrogator-receiver in the projected Identification Friend or Foe system. Tachi-17 is a simplified Tachi-13 giving considerably less directional accuracy.

There is considerable doubt that the above measures would have gone very far towards solving one of the Japanese's most urgent problems; how to knock the B-29s out of the sky in such numbers as to seriously interfere with their bombing operations. We would have had great difficulty ourselves with our much superior PPI GCI scope presentations and our 10 centimeter AI equipment.

5. Development of Navy Radars. Research and development of navy radar and allied equipment was vested in the Electronics Section of the Second Naval Technical Institute located near the Yokosuka Naval Base. The section was under the direction of Vice Admiral Nawa, an electrical engineering graduate of Tokyo Imperial University. A quite capable staff of physicists and engineers was employed, some civilians, some commissioned. Dr. Takeyanagi, a name known in television circles, was Assistant Chief of Radar Research. They received no outside assistance except for one Mr. Brinker, an unwelcome arrival from Germany who came to work in their laboratory at the direction of higher Navy officials. The Japanese engineers felt that they were quite adequate to meet any radar problems the navy might bring up. Thus the navy handled the majority of their own electronic research work while in the army the tendency was to assign various projects to outside research agencies, such as the universities and the manufacturers.

Of particular interest is the work conducted on magnetron research under the direction of Captain Ito, a former student of Professor Okabe at Osaka University. It may come as something of a surprise to American intelligence officers and radar engineers that the navy was producing 10 centimeter magnetrons suitable for use in their shipborne search sets as early as the fall of 1941. Thus their microwave studies at that time were but a few months behind our own.* In the succeeding years, however, American development drew away from the Japanese since the best the latter could do was to produce a tube giving about 5 or 6 kilowatts peak output at 10 centimeters. Near the end of the war, however, experimental magnetrons were being made which gave 1.5 kw peak at 2.7 cm, and experiments were being conducted at wavelengths as low as 0.7 cm.

5.1. Navy Warning Radars. Research and development work on Type B (pulsed) radar was begun by the Japanese navy early in 1941. The well known Type 11 (Mark 1 Model 1) 100 megacycle set found at Attu and Guadalcanal was developed in the period between April 1941 and March 1942. The Japanese report that the first No. 11 set was installed at Rabaul. Altogether about 80 of these large early warning sets were manufactured.

Work was shortly begun on a portable set which would not require the building of the large No. 11 sets on distant islands. Set No. 12 appeared at the end of 1942; it was later adapted for shipborne use also. Set No. 13 followed as a very lightweight unit in 1943, while simplified No. 13, that is No. 13K, was just making its appearance as the war ended. In the fall of 1944 when the B-29 raids began in earnest, the Japanese decided they needed a set which would give them longer range warning than any of the above. A long wave (6 meter) set was crash engineered and then

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*Captain Ito is writing a detailed report of his magnetron researches for the Scientific and Technical Advisory Section (Dr. Compton), GHQ; this will be ready about February 1946.

built in three weeks by Tokyo Shibaura Company. Three of these sets were eventually installed, two on the southern shores of Honshu, and the third at the very southeastern tip of Kyushu. Ranges obtained on high flying B-29s were consistently of the order of 300 km.

The first of the long line of No. 22-type shipborne 10 centimeter search sets was completed in June 1942. Magnetrons were used for both transmitting and receiving tubes. Wave guide transmission lines ended in horn antennas, mounted in pairs, rotatable through suitable gears so they both always pointed in the same direction. With the latest M-312 water cooled magnetron delivering 6 kw, the range obtainable on a battleship was approximately 25 km.

For shipborne air warning, as mentioned above, a modification of the No. 12 land based set (renamed No. 21) was used, and also the No. 13 land based set was adapted for the same purpose.

The first development work on airborne radars was done by the navy in November 1941 resulting in a patrol and search set (No. H-6) working at 150 megacycles. During the years that followed some 2000 of these sets which gave excellent satisfaction were manufactured by the Nihon Musen Company. The H-6 eventually gave way to the lighter and more compact FK-3 in the latter months of the war.

The navy well appreciated the desirability of obtaining better definition than could be got from the 150 megacycle sets used for sea patrolling, if they were to be able to do radar bombing. Some work was done in an attempt to adapt the 10 cm No. 22 shipborne set to this purpose, but the project was unsuccessful. Meanwhile design specifications on a 10 centimeter airborne search set called the Rotterdam Gerate had been received by radio telegraph from Germany. (It is now believed the data came from an early British H2S set shot down by the Germans over Rotterdam.) On the basis of the received data the navy electronics laboratory set out to build such an equipment. The result was the magnetron powered No. 51 set with cut parabola rotating antenna and PPI display. Test results were not as good as hoped, showing only about 20 km range on shorelines. Two of the three sets built were demolished; the third set is being sent by the Air Technical Intelligence Group, Far East Air Forces, to the U.S. for examination. Circuit diagrams of No. 51 are given in Appendix II of this Survey.

5.2. Navy Locator-type Radars. The first navy locator-type radar was based on the American SCR-268's captured at Corregidor in the spring of 1942. "Research" on the resulting S-3 AA fire control set was begun in August 1942 and concluded a year later. The Sumitomo Company was given drawings of the desired equipment and produced about 80 sets, although at a very slow rate of 5 per month. Meanwhile production was started on a searchlight control set L-1 built along the lines of the British SLC. Attempts were also made to adapt the latter for fire control purposes resulting in the S-23 set. However the directional accuracy was not good enough, and after making a few equipments the project was abandoned.

Difficulties in building and maintaining the S-3 caused the design of a simpler 200 MC AA control set known as the S-24; oddly enough this set had both more range and accuracy than the S-3, and it became the navy's standard land based fire control radar. Its accuracy, however, was still pretty poor as American standards go, and with its susceptibility to jamming was thoroughly inadequate to handle the much needed AA fire control problem. They had no better luck with these sets in hitting anything than we did with the SCR-268.

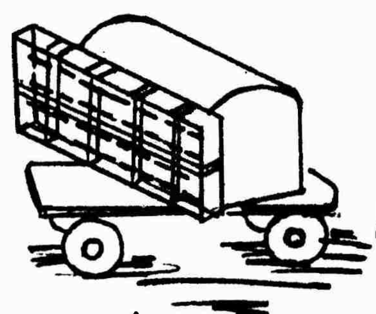
The navy's initial answer to the jamming problem, as well as the relative inaccuracy of the S-3 and S-24 sets, was to build a higher frequency set. This was done in the experimental No. 61 which at a wavelength of 60 centimeters has much the appearance of the Small Wurzburg. The navy had also spoken for a share of the production from the army's Wurzburg program.

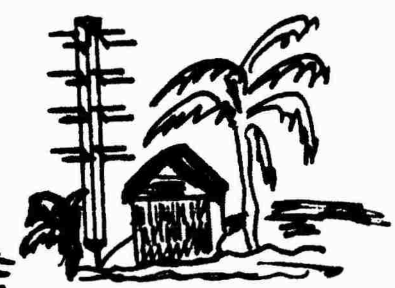
5.3. Navy Ground Controlled Interception. The navy plan for controlling friendly fighters was quite similar to that proposed by the army. A ground interrogator with broad band antenna so that it might operate anywhere from 145 to 155 megacycles trips the transpondor in the plane which replies at a slightly different frequency (up to 3 MC difference). Radar No. 62 obtains range on an A scope, and shows bearing on another scope by matching pips through a mechanical lobe switching device. It may be noted that the IFF transpondor in the plane, when not being employed for GCI work, sweeps a band of 150 + 5 MC, and replies on the interrogation frequency, so that any 150 MC radar set such as the navy's No. 13 can identify friendly planes by the fluctuating increase of the target return at regular intervals. This corresponds exactly to the old American Mark 2 IFF system. For locating the foe plane, the navy was developing a long range (200 km) 100 MC/S lobe switching radar; this was to be called No. 63. As with the army's proposed scheme for making interceptions by means of separately tracking the friendly and the foe airplane with radars having relatively poor bearing accuracy, it would seem highly likely that the navy's plan would have given very disappointing results unless exceedingly skilful operators were employed.

The navy was developing two night fighter radars at the time the war ended. The 500 MC/S No. FD-2 set had a presentation giving azimuthal corrections only; the scope indication was quite similar to that of the American SCR-521. The other set, working at 150 MC/S was known as Gyoku-3, employed an unusual fixed antenna built in two forward facing layers. By feeding them through a rotating goniometer type of coil, a rotating forward lobe was generated; the corresponding display was shown on a PPI scope. The definition in this set would seem to be very poor since the beam is some 70 degrees in thickness. Japanese navy engineers insist, however, that you must have such a thick beam or the entire area in front of the plane cannot adequately be searched. Apparently the idea of rapid scanning by a very narrow forward looking pencil of radiation had not appeared to them to be practicable.

6. Disposition of Early Warning Equipment. Except for a half dozen army sets of the Tachi-6 and Tachi-7 types in such rear areas as Java, Ceram and Timor in the Netherlands East Indies, the radars predominantly used on outlying captured islands in the Pacific were the navy sets Nos. 11, 12 and 13. The 11's came first, naturally, but in the later stages of the war the 13's predominated. Rough sketches of these are shown below, and will immediately recall the numerous pictures previously published by Allied Intelligence sections of sets seen or captured during our retaking of the Pacific islands.


No. 11


No. 12


No. 13

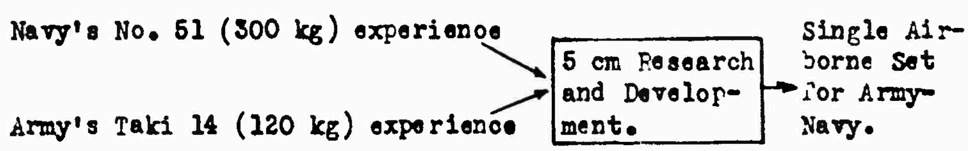
In the Japanese owned or mandated islands there were more of the larger field and fixed installations as might be expected. Tachi-7, a mobile job with 3 trucks was set up at Chichi Jima, Miyako Jima, in the Philippines and Okinawa. Tachi-6's which have a transmitter surrounded by 3 to 6 receiving stations at distances up to 1000 feet were fast becoming the backbone of the early warning system. Typical installations were at Amami Oshima and Hachigo Oshima in the Nanpo Shoto group of islands leading southeastward from Tokyo. Many more Tachi-6's were built or were being built in southern Kyushu, as well as at points closer to Tokyo on the home islands. Some idea of their numbers and distribution is given on the air defense maps of Section VIII.

7. Navigational Aids. Both the army and navy had developed low altitude FM altimeters which they claimed had been of good service during low altitude torpedo bombing attacks on enemy shipping. The army also had a high altitude pulsed altimeter but it gave so much trouble and read so erratically that the flyers would not rely on it. Neither the army nor the navy had any program of vectoring home lost pilots by means of radar plots. No mention of the use of the IFF sets in the planes to extend their locating coverage for this purpose was mentioned in discussions of the various associated equipments.

The army had plans drawn up and equipment partly installed for a simple hyperbolic navigation system, very similar to our LORAN. The equipment carried in the plane, however, was much simpler than ours. Very likely the accuracy does not compare with that obtained by our sets either; it may well be good enough, however, to be of great value to airmen.

8. Army-Navy Liaison. The great majority of the radars installed on the islands which the Japanese invaded stretching from the Gilberts and Marshalls to the Solomons and New Guinea were navy types and were operated by navy personnel to protect their own installations. In this way the navy became experienced in early warning activities near the beginning of the "Pacific War"--as the Japanese say it. In the Japanese homeland, however, the army was charged with the responsibility for general air raid warning and covered the islands with a network of stations both of Types A and B. There was an almost negligible liaison between the army and navy all the way from research and design through manufacture, installation and most importantly in operation. As a result in Japan proper the navy practically duplicated the army's early warning coverage but the information so obtained was used almost exclusively for alerting their own air and sea bases and such AA and fighter protection as was available.

The severe loss in efficiency caused by the unwillingness of the two branches of the service to exchange ideas or use any of the same equipment was strongly pointed out by the manufacturers who had to maintain two entirely separate research, engineering, and manufacturing sections in each factory. This was finally appreciated in certain high quarters and a joint A-N Committee (called Niku-Kai-Gun Dempa Gijitu Iinka) was set up in August 1943 to correlate the army and navy programs. Although the committee met once a month their ineffectiveness is seen by the fact that they could not even get agreement between the army and navy on using the same IFF set. The navy adopted a set with transpondor sweeping 145 to 155 mc while the army's set in the plane received at the spot frequency of 184 mc and retransmitted at 175 mc. Thus the army could not distinguish Japanese navy planes from enemy planes, and the navy could do no better for the Japanese army planes! The chief contributions of the AN Joint Committee seem to have been to get the two services together on ordering the Small Wurzburg sets, and to obtaining agreement that the next airborne set following the current navy's No. 51 and the army's Taki-14 would be a jointly sponsored 5 centimeter equipment;



Some question even exists as to the cooperation present on this last project since at the close of the war the army was actively experimenting with 5 cm sets (Tachi-34) with apparently no participation by the navy.

9. JAPANESE Countermeasures. Both the army and the navy appreciated the need for knowing what manner of radar sets were being used against them.

both had developed a line of search receivers with various means of displaying or recording the signals picked up. Some were equipped with scope presentations whereby homing on a signal was possible. The army in addition had built a pair of "wave disturbers", Taki-8 and Taki-23, which were spot jammers of either the impulse or CW type, covering the wavelengths from 7 meters down to 80 centimeters. A magnetron jammer especially designed for the X-band of the B-29's was under construction.

Repeated questioning of army and navy radar engineers brought emphatic denials that the Japanese had ever installed a captured American IFF set in their ships or airplanes. This makes very difficult an explanation of certain observed instances where our forces were sure that our IFF system had been compromised. The upper end of the navy IFF M-13 sets' sweep at 155 mc would nearly overlap the lower edge of Allied frequencies. However, the Japanese navy claimed that development of this set was completed only in July of 1945 and that of the 50 sets manufactured none was yet in operational use. The army equipment, with split interrogating and responding frequencies should not have shown up on our radars at all.

10. Effectiveness of Allied Jamming. According to all accounts the effect of Allied jamming was of such great extent that after 1 May 1945, it was impossible for Japanese antiaircraft guns to shoot unless they had visual tracking. This meant that our bombers had to be picked up first by searchlights which themselves were having plenty of trouble finding the target because of the very same electronic jamming on their 200 megacycle frequency.

Inquiry revealed that our window use, while effective, did not cause nearly the difficulty that the electronic jamming produced. Skilled operators at such places as Kobe, were shortly able to distinguish airplanes from the false window targets and give some rough indications of the planes' locations. However, the electronic jamming created a sea of grass all over the scope and it was impossible to distinguish targets of any kind along the trace.

11. Accuracy of Our Radar Intelligence. Preliminary comparison of the locations of Japanese radars and their types at each place with the intelligence information compiled by allied forces during the progress of the war, indicates a very high degree of accuracy in the latter. This matter is being made the subject of reports by other investigating units.*

12. Japanese Air Defense System. The Japanese air defense system was an elaborate combination of ground observers and Type A and B radars. Partly on that very account it was unwieldy and slow to function. Certain features of the amazingly complex fighter control centers were excellently conceived and built. The display of radar information on a lighted gridded

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*A unit of the United States Strategic Bombing Survey is conducting such a study.

map without the use of cluttering stands was good. But the equally important ground observer reports appeared at another location, and in a quite different presentation form. It must have been impossible for an ordinary human controller to coordinate and filter in his mind all of the information arriving during a large raid.

There was apparently little or no system by which fighters could be properly directed to get into an advantageous position for making an interception as the B-29's arrived even though in most cases early warning of an hour or more was available. Apparently very poor liaison was maintained between the army and the navy information centers. It would have been a long step forward to have consolidated the two early warning systems, and have all stations report in to a single information center in the area. Full information would have been had, then, with half the expense and confusion. In addition there was the problem of using the data from the AA radar systems which came in over a loudspeaker and was plotted on a third display position. Allied information center designers occasionally appeared to run a little wild with elaborate schemes of presentation. They are a poor second compared with the Japanese.

13. Critique of Japanese Radar. All in all it must be said that the Type A plus the Type B equipments gave entirely adequate air early warning on B-29 raids. Occasionally single bombers flying low and fighters in small formations could slip through the net but not so often as to be serious. The far flung system of ground observers tended to fill in any warning shortcomings of the radar equipments.

The good Japanese air raid warning service was useful in that it gave people a chance to seek shelter in time to save their lives. At the same time the resistance offered to the approaching bombers by AA fire and by fighter interceptors was pitifully small. This was very largely because the Japanese did not have:

a. Sufficiently accurate fire control radar,

b. Ground and airborne radars adequate for effective GCI work, nor much of a system for using what radar they did have in this direction.

Hence considerable of the responsibility for the poor showing made in resisting our raids must be attributed to the lack of technical development by the Japanese of radars accurate enough for good fire control or for fighter direction, i.e. the equivalents of our SCR-584 and SCR-527 and, of course, the MEW. Fortunately, they captured only the SCR-268 in the Philippines in the early days of the war--and although they duplicated it beautifully (see the navy fire control equipment S-3 in Section IV), they had no more success with it for training guns than we did. Nor was the navy's improved S-3, that is the S-24, much more satisfactory in this respect.

The Japanese attempted to duplicate our 3 centimeter airborne magnetrons without success. Nor were they able to make permanent magnets of sufficient strength to eliminate heavy and clumsy electromagnets. One Japanese airborne radar engineer claimed to have got a renovated APQ-13 into bench operation. He considered it a beautiful job--and said they could readily have duplicated everything in it except the magnetron.

All of the Japanese designed radar equipment examined appeared to be crude both electrically and mechanically in comparison to the later U.S. sets. There is some doubt whether they could have duplicated successfully our modern fire control and GCI radars even if they had captured them. As a matter of fact they had obtained fairly good specimens of our IFF sets and the APQ-13 from B-24s and B-29s, but generally stated they had never been able to put them in complete operation. Admiral Nawa, head of Japanese navy electronics research, stated that their greatest defect in comparison with American radar design was their inability to turn out a high powered centimeter transmitting tube. Most students of the situation will agree.

Very severe criticism must be levelled at those Japanese military leaders who so long insisted that army and navy research, development, production, and operation must be kept entirely separated. The number of scientists in Japan sufficiently skilled to undertake radar research is much more limited than in the United States; it was inadequate to begin with. It was then the height of folly to insist on reducing their effectiveness by nearly one-half by requiring all projects, oftentimes parallel, to be studied secretly within each of the two services.

It reflects great credit on our military and civilian leaders that they had the foresight and broadmindedness to combine all our talent in a common research for both the army and the navy. It is a tribute to our country's physicists', mathematicians', and engineers' skill in electronic research and equipment development that we were able to conceive and build radars of exceeding accuracy for fire control and ground controlled interception. While these were not vitally necessary to us in our offensive, had they been developed by Japan's scientists they would have helped her immeasurably in defending for three years her ships and ground forces all the way from Guadalcanal to Tokyo.

II - ELECTRONIC RESEARCH*

1. General. Electronic research was handled entirely separately by the Japanese Army and Navy. A certain amount was done by research laboratories directly under the respective ministries. Much of the fundamental navy research was done in this fashion. The army, however, assigned more of its pure research to various universities and technical institutes. At the same time several of the larger radio and radar manufacturers were actively engaged in vacuum tube and materials researches, some by direction of the military people, and the rest under their own inspiration. Besides this, of course, the manufacturers were heavily engaged in the problems, many of which bordered on the field of research, of trying to meet the specifications of sets ordered by the two services.

2. Army Research in Electronics. After the development in 1941 of the first detector by the Sumitomo Company and the first locators in 1942 by the Tokyo Shibaura Company, an army unit called Tama Research Institute was formed to foster the expansion of radar research. This Institute, with headquarters located since June 1943 in a schoolhouse at Kunitachi on the western outskirts of Tokyo, and earlier at Tachikawa, was charged with the responsibility for all radar research for the army. The laboratories which were established nearby were bombed heavily on 3 April 1945 and about 50% destroyed. The various sections of the research work were then disbursed according to geographical locations shown in the following outline. The approximate number of engineers and scientists in each section is shown in parentheses.

The staff shown below comprised 88 officers; they had 96 trained assistants, and they had some 600 more on the payroll of whom about half had some technical knowledge. The rest were stenographers, guards, etc. The Institute's appropriations for the past three years were:**

1943 - ¥ 12,000,000
1944 - ¥ 16,000,000
1945 - ¥ 16,000,000 (of which only about ¥ 7,500,000 was spent).

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*This field is the subject of a special report by the Scientific and Technical Advisory Sections, GHQ, U.S. Army Forces, Pacific.

**The current military exchange rate of 15 yen for 1 dollar is likely to be quite misleading as to the magnitude of the budgetary figures shown here and elsewhere in this report. The average factory worker in Japan is paid from 7 to 10 yen for a 10 hour day or say 1 yen per hour. For equivalent work factory employees in the United States would be paid perhaps 1 dollar an hour. For a rough estimate of the equivalent American purchasing power allotted for these activities the yen sign might be replaced by the dollar sign.

ORGANIZATION OF ARMY RADAR RESEARCH

- Chief of Institute (Lt. Gen. Suda)
  - General Administration - Kunitachi (4) (Col. Hatao)
  - Paymaster - Kunitachi (5)
  - Research
    - Planning - Kunitachi (5) (Col. Hatao)
    - Airborne Radar - Ome (17) (Lt. Col. Ochai and Major Takamura)
    - Fundamentals, Countermeasures - Fujioka (15) (Majors Katzuki and Ikeda)
    - Ground radar for Plane Detection - Kugayama (17) (Col. Satake)
    - Tubes, Parts - Suwa (12); Note the tube research was done principally at various universities, and headed up at the Suwa laboratory. (Major Mano)
    - Service Branch - Kobe (12)
  - Test Flight Section - Kunatachi (3)

This included certain costs for models constructed, and of the balance 80% was spent for experimental work, and 20% for fundamental research. The Institute also provided a consulting service for the army forces operating the equipment. For example they assisted in selecting sites in difficult cases, Major Fukano being mentioned as their expert consultant on such matters in mountainous terrain. When continuing troubles arose in certain sets, Tama attempted to find the answers.

The accompanying Table 1 lists the research projects under way at outside universities and laboratories at the close of the war. Table 2 lists certain other projects conducted at the Suwa Laboratory which was one of the Tama Institute branches. A few additional projects not included in the tables may be mentioned;

a. No magnetron research was directed by the army; it was all handled by the navy who turned them over to the army for use.

1.

August 15,1945

PRESENT SET UP OF OUTSIDE COORDINATED RESEARCH PROGRAM

PLACE OF RESEARCH		RESEARCH HEADING	STATUS OF PROGRESS AS OF AUGUST 15, 1945	PERSON IN CHARGE
TOKYO IMPERIAL UNIVERSITY	NAVIGATION RESEARCH	Basic research on Radar Altimeter	Research completed. Change in instrument completed	Hitoshi Ihoue
		Drafting of plans for distance scale adjuster of detector	Research completed. Direction of construction underway	Noboru Takaki
		Basic tests on air-borne antennas	Research, conducted with models, relative to the effect fuselage bears on ability of A-C to keep on course. Nearly completed	Yoshio Moriwaki
		Basic research on crystal detectors	Test underway on ore and ultra-ultra short wave transmitter-receiver circuit using crystal detector	Katsufuea sakamoto
		Research on the Braun tube	Test underway on characteristics of the substance of light remaining on the Braun fluorescent light tube (C.R.T.)	Chohei Fujitaka
			SUPERVISOR OF FIVE HEADINGS LISTED ABOVE	Seiji Hoshiai
	THEORY	Research on cavity resonators	Basic research on the method of drafting a cavity resonator and a practical vacuum tube.	Masao Kotani
	MFG	Research on selenium rectifier	Research underway on the improvement of the capabilities of the selenium rectifier	Risaburo Tokikai
TOHOKU IMPERIAL UNIVERSITY	RESEARCH ON COMMUNICATION	Research on the ultra-ultra short wave receiver	Research underway on ultra-ultra short wave receiver formula and on receiver tube	Shintaro Una
		Research on antennae	Research underway to correct defects on aerials used in the different radar equipment	Yujiro Koike Koki Hiroshina
			SUPERVISOR OF TWO HEADINGS LISTED ABOVE	Heichi Nukiyama
	METALLURGY	Research on metals	Experiments mainly on magnets for use on magnetrons underway	Son Nishina
OSAKA IMPERIAL UNIVERSITY	PRODUCTION	Research on methods of transmitting and receiving on ultra-ultra short wave	Carrying out basic experiments mainly on radar equipment with Doppler effects. No expectation of putting into immediate operation.	Kinjiro Okabe
		Basic research on resonant cavities	Carrying out tests on the basic calculation of the wave director tube(wave guide) and its practical use	Shinobu Sonoda
		Research on high frequency insulating material	Carrying out research on synthesis of a superior polyethylene	Yukichi Kure
	THEORY	Basic calculation on resonant cavities	Engaged in calculation and general theory on cavity resonators	Yasuji Fishimi Keno Nagamiya
HOKKAIDO IMPERIAL UNIVERSITY	RESEARCH ON SHORT WAVE	Research on slot radiators	Carrying out basic tests on slot radiators with models.	Yoshihiro Asami
		Research on resonant cavities	Engaged in research on basic theory of wave director tube	Tadashi Matsumoto
		Research on theory of warning devices	Engaged in work in basic theory of warning devices in general.	Katsumi Emabori
TOKYO INDUSTRIAL COLLEGE		Basic studies on wave radiation	Studies and tests being carried out mainly on vertical lobe patterns of the meter wave band nearly completed.	Ichisaku Koga
		Research on ultra short wave transmitters receiver	Research on amplification of sending and receiving tubes.	Kiyushi Morita
		Research on high frequency materials	Engaged in the improvement of wireless insulation Engaged in tests to determine effects of the presence and absence of electric wave absorbent material	Tadao Korenami
TOKYO LIBERAL ARTS COLLEGE		Research on resonant cavities	Engaged in studies of the basic theory of the wave director tube.	Shinichiro Asanaga
WASEDA UNIVERSITY	THEORY AND MFG	Basic studies on wave radiation	Engaged in studies on the spreading of electric waves on STD terrains and on the attentuation of electric waves when in various mediums.	Tomoyshi Hirota
		Research on the Braun tube	Engaged in improvements on the Braun tube electron gun.	Sueo Tanaka
			SUPERVISOR OF THE TWO HEADINGS LISTED ABOVE	Kenzaburo Kurokawa
PHYSICAL LAWS		Tests on reflect-	Engaged in tests on reflection of meter wave band	Kenichi

INDUSTRIAL COLLEGE		wave radiation	vertical lobe patterns of the meter wave band nearly completed.	Koga
		Research on ultra short wave transmitters receiver	Research on amplification of sending and receiving tubes.	Kiyushi Morita
		Research on high frequency materials	Engaged in the improvement of wireless insulation Engaged in tests to determine effects of the presence and absence of electric wave absorbent material	Tadao Koremami
TOKYO LIBERAL ARTS COLLEGE		Research on resonant cavities	Engaged in studies of the basic theory of the wave director tube.	Shinichiro Asanaga
WASEDA UNIVERSITY	THEORY	Basic studies on wave radiation	Engaged in stuuies on the spreading of electric waves on STD terraine and on the attentuation of electric waves when in various mediums.	Tomoyshi Hirota
	AND MFG	Research on the Braun tube	Engaged in improvements on the Braun tube electron gun.	Suge Tanaka
		SUPERVISOR OF THE TWO HEADINGS LISTED ABOVE		Kenzaburo Kurokawa
PHYSICAL LAWS OF ELECTRIC WAVES		Tests on reflection from a/c	Engaged in tests on reflection of meter wave band from A-C	Kenichi Maeda
		Study of wave interference	Engaged in study of interference on various standard terraine.	Kenichi Maeda
ELECTRIC TESTING STATION		Basic research on navigation equipment	Engaged in basic research on methods of guiding friendly aircraft	Minoru Okada
		Research on computers	Expediting the production of uniform models of computers	Sadao Matsumura
		Research on high frequency insulators	Engaged in research to improve insulating material on wire and wireless	Sakuji Komagata
		Basic research on spreading of electrical waves.	Engaged in test and research on unusual electric wave reflection	Tetsuo Kawano
		Basic research on electron tubes.		Hiroshi Kiyomiya
		SUPERVISOR OF ABOVE FIVE HEADINGS		Kanichi Ohashi
COMMUNICATION INSTITUTE		Basic test of spreading of electrical wave	Engaged in test on the spreading of the meter wave band on various terrains	Shigeru Yonezawa
BROADCASTING ASSOCIATION	TECHNICAL RESEARCH INSTITUTE	Research on ultra-ultra short wave transmitter receiver	Relative to centimeter frequency transmitter receiver	Tatsugi Nomura
		Research on ultra-ultra vacuum tube	Same as above engaged mainly in experiments and research on receiver tube	Yoshihiko Aoyama
		Research on measuring equipment	Engaged in research on centimeter wave meter signal generator	Shichiro Miki
		SUPERVISOR OF ABOVE THREE HEADINGS		Gennosuke Hara
KOKUSAI ELECTRIC COMMUNICATION COMPANY	TECHNICAL RESEARCH INSTITUTE	Research on Antennas	Engaged in research to develop antennas for the various types of radar equipment	Hikotaro Takeuchi
		Research on ultra short wave tubes	Engaged in experiments and researches to develop tubes for transmitters and receivers using meter waves and lower.	Minoru Yamashita
		Research on high frequency materials	Engaged in research on wireless insulation materials. Emphasis on the improvement of the titanium oxide porcelains	Taru Moritani
		Research on high vacua	Engaged in research mainly to improve the vacuum pump oils	Katagiri
		SUPERVISOR OF ABOVE FOUR HEADINGS		Shugo Namba
MUNITIONS MINISTRY	CEREMIC WARE TEST	Research on wireless insulation	Engaged in research to increase war time production of wireless insulation materials making use of research results gained thus far.	Toru Akitsuki

Table 1. - Japanese Army Electronics Research at Outside Laboratories

Table 2.

RESEARCH TO BE CONDUCTED AT SUWA LABORATORY -
A BRANCH LABORATORY DIRECTLY UNDERT TAMA

Subject	Abstract	Status 15th Aug
Crystal Detector for detection mixing	Crystal: Pyrite and metallic silicon Needle: Tungsten or Nickel	Trial product at laboratory
Improvement of vacuum tube	Improvement of bad parts; work to reduce the quantity of critical materials required - e.g., tantalum was scarce. Some tubes studied were the SY-5 and SN-7.	Under way
Secondary electron multiplier	(1) 1 stage or 3 stage radio-frequency multiplier gm = 12,000 (at Ip = 15 ma.) (2) Target: Ag and Mg alloy	Making tests
Antenna or trans-receive switching valve (T/R device)	(1) Jointing of glass and mettalic plate. (2) Enclosure of gas (example, H_2) (3) Construction of electrodes	Part (1) already studied. Electrode study, making tests.
Glass working with-out town gas	Glass working with gasoline or alcohol portable burners	Gasoline 50% alcohol 50% Possible to work hard glass.
Oxide cathode for pulsed transmitter tube	(1) Ba and Sr oxide treatment (2) Measurement of emission current	Planning only
Titanium condenser	E = 200 Power Factor order of 10^{-3}	Making tests
Tube socket	(1) 8 pin cushion socket (2) Acorn tube socket	Design complete only.

b. A project was under way to "countermeasure" the 3 cm equipment in the B-29s. They planned a set with a 1 kilowatt output average, with a peak power of 150 kw. This they proposed to obtain by parallelling 8 water cooled magnetrons. The only hitch was that they never were able to build a suitable 3 cm magnetron.

c. The plans and parts received from Germany by submarine on the Wurzburg set were handled by Tama Institute, and later turned over to the Nihon Musen Company for engineering and manufacture.

d. The highest frequency set actually built and installed under Tama direction was the Tase-2 15 centimeter equipment designed for mounting on army transports as warning against enemy submarine attack. This set's performance, however, did not come up to expectations.

e. Until June 1945, the army radar school Dempa Heiki Renshubu, near Tachikawa was under the direction of Tama Institute; at that time the school was transferred to a position under the Education Bureau of the Air Force.

f. Various captured American radar equipments were analyzed by Tama Institute scientists and engineers. They admit to studying an American IFF from a B-24 shot down at Sasebo, Omaha Bay, about October 1944. It was damaged, however, and could not be made to work.

g. Parts of radars from shot down B-29s were collected by Tama and turned over to various manufacturers for examination and duplication if possible of magnetrons. They claimed that they never got all of the parts for an AN/APQ-13 so that they could actually put one together and make it run. Conflicting statements from manufacturers' engineers seem to indicate that enough components were repaired and assembled so that bench observation of operation was possible. All estimates made by the Japanese of the magnetron power output of the Q-13 were surprisingly far too low.

3. Navy Research in Electronics. The navy's equivalent to the army's Tama Institute was the electronics department of the Second Naval Technical Institute, with headquarters at Kanazawa, near Yokosuka Naval Station, thirty miles south of Tokyo. Several branch laboratories and test stations were established in the Tokyo vicinity. The general activities of each were:

Second Naval Technical Institute - Kanazawa - Airborne radar and radio development and test.

Meguro Park, Tokyo	- General Offices--Communication, IFF and airborne radar development.
Shimada	- Theoretical Study of Radar, magnetron research
Takorazawa	- Direction Finders, Radar Detectors
Daito, Chiba	- Radar
Tsukishima, Tokyo	- Radar Field Laboratory for shipborne equipment.
Hiratsuka (Chigasaki)	- Wave Propagation, and field testing of early warning, locators, and guide radars
Negishi, Yokohama	- Radar (Type 14)
Kawania	- Beacons

The activities of the electronics department of the Second Institute were headed by Vice Admiral Nawa; some of his assistants were:

Captain Yajima	- Administrative Officer
Captain Arisaki	- Communications Research Engineer
Captain Ito	- Chief of Magnetron Research
Dr. Takeyanagi	- Assistant Chief of Radar Research
Mr. Uyeminami	- Engineer and Interpreter (MIT graduate)

The Institute's electronics division employed 350 technicians including 80 engineers and scientists. The annual budget amounted to ¥100,000,000 which included the costs of making prototypes for all land, air and shipborne communications and radar. The actual installation on ships however was not handled by the Institute. A list of the research projects carried out since 1940 by the Radar and Communication Department is given in Table 3. Included are studies on tubes, materials, test equipment, circuit development and the testing of many components and complete radar and radio sets. One of some interest was Apparatus "A" by which it was proposed to cause their own shells to explode at predetermined positions or heights by their passing through a strong beam of centimeter radiation. As noted their failure was due to the "lack of an adequate receiving apparatus." They did succeed in 1944, however, in generating 10 kw of continuous power at a 20 centimeter wavelength. Most recent magnetron researches had resulted in tubes yielding 1.5 kw of pulsed power at 2.7 cm, and "just observable" powers at 0.7 cm. A running history of their radar development may be gained by following the projects for the improvement of each set or a better substitute for it as shown in the table. The list of developments in the radio field is also included as being of possible interest and indicative of the state of the electronic art in the Japanese navy at various times. A supplementary statement of the research time used for the development of each navy radar set will be found in the table listing their characteristics on page 2 of Section V.

Table 3.

TABULATION OF RESEARCH PROJECTS CARRIED OUT SINCE 1940

RADAR AND COMMUNICATION DEPARTMENT

THE 2ND NAVAL TECHNICAL INSTITUTE

Subject	Purpose	Remarks
Magnetrons for centimeter wave lengths	Transmitter and receiver tubes for radars	(1941) Transmitter magnetrons of "Tachibana" type; wave length 10 cm.; peak power output (Pi) 2kilowatts. Receiver magnetrons of "Tachibana" type. (1942) transmitter magnetrons of: wave length 20 cm. Pi 2 kw., wave length 15 cm. Pi 5 kw. (1944) transmitter magnetrons of: wave length 5 cm. Pi 10 kw., wave length 3.2 cm. Pi 10 kw., wave length 4.2 cm. Pi 10 kw., wave length 5 cm. Pi 10 kw.
Apparatus "A"	Igniting detonators by radio	(1944) using transmitter magnetrons of wave length 15 cm., continuous power output (Pc) 3 kw., and those wave length 20 cm., Pc 10 kw., experiments were carried out without success due to the lack of adequate receiving aparatus.

Subject	Purpose	Remarks
Researches on electron tubes	To obtain electron tubes of high quality for radars and communication aparatuses.	(1) New types of tubes developed for radars and communication aparatuses: M-312; transmitter magnetrons for type 22 radar. M-60; receiver magnetrons for type 22 and type 51 radars. M-314; transmitter magnetrons for Type 51 radar. RE-3 and RC-4; intermediate frequency amplifier tubes. RT-326; triode oscillator tube for 60 cm wave length. (2) Constant check on quality of all types of tubes in general use.
Antenna system capable of both transmitting and receiving for 10 cm radar.	To get design data for the high frequency circuits of radars using 10 cm waves.	Successful circuits developed for Type 220 and Type 51 radars.
Crystal detector for extreme ultra-high frequencies.	To develop sensitive crystal detector for extreme high frequency reception.	Detector circuit developed, using pyrite crystals and nickel contact wires for radars Types 22, 220, and 51.
Discharge tube for modulating transmitter circuit.	To get impulse modulator of high power and of small size.	This new type of modulator was used for the Type 51 radar.

Subject	Purpose	Remarks
Standardizing parts and materials.		During the past two years about ninety parts and materials were standardized, and their specifications have been accepted by the navy, the army, and JES.
Experiments on testing methods for parts and materials.		Aparatuses for measuring and testing parts and materials have been built and data obtained were used in writing specifications.
Researches on various insulating materials.		Researches on improving polystyrene, ebonite, steatite, etc., were carried out, and manufacturers were instructed.
Land based aircraft warning radars:		
Model 3	Aircraft warning radar.	Completed in Oct.,1942, but not used in the war. Crystal controlled transmitter and receiver; wave length 5 meters; simple system using interference principle.
Model 11	As above.	Completed Oct., 1941; wave length 3 meters, peak power output 5 kw; receiver is double superheterodyne. Effective range against aircrafts 100 km.
Model 12	As above, except portable.	Completed May, 1942; wave length 1.5 meters. complete aparatus installed on trailer for portability. Effective range against plane 80 km.
Model 11, Improved-2	Aircraft warning radar.	Completed Aug.,1943; increased power output of Model 11. peak power output 10 kw. Effective range against aircrafts 150 km.
Model 13	As above, except transportable by plane	Completed Dec.,1943; wave length 2 meters, effective range against aircraft 100 km. Size and weight designed for air transportation.

Subject	Purpose	Remarks
Land based aircraft warning radars:		
Model 11-K	Aircraft warning, installation simplified.	Completed Oct.,1944; wave length 2 meters. Improved for easy installation, mass production, and effective range extended, Range against aircraft 150 km.
Model 14	Long range warning.	Design started Feb.,1945, completed May, 1945. Wave length 6 meters, peak power 100 kw. Effective range 300 km.
Anti-aircraft gun control radar:		
L-1 (Model 4 Type 3)	Search light control.	Completed Sept.,1943; wave length 1.5 meters, peak power 10 kw. installed on frame work of 120cm search light; land base and ship board equipment.
L-2 (Model 4 Type 3 Improved-1).	As above.	Completed Feb., 1944. Above improved in accuracy and simplicity of control. Installed on 150 cm search light; land base equipment.
L-3 (Model 4 Type 3 Improved-2).	AS above.	Completed July, 1945; peak power 20 kw. Accuracy and performance of above improved.
S-3 (Model 4 Type 1)	Anti-aircraft gun control.	Completed April, 1943; wave length 1.5 meters, peak power 20kw, band width of receiver 1 megacycle. Effective range against aircraft 20 km. $\Delta\alpha, \Delta\beta = \pm 1°$, $\Delta R = 100$ meters.
S-2 4 (Model 4 Type 2 Improved-2)	Simplified construction of above.	Completed March, 1944; wave length 1.5 meters. Armored, construction simplified, and accuracy improved of above. $\Delta\alpha, \Delta\beta = \pm 1°$, $\Delta R = \pm 100$ meters.

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Subject	Purpose	Remarks
Airborne radars:		
H-6 (Mark 3 Model 6 Type 4)	For large patrol planes.	Research started Dec.,1941 on stabilization of performance and standardization of tubes, completed about year later; in mass production and used in the war. Wave length 2 meters, power output 3 kw; effective range against large surface craft 110 km, against large aircraft 50 km.
FD-1 (Experimental mark 18 model 6 Type 2)	For small patrol planes.	Experiments started June, 1943 but stopped due to inadequate range. Wave length 2 meters, power output 1 kw.
FM-1	For medium size patrol plane.	Research from Sept.,1943 to March, 1944. Smaller and lighter than H-6, and performance comparable, however arrangement unsuitable for practical use and production stopped. Wave length 2 meters, power output 3 kw.
FD-2	For night fighter	Prototype tested Jan., 1944 to May, 1944; range inadequate. Wave length 60 cm, power output 1kw. Range against plane 3 km., against ship 10 km or more. Accuracy; $\Delta\lambda$, $\Delta\beta = \pm$ a.r degrees.
N-6 and N-6 Improved-1	For small patrol planes.	Prototype tested March, 1944 to Nov., 1944. Improvements were undertaken to increase range. Wave length 1.2 meters, power output 2 kw., range 50% of that of H-6.
FK-3	For small patrol planes, 2 to 3 seater.	Production undertaken before completing test, March, 1944 to Feb.,1945. Not in service. Wave length 2 meters, power output 2 kw. Effective range against large ships 80 km., accuracy of angle 5 degrees.

Subject	Purpose	Remarks
GYOKU-3	For night fighter	Production undertaken before completing test, Aug., 1944 to May, 1945. Installed in few planes.
FK-4	For large patrol planes	Research from Nov., 1944 to April, 1945; experiment stopped July, 1945 because prototype could not be completed due to air raids. Wave length 2 meters, power output 20 kw.; desired range against ships 100 km.
KASUMI-51	Panoramatic scanning, for large planes.	Research from April, 1944 to July, 1945: under test but discrimination of shore line not satisfactory. Wave length 10 cm, power output 5 kw.
Radio altimeter, (FH-1)	For torpedo bomber Plane.	Experiment from April, 1944 to Jan., 1945; in practical use. Wave length 90 cm, power several watts, from 20 meters to 100 meters measurable, error within 5%.
I. F. F. (M-13).	Airborne and shipborne equipment.	Experiment from Nov., 1944 to May, 1945. Has special code keying device. In mass production and going into service. Wave length 2 meters, range 100 km at altitude of 3000 meters.
Aircraft radar antennae:		
Mark 5 Model 1 or 2.	For good matching.	Experiment from Sept., 1944 to April, 1945. In production but not in service.
Embedded in wing.	For high speed planes.	Experiment from Jan., 1945 to April, 1945; test satisfactory and being prepared for service.

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Subject	Purpose	Remarks
Airborne radar detector (FTB & FTC)	For aircraft	Research from June, 1944 to Feb., 1945, test completed July, 1945, but not yet in practical use. Wave length: 75 cm--4 m Effective range: Insight range

Subject	Purpose	Remarks
Model 22 and Model 103	Look out for surface crafts.	Prototype of Model 103 completed June, 1942. Wave length 10 cm. Transmitter uses magnetron M-312, receiver M-60; parabolic reflector type antenna used; super-regenerative receiver. Effective range, battleship to battleship 35 km.
Model 22 Improved-2	As above, but for small ships.	Improvement of Model 22, uses electromagnetic horns and wave guides; test completed Feb., 1942. Transmitter tube M-312, receiver tube M-60 used. Range, from destroyer to destroyer 12 km.
Model 22 Improved-3	As above, but for submarines.	Redesigned for compactness June, 1943; indicator simplified. Transmitter tube: M-312-B, receiver tube: M-60. Electrical source; 500 cycles per second. Effective range from submarine to submarine 8 km.
Receiver Improved-1	Stability of reception.	Redesigned for autodyne circuit, Dec., 1943. Effective range, from destroyer to destroyer 13 km, from submarine to destroyer 9 km.
Model 22 Improved-4	General improvement.	Redesigned to avoid set breakdown, and for ease of production, Dec,, 1943.
Receiver Improved-2	Improved stability.	Receiver redesigned Sept., 1944 for superheterodyne circuit using crystal detector as mixer. Range: from destroyer to destroyer 15 km, from battleship to battleship 30 km, submarine to submarine 10 km.
Single wave guide	For submarine installation.	Type 22 Improved-3 transmitter and receiver used with the single wave guide and electromagnetic horn; range, from submarine to destroyer 10 km.
Type 21	Lookout for aircraft and surface crafts.	Completed June, 1942, wave length 1.5 meters. Transmitter tubes; two T-310; receiver tubes; Un955 and UN 954. Array beam antenna used. Range: from battleship to battleship 20 km, from battleship to aircraft 50 km.

Subject	Purpose	Remarks
Type 13	As above.	Compact antenna designed for small vessel installation. range against aircraft 40 km.
Type 13 Improved	As above, for submarine installation.	Antenna of Type 13 redesigned, Jan., 1944 for submarine installation; short wave communication lift mast used, non-directional characteristics. Transmitter and receiver made compact. Range against aircraft 30 km.
As above	As above	Feb., 1944 antenna of above simplified to 2 X 4 array. Effective range against plane 50 km.
Locating radar Type 213	Meter wave locating radar for surface	Completed Jan., 1944. Antenna of Type 21 separated into two and switched alternately. Indicator improved, accuracy improved and range extended. Accuracy of angle: $\Delta\beta = \pm 1.5$ degrees, of range $\Delta R = 200$ meters.
Type 215	As above.	Experiment stopped May, 1944, tests failure.
Type 23	As above.	Aug., 1944 the Model 2 Type 3 completed. Wave length 58 cm. Accuracy of range $\Delta R = 50$ meters, accuracy of bearing $\Delta\beta = 30'$. Effective range: battleship to battleship 20 km. In spite of good accuracy, not used due to short range.
Type 24	As above.	Prototype completed Oct., 1944. High accuracy but not accepted due to inability to produce tubes.
Type (105-S2) (32)	As above. (10 cm)	Completed Sept., 1944 for battleship installation. By enlarging the electromagnetic horns and using equal deflection method, and improving the indicator, the accuracy of bearing and range improved. Transmitter and receiver are Type 22 Improved-4. Accuracy of measuring range ± 100 m of bearing $\pm 10'$. Effective range:

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		35 km. Not as yet installed on battleships, but April, 1945 installation undertaken at land base.
Type (220) (31)	As above.	Completed March, 1945. Uses Parabolic refrector which increased antenna gain. Transmitter and receiver same as Type 22, maximum method of indication. Accuracy of range ± 100 meters, of bearing ± 40'.
Radar for guiding boats, Type TH	To guide small size boats.	Experiment stated May, 1944. uses existing equipment such as radar L-3 and I. F. F. M-13; tests completed but not accepted due to inffective range. Wave length 1.5 meters, peak power 20 kw., effective range 15 km., accuracy within 1 degree.

Subject	Purpose	Remarks
Portable Direction Finder for Long and Medium Wave Length.	For removable airfield use.	Experimental set completed April, 1942; is modification of Telefunken apparatus. Frequency range 115 kc to 3,500 kc. Antenna, rotating 100p. Receiver gain, 110 to 120 db. Range about 100 miles. Accuracy ± 5 degrees to ±1 degree.
Medium Wave Direction Finder Type 2.	For land base use.	Experimental set completed June, 1942; installation begun Dec., 1942. Frequency range from 500 kc. to 4,200 kc. Receiver gain, 135db. Antenna system, coupled U Adcock. Range about 1,500 miles. Accuracy ± 3 deg. to ± 1 degree.
Short Wave Direction Finder Type 3.	For land base use.	Experimental set completed March, 1943; installation begun Jan., 1944. Frequency range from 3,500 kc. to 20,000 kc. Receiver gain, 130 to 135 db. Antenna system, double coupled U Adcock. Range about 2,000 miles. Accuracy, ± 3 degrees to ± 1 degree.
Long and Medium Wave Direction Finder.	For shipborne installation.	To extend frequency range into medium wave lengths, experiments stated in March, 1943. Proto-Type completed May, 1944, and installed aboard experiment boat for further study; valuable data obtained for determining correct installation. Frequency range 115 kc. to 5,000 kc. Receiver gain, 125 db. Antenna system, fixed crossed loop with plane goniometer. Range about 300 miles. Accuracy less than ± 5 degrees.
All Wave Direction Finder.	For submarine use.	Experimental set completed Sept., 1943. Experimental installation made. Bearing error anticipated from model tests. Frequency range, 115 kc. to 15,000 kc. Antenna, waterproof rotating loop. Range 150 miles, error ± 5 degrees.

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Subject	Purpose	Remarks
Radar detector for submarine use (E 27)	Enemy radar wave detector	At first almost the same kind of radar intercepts as for surface craft was used for submarines. Recently, after several improvements, directional and non-directional sets were in use. Wave length: 75 cm--4 m
Portable short wave direction finder	For submarines	Prototype completed Dec, 1944, and in test production. Wave length, Ko: 10,000--6,000 KC Otu: 8,000--3,000 KC

Subject	Purpose	Remarks
Ultra Short Wave Radio Beacon (URB).	For guiding ships.	Experimental apparatus completed Feb., 1941; experiments concluded June, 1944. Frequency range from 120 mc. to 150 mc. Effective distance up to 40 km.
Medium Wave Radio Beacon (MRB)	For guiding ships.	Experimental set completed June, 1945. Wave length 100 meters. Effective distance 100 km.
Propagation of electic waves.	To get data for selection of frequencies.	Continuous observation of ionosphere, and field intensities of radio waves. Made radio wave propagation charts, and charts for ultra-high frequencies for radar use. Gave prediction on propagation characteristics.
Frequency standard	Improving accuracy of setting communication frequencies.	Designed apparatus for primary standard. Observed standard frequency waves broadcasted by the Department of Communications. Designed apparatus for checking frequencies for power plants. Researches on various mechanical vibration systems, Facilities destroyed in air raid April, 1945.
Short Wave Receiver Mark 97.	For shipborne installation.	Experiment completed 1941. Straight amplification, A1, A2, A3 reception, frequency range 3,000 kc. to 20,000 kc. About 100 sets produced and further production stopped.
Ultra Short Wave Receiver (TR 10).	Shipborne	Experiment concluded 1941; in service. Superheterodyne, A1, A2, A3 wave reception; frequency range 30,000 kc. to 80,000 kc.
Preamplifier for Long Wave Receiver (E 12).	Adaptor for underwater signal receiver.	Research concluded 1941, in service. Two stage amplifier giving 90 db., Frequency band 17 kc. to 33 kc.

Subject	Purpose	Remarks
Space Keying Apparatus	As adaptor	Experiment completed 1941. Not in service.
Short Wave Receiver	Compact set for long distance work.	Experiment completed 1942, not produced. Double superheterodyne for A1, A2 A3 reception. Frequency range 3,500 kc to 30,000 kc, gain 140 db.
Short Wave Receiver Model 5.	Shipborne	Experimental set completed 1943, experiment stoped. Superheterodyne for A1 A2 reception. Frequency [illegible],000 to 10,000 kc.
Long Wave Receiver Mark 92-A (OTC)	Land base equipment	Experimental set completed 1944. Superheterodyne for A1 A2 reception. Frequency range 10 to 100 kc, with limiter tonekeyer.
Ultra Long Wave Receiver (K 26)	For submarine	Research completed 1943; in service and in production. Straight amplification, A1 reception. Frequency range 13 kc to 25 kc, gain 160 db.
All Wave Receiver Mark 3	General use	Research completed 1944. In production and in service. Superheterodyne for A1 A2 A3 reception. Frequency 20 kc to 20,000 kc. Crystal can be used for 1st local oscillator.
All Wave Receiver Mark 19	For Communication base	Research completed 1944; in production, and partly in service. Superheterodyne for A1 A2 A3 reception. Frequency 150 kc to 20,000 kc.
Medium Wave Transmitter Mark 1-5	Shipborne	Experimental set completed 1941. power output 250 watts, frequency band 4,000 kc to 1350 kc, A1 A2 A3 waves. In service.
Medium Wave Transmitter Mark 2-5A	Shipborne	Experimental set completed 1943. power output 250 watts, frequency-band 4,000 kc to 1200 kc, A1 A2 A3 waves. In service.

Subject	Purpose	Remarks
Medium wave Transmitter Mark 3- 7	Shipborne for local communication	Frequency band 3500 kc to 1150 kc. Al waves. In use.
Medium wave Transmitter Model 6	Shipborne	Experimental set completed 1943. Power output 50 watts, frequency band 3500 to 1150 kc, Al A2 A3 waves. Not in production.
Short Wave Transmitter Mark 1-5	Shipborne	Experiment stopped, prototype destroyed by fire.
Short Wave Transmitter Model 2	Shipborne, for long distance work	Experimental set completed 1943. Power output 5 kw. Frequency band 25,000 kc to 6,000 kc. Al A2 waves. Not produced.
Harmonic Transmitter Model 4	Shipborne, for long distance work.	Experimental set completed 1943. transmits three waves simultaneously. Power output 500 watts, frequency band 24,000 kc to 6,000 kc, Al waves. Not produced.
Short Wave Transmitter Mark 3-4	Shipborne	Experimental set completed 1944. Power output 500 watts, frequency band 18,000 kc to 3,500kc, Al waves. In use.
Short wave Transmitter Model 5-4	Land base use, phone communication with aircraft	In trial production. Power output 250 watts (A3 wave). Frequency band 10,000 kc to 2,500 kc. Al A2 A3 waves.
Ultra Short Wave Transmitter Mark 3-6	Shipborne	Experimental set completed 1944. Power output 60 watts, frequency band 80 mc to 40 mc. Al A2 A3 waves. Not used.
Wireless Remote Keying Apparatus	Land station	Experimental set completed 1944. Power output 500 watts, carrier frequency 61 mc to 57 mc, five channels. In use.
Radar Model 3	Aircraft warning, land based	Experimental set completed 1942. Power output 150 watts. Frequency band 18,000 kc to 1750 kc. Not used.

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Subject	Purpose	Remarks
Short Wave Portable Telegraph Apparatus Mark 1-4	Mobile communication	Experimental set completed 1944. Power output 150 watts, frequency band 18,000 kc to 1750 kc. A1 signal. Not used.
Portable Telegraph Apparatus Improved-1	Shipborne	Experimental set completed 1942. Power output 30 watts, frequency band 10,000 kc to 1,750 kc, A1 A3 signals. In use.
Portable Telegraph Apparatus	General communication	Experimental set completed 1943. Power output 0.1 watt, frequency band 50 mc to 25 mc, A2 A3 waves. in use.
Improvement of Short Wave Telegraph Apparatus Mark TM-C	Communication base	Experimental set completed 1945. Frequency band 14,000 kc to 1,875 kc (old set 12,000 kc to 3,750 kc).
Matching box Type 4	Shipborne	Prototype completed 1943. for frequency band 4,000 kc to 1,200 kc. In use.
Rectifier	For Transmitter	Experiment completed 1942. Dry rectifier using selenium cells. In production.
Carrier Telegraph Terminal Apparatus Model 3	To add carrier telegraph to voice frequency band.	Experiment from March, 1942 to May, 1943. Carrier frequency 1,615 cycles, line loss about 25 db. In production.
Portable Carrier Telephone Terminal Apparatus Model 1	To develope five channel carrier telephone for bare aerial lines	Experiment from March 1943 to March 1944. Carrier frequencies in kc: 60, 68, 76, 84, 92, 108, 116, 124, 132, 140, Line loss about 25 db. In production.

Subject	Purpose	Remarks
New wireless telephone for fighter	For fighter	Research completed July, 1945, in mass production, but not yet in practical use. Freq. range 3750--6000 KC Two wave selection is possible by push button.
Adapter for modulation or wireless telegraph into telephone	For medium and small size planes	Adapter for changing wireless telegraph apparatus into telephone communication apparatus (for medium and small size planes). Research completed July, 1945 and in mass production.
Adding medium freq. band to the short wave transmitter		Adding 1750 KC to 3750 KC band to the short wave band. Several experimental sets completed but not yet in practical use.

Subject	Purpose	Remarks
Portable Carrier Telephone Terminal Apparatus Model 2	One channel telephone for cables	Experiment from March 1943 to March 1944. Carrier frequencies: lower side bands of 7.7 kc and 12.4 kc. Line loss about 60 db. Production models destroyed by air raids.
Carrier Telephone Terminal Apparatus Model 5	Six channel telephone terminal equipment for bare line	Experiment from June, 1944 to March, 1945. Carrier frequencies in kc: 36, 44, 52, 68, 76, 84, 100, 108, 116, 132, 140, 148. Line loss about 25 db to 35 db. Improved Model 1, not in production.
Research on transmission characteristics of various lines	Study of steel and insulated wires	Study started August, 1944, on rubber insulated steel wires. Data destroyed by air raid.
Ultra-violet Ray Signal Apparatus	Invisible ray Signaling for warships	Fundamental study of transmission and absorbtion of ultra-violet rays in air and water made. Prototype using high presure mercury arc lamps tested. Audio amplifiers studied. Range limited, not in production or use.
Radio Control Apparatus	Radio control of targets	Several types designed. Experimental apparatus installed on old destroyer and battleship.

III - MANUFACTURE OF RADARS

1. General. The production of radars for both the army and navy was contracted for by a relatively few large manufacturing concerns, who in turn were supplied parts and minor assemblies by a myriad of small producers. The method of handling was not unlike that used in the United States. The three principal Japanese radar manufacturers were the Nihon Musen Company, the Tokyo Shibaura Denki, and Sumitomo Tsushin Kogyo. Each maintained a staff of electronic research workers principally recruited from the company's peacetime research engineers, physicists, chemists and metallurgists. In the following sections a brief resume of the capabilities and work of each company is given.

2. Nihon Musen.

a. Personnel: Mr. Seingi Nakajima, Managing Director (President).
Mr. Tsugamura, Engineer for Army radar equipment.
Mr. Shigeru Nakajima, In charge of Vacuum Tube Research.
Mr. S. Funabiki, Engineer and Interpreter.

b. Company, Size and Affiliations.

The Nihon Musen Company has been a Telefunken (German electrical equipment manufacturer) affiliate since 1923. At that time the company was capitalized at one million yen, one-third of the shares being held by Telefunken. When capital was increased 10% of this increase went to Telefunken. By the time of the present war the company had expanded greatly, and was capitalized at 30 million yen. In the first ten years of the association Telefunken supplied technical information freely, but in following years this was considerably curtailed since the Japanese had little technical information to supply in exchange. Nihon Musen sent only one man, a vacuum tube expert, in 1937 to Germany where he stayed for 2 years. A commercial representative of Telefunken was in Tokyo during the war, but no technical men. The commercial man had not been seen by Nihon Musen for several months. In 1943 the contract with Telefunken expired; Nihon Musen desired to renew it but no communication with Germany was possible. It was apparently partly through this historical connection that plans and some model parts for the small Wurzburg were acquired in Germany and sent to Japan by submarine in January 1944. Nihon Musen officials expressed their desire to establish technical information exchange and perhaps other connections with some American firm to replace their former association with Telefunken.

c. Plants.

(1) Mataka (20 km NW of Tokyo). This is the main Nihon Musen plant, manufacturing radio and radar equipments. During the war a maximum of 8000 employees were engaged. One shift only was worked. At one time the company was ordered to work 2 shifts, but the night efficiency was so poor, due considerably to the employees having to huddle about

charcoal heaters to keep warm that a rapid return was made to the one-shift program. This plant was uninjured by Allied bombings, and appeared to be in excellent repair. Plans were actively being made to transfer the plants chief energies to the post war manufacture of civilian radio sets and heating applianc s.

(2) Nagano (250 km NW of Tokyo). In this plant which employed 5000 persons, 60% of which were women, ground and airborne military and navy radio sets were chiefly manufactured. The management stated that the Japanese women made excellent workers for small assembly jobs and excelled the men for fine work such as winding coils.

(3) Ueda City. Here the principal work during the war was manufacturing communication apparatus and direction finders for the Navy. Maximum number of workers employed was 2500.

(4) Suwa. This plant was still under construction when the war ended, and would have built vacuum tubes. About 1000 persons would have been employed.

(5) Hammamatsu. This was an idle silk spinning factory purchased by Nihon Musen near the end of the war for the purpose of building vacuum tubes. However, it was destroyed by bombing before any production was obtained from it.

d. Research. The research section, located at the Mitaka plant, was divided in two parts, one on vacuum tubes employing about 60 scientists and engineers, and one on general matters employing about 40 engineers.. Nihon Musen's vacuum tube development under the leadership of engineer Shigeru Nakajima was outstanding. He is given much credit by the president of the company for the design of the magnetrons used in the army's and navy's most advanced radars. Experimental magnetrons down to 0.7 cm wavelength had been built; they estimated they could produce 2 kw of peak power at this wavelength, but a description of their method of measurement makes this figure highly problematical. Down to 2 cm they claimed to have a reliable lamp load method of measuring power outputs.

Claims were also made by Nihon Musen engineers that they had experimental magnetrons which would operate as follows:

No. S-60 - 5 cm wavelength; 18 kw peak power output
No. S-51 - 3 cm " " ; 22 kw " " "

Comparing these claims with those of Captain Ito, chief magnetron researcher at the navy laboratory which worked very closely with, if indeed it did not lead, the Nihon Musen vacuum tube workers, makes them appear extravagent. The best the navy laboratory had been able to do was 1.5 kw at 3 cm.

A laboratory test set up at Nihon Musen of a 10 cm magnetron of the type used in the navy's airborne set No. 51 is shown in Fig. 1.

Fig. 1 - Magnetron Test Set Up at Nihon Musen Company

Other types recently developed here are shown on the company's display board a picture of which is shown in Fig. 2. More complete details are given in another report by this section.*

e. Radars Manufactured. The Nihon Musen plant was carefully divided into two parts, one for manufacturing army equipment and the other for navy. Engineers working in one section were not allowed in the other. Nor were their engineers permitted to observe any tests of the equipment they manufactured after it was installed on ships or planes or at ground positions. This policy was strongly criticized by company officials.

Nihon Musen officials claim to have built the first Army radar in Japan in 1943. This was the Taki 1, a 200 megacycle 10 kw peak airborne search set using a nose Yogi antenna for transmitting and switched antennas on either side of the fuselage for receiving. Notable was the fact that only 6 months elapsed from specifications to manufacture. (See description of set in Section IV of this report.) About 1000 sets were turned out.

* "A Survey of Recent Japanese Vacuum Tube Developments"--Marvin Hobbs, 2d & 3d Operations Analysis Sections Report, FEAF, 19 October 1945.

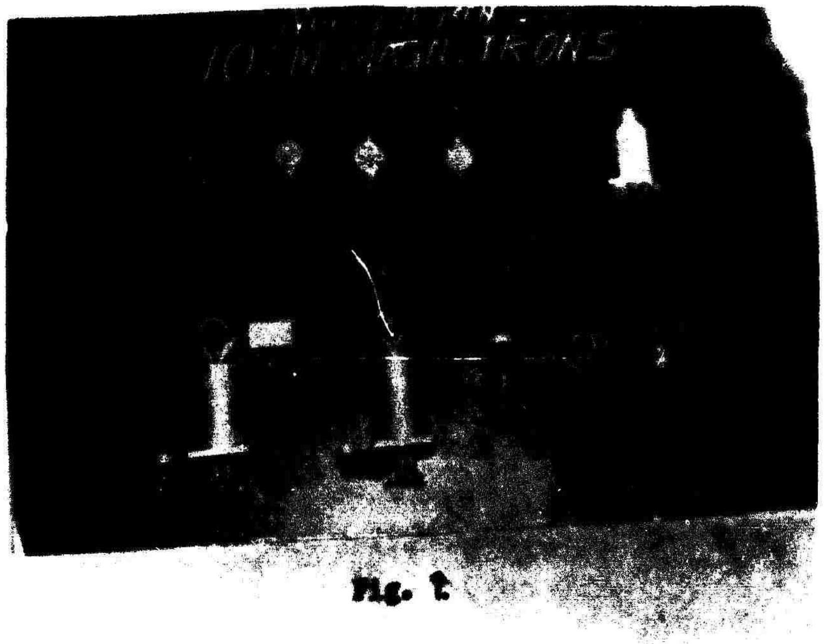

Fig. 2 - Tubes Recently Develcped by
the Nihon Musen Company.

The only ground search equipment furnished the army was a large early warning set built to Sumitomo specifications. Nihon Musen made approximately 40 of these sets.

An army shipborne set (Tase 2) for transports' protection against submarines, and a navy shipborne set (No. 22) for search use on naval vessels were manufactured. Both were magnetron powered, Tase 2 working at 15 cm with peak power of 1-2 kw, and No. 22 at 10 cm with 2.5-5.0 kw peak power. Nihon Musen regarded the army's Tase 2 as a toy compared with the navy's No. 22. Tase 2 used a large parabolic reflector, while No. 22 operated through a waveguide-horn antenna. About 60 Tase 2's were built and about 500 No. 22s. It was generally admitted by Japanese army and navy radar personnel that No. 22 "was the best radar set in Japan."

Nihon Musen was commissioned in early 1945 to build three model sets as soon as possible of an exact copy of the German Giant Wurzburg. This set in Japan was called Tachi 24. Complete drawings were made available to them as well as a small number of the important critical parts including the vacuum tubes, many of which were of special German design. These models were to be given to Sumitomo and Tokyo Shibaura from which they too were to go into production on the Wurzburgs. Manufacture of the models began in March 1945 and the first set was within one month of completion when the war ended on 15 August. One of the short items was Braun (cathode ray) tubes which were to have been manufactured by Sumitomo and Shibaura both of which were having trouble meeting schedules due to heavy bombing of their factories. This would have been the first radar jointly ordered by the army and navy; 50 sets were said to compose the initial order.

Two airborne radar sets were produced for the navy by Nihon Musen. One, developed in 1942, and known as H-6 (or Kaze 1) fulfilled the same purpose for the navy and had about the same characteristics as Taki 1 built for the army. The two sets were constructed quite differently however having different wavelengths and no interchangeable parts. Several modifications were made during the production of some 2000 sets of this H-6 type. The smaller and lighter FK-3 was developed to replace the H-6 but Nihon Musen was not awarded the contract for it.

The second navy airborne set known as No. 51 was still in its experimental stages when the war ended. It was a 10 cm search set powered by a solonoidal type of magnetron. It was reported by personnel at the navy research laboratories that it was modelled after an early British H2S set shot down by the Germans over Rotterdam; hence the origin of its common name at their laboratory, "the Rotterdam Gerate". They said plans of this set had come from Germany over 2 years ago. A block diagram of this set and several pictures will be found under No. 51 in Section V; detailed schematics are given in Appendix II . In flight tests the results were reported as encouraging but not yet all that was desired.

3. Tokyo Shibaura Denki.

a. Personnel: Mr. Suda, Manager of Kawasaki Plant.
Mr. Hamada, Manager of Research Section.
Mr. Shimzu, Manager of Communications Section.

b. Company, Size and Affiliations.

Tokyo Shibaura Denki is the Japanese counterpart of the General Electric Company in the United States, and in fact is affiliated with that company and RCA as far as exchanges of information and certain patents are concerned. Of course no help from those companies was received during the war. Mr. Shimzu and Mr. Hamada had been to America several times and were well acquainted with Dr. Langmuir, Dr. Suits and others at Nela Park and Schenectady. They are planning to salvage what materials and vacuum tubes were left from building military radios and radars and go into home radio and television set building. They are also builders of commercial radios and broadcast transmitters. To aid in expanding the listening public they have proposed to the Japanese Government that they be permitted to construct and operate a private broadcasting station under the rumored plan to permit more than government operated stations. With this possibility in mind they spoke strongly in favor of General MacArthur's directives to liberalize the broadcasting service in Japan.

c. Plants.

(1) Koikawa Cho at Kawasaki (south Tokyo suburb). During the war this plant had 10,000 employees making lamps, small vacuum tubes, fluorescent lamps and the like. It was approximately 50% destroyed by fire bombings.

(2) Yamagi Cho at Kawasaki. This plant with 4000 employees made large radio transmitters, and vacuum tubes, and various radar sets. It was 80% destroyed. Fig. 3 shows the administration building which suffered considerable damage. Figs. 4 & 5 are of adjacent buildings where radars were under construction until the buildings became untenantable.

(3) Komuki - Kawasaki. Here 6000 employees were engaged in making radars and small transmitting and receiving radios for the army and navy. This plant which was 70% destroyed will be rebuilt for the making of heavy radio transmitters.

(4) Fuji (80 miles SW of Tokyo). This was a new factory originally built for rayon spinning. Shibaura began there a program of army radar manufacture with 3000 employees. It was partly destroyed by bombing.

Fig. 3 - Administration Building at Yamagi Cho Plant of Tokyo Shibaura Denki - Kawasaki.

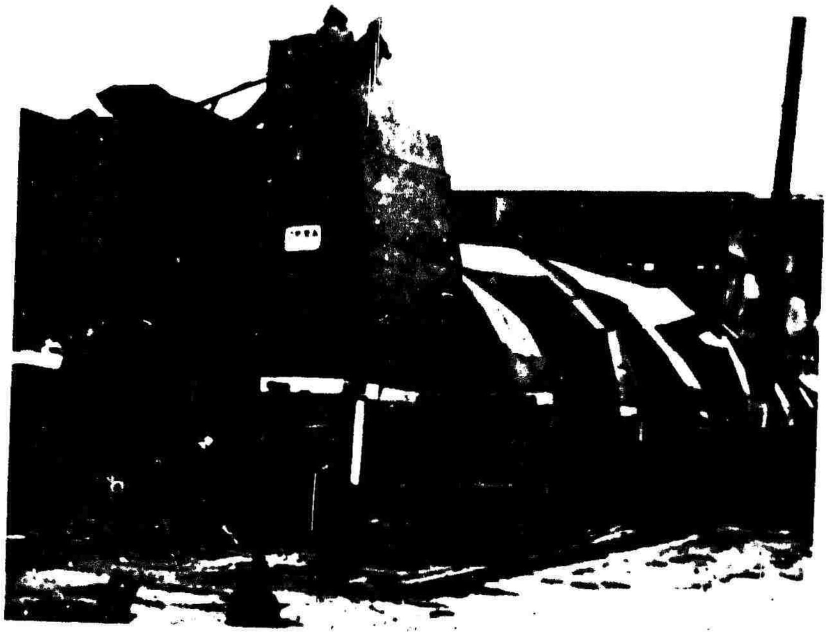

Fig. 4 - View of Radar Factory Building at Yamagi Cho Plant of Tokyo Shibaura Denki - Kawasaki.

Fig. 5 - View of Radar Factory Building at Yamagi Cho Plant of Tokyo Shibaura Denki - Kawasaki.

(5) Yobe (southern Honshu near Shimizu). Here the chief activity was the manufacture of vacuum tubes of all types. Four thousand people were employed. The plant was undamaged by our bombings.

d. Research. The General and Electronic Research Laboratories were located in the Koikawa Cho plant and both were completely destroyed by the B-29 bombings. The General Research section had comprised about 100 engineers and scientists, with 100 more assistants; the Electronics laboratory employed about 1½ times this number.

In the electronics laboratory considerable effort was being expended to produce magnetrons putting out considerable power at higher and higher frequencies. (A 15 cm magnetron for the Tase 2 set was their highest frequency set actually in production.) They studied tubes down to 3 cm, but only built a few of these. In the sketch of Fig. 6 is shown an experimental all metal type seen at their plant; it is claimed to be 9 cm with a 10 kw peak power output when 10,000 volts are applied to the anode. The following performance was said to be obtained from their experimental magnetrons; (See Fig. 7):

3 cm - 1 kw peak - air cooled
5 cm - 3 kw peak - air cooled
10 cm - 5-10 kw peak - air and water cooled

Experiments had been made with materials for permanent magnets. In permanent magnets fields of 2000 gauss were obtained; with electromagnets fields to 3000 gauss were attained.

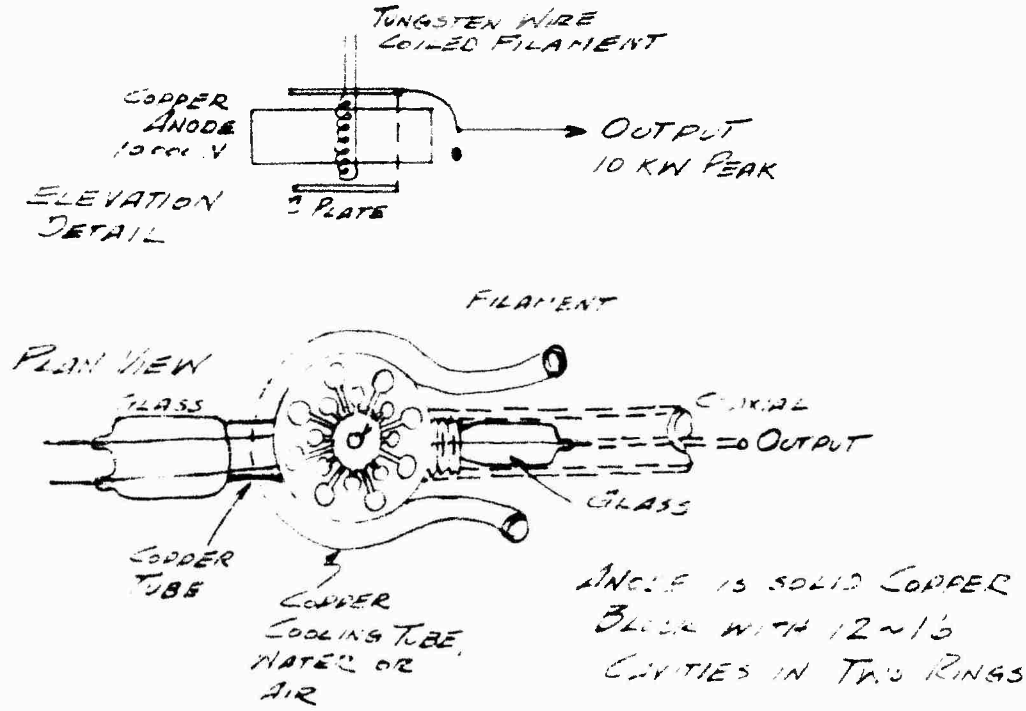

Fig. 6 - Sketch of 9 cm Experimental Magnetron at Tokyo Shibaura Denki.

Some experiments had been made with a Barkhausen local oscillator with positive grid and a crystal detector for receiving sets. They had tried to build power klystrons 5 years or more ago at about 20 cm but without much success. More recently they had experimented with klystrons for receivers at 3, 5 and 10 cm.

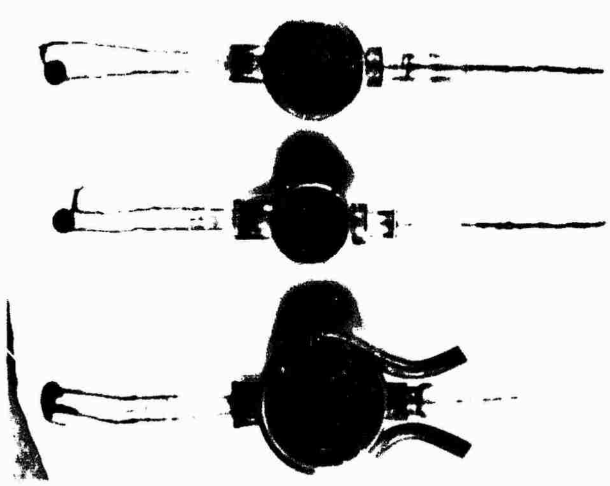

Fig. 7 - Experimental Magnetrons designed by Dr. Harada of Tokyo Shibaura Mfg. Co. Reading top down, they are 5, 3, and 9 centimeters.

TABLE I - Radar Equipment Manufactured by Tokyo Shibaura Denki

Type	Units Made	Wave length	Range	Type Antenna	Approx Number Produced	Comments by Company Representative
				For the Japanese Army		
Taki 1 Model 4	Detector	2 m	100 km	Yagi	Few	Still experimental
Taki 14	Omnidirectional Detector (PPI) Rotating	27 cm	75 km	Yagi with paraboloid reflector	Few	Just getting into production
Taki 18	Detector	3 m	150 km	Yagi	5	Changed to Taki 1 - Model 4
Taki 21	Detector	6 m	100 km	Dipole. Nose aircraft homing; side antennas for search.	Few	Production stopped by end of war
Taki 22	Locator	27 cm	10/3 km	Yagi	Few	Production held up to get out Taki 14
"Sempaku" (meaning ship) or Tase 1	Detector	3 m	300 km	2 x 2 Array	60	Old (1941) design; used on ships and land
"4" (or Tachi 18)	Detector	3 m	300 km	4 x 6 Array	80	
Tachi 13 with Taki 15 (IFF)	Locator	1.7 m	150 km	Ground: (Trans. 3 Dipole Array. (Rec. 2 Dipole Array. Air = λ/4 stub	30	Claimed quite successful.
"Kogata" (meaning small type) or Tase 10	Detector	2 m	150 km	Dipole on "Submarine". 2 x 3 Array with 3 reflectors on land	10	Originally for portable set; later installed on a transport submarine
"Tago" 4-4 (Locator) or Tachi 4 and Tachi 31	Locator	1.5 m	40 km	Yagi	20	Tachi 31 is a modified Tachi 4

TABLE I - Radar Equipment Manufactured by Tokyo Shibaura Denki (continued)

Type	Units Made	Wave length	Range	Type Antenna	Approx Number Produced	Comments by Company Representative
		For the Japanese Army (continued)				
Taki 13	Altimeter (low altitude)	75 cm	12 to 150 m	2 Dipoles (Trans & Rec)	1000	Very useful for torpedo bombing
Tase 2	Periscope Detector	15 cm	----	Dipole and director in paraboloid	20 (Nihon Musen made 60)	
		For the Japanese Navy				
"250" or No. 12 in Trailers. No. 21 on Ships.	Sender	1.5 m	150 km	Land 2 x 6 Array. Ship: various arrays.	300	---
"252" or No. 11K	Sender	2 m	150 km	4 x 5 Array	50	---
No. 13	Sender	2 m	300 km	Ships: Various Horizontal Arrays. Land: Single pole with 4 horizontal dipoles.	1500	Designed for ships but used also on land; a widely used set.
S-3	Sender	1.5 m			50	---
S-24	Sender	1.5 m	300 km	(?)	10	Higher powered than set originally made by Sumitomo
EDC2	Indicator for No. 12		150 km 300 km		50	
1112	Indicator for No. 11K		300 km		1000	
222	Indicator for No. 22 on submarines.		50 km		120	
213B	Indicator for No. 22 on other ships.		60 km		300	

TABLE [illegible] - Radar Equipment Manufactured by Tokyo Shibaura Denki (continued)

Type	Units Made	Wave length	Range	Type Antenna	Approx Number Produced	Comments by Company Representative
		For the Japanese Navy (continued)				
14	Detector	6 m	500 km	Large horizontal Yagi. Antenna 18 meters in diameter. 20 meters high.	10	Made this set last winter in 3 weeks since other transmitters "couldn't catch B-29s"
S8 (F-8?)	Locator	58 cm	40 km	Rotating dipole with 1.7 meter steel paraboloid reflector.	15	Built for ships but not used since No. 22 was superior.
61	Locator	60 cm	80-120 km	7 meter rotating paraboloid	3	Set S-8 was modified and power increased and became No. 61 for land use.
216	Locator	2-1.5 m	80 km	4 x 4 Array	2	Made originally for ship use; navy then attempted to use 216 transmitter in S-24; made 2 complete 216 sets, and 10 transmitters for S-24s.
H6	Detector	2 m	150 km	Yagi	200	Nihon Musen design.
FM1	Detector	2 m	150 km	Yagi	100	Improved H-6
FD2	Locator	60 cm	20 km (?)	Yagi	70	
FH-1	Altimeter (low altitude)	340 mc ± 15	10-150 m	1 Dipole for Trans; 1 Dipole for Rec.	100 (?)	

4. Sumitomo Tsushin Kohgyoh Kabushiki-Kaisha. (Sumitomo Communication Industries Company).

a. Personnel, General Office:

Mr. S. Furuta, Chairman Board of Directors
Mr. T. Kajii, President
Mr. C. Saeki, Managing Director
Dr. Y. Niwa, Assistant Managing Director
Mr. Hirata, Interpreter (from Legal Department)

Ikuta Research Laboratory.

Mr. M. Kobayashi, Superintendent
Mr. J. Ohsawa, Chief of Materials, Basic Research
Mr. M. Kobayashi, Chief of Applied Research
Mr. O. Harashima, Chief Vacuum Tube Research
Mr. T. Shimizu, Chief Airborne Radar Development

b. Company, Size and Affiliation.

The Sumitomo Communications Industries Co. is the principal manufacturer in Japan of telephones and automatic and manual switchboards. They are also leading producers of wireless telephone and telegraph apparatus, home radio sets, broadcasting equipment, vacuum tubes, insulating materials, rectifiers, measuring apparatus and meters, and picture transmission and television equipment. The company was established in 1899, and for many years was affiliated with the American Western Electric Company. Later the International Standard Electric Company, manufacturing subsidiary of International Telephone and Telegraph Company, purchased the Western Electric interests which amounted to 33% of the total shares. These are now held in trust by the Japanese Government. At the beginning of the war the company was capitalized at ¥150,000,000 with 3,000,000 shares issued.

c. Plants and Offices.

		Peak No. Employees	% Damaged By Bombs
(1)	Head Office, 2 Mita-Shikokumachi, Tokyo	---	0
(2)	Mita Plant, 2 Mita-Shikokumachi, Tokyo and Shibaura, Tokyo	7000	0
(3)	Tamagawa, Kawasaki City	15000	60
(4)	Ohgaki, Ohgaki City and Higashi Kasugai-gun	2500	0
(5)	Okayama, Okayama City	3000	100
(6)	Ohtsu, Ohtsu City, Shiga Prefecture	4000	0
(7)	Takasaki, Takasaki, Gunma Prefecture	500	0
(8)	Laboratory, Ikuta-aza, Masugata, Kawasaki	500	0
(9)	Tientsin, China	200	0
(10)	Shanghai, China	200	0

The average total employment during the war was 25,000 persons, working 10 hours a day, 2 days off a month.

d. Research. The Sumitomo Research Laboratory located at Ikuta, 12 miles southwest of central Tokyo is one of the largest electronics research groups in Japan. Three small branch laboratories are maintained at Chiba, Takasaki and Tamagawa. The numbers of persons employed in each as of 15 August 1945 is as follows:

		Ikuta Laboratory	Chiba Branch Laboratory	Takasaki Branch Laboratory	Tamagawa Branch Laboratory	Total
Staff	Engineering	232	2	6	10	250
	Clerical	34	0	0	0	34
Workers and Miscellaneous Hands		382	11	12	12	417
TOTAL		648	13	18	22	701

A considerable portion of the talent in this laboratory was devoted to radar research in one form or another. Ultra High Frequency transmitting tubes and special cathode ray tubes were among their large studies.

In November 1944 Tama Institute directed the Sumitomo Company to develop and build a 5 cm airborne search radar, with the single specification "with as much power and range as possible." At that time they did not know that our B-29s were equipped with 3 cm radars or they might have attempted that wave length.

The tube research section finally succeeded in devising a 5 cm magnetron with equalizer ring which developed 1 KW of pulsed power. This was patterned something after the ones later recovered from APQ-13 sets in crashed B-29s. The Army's Tama Research Institute made these available for study early in 1945; a number of them were in operating condition.* Below is reproduced a sketch by Mr. Harashima of his 5 cm magnetron "copy."

Sumitomo 5 CM Magnetron -- 1 KW Peak Power.

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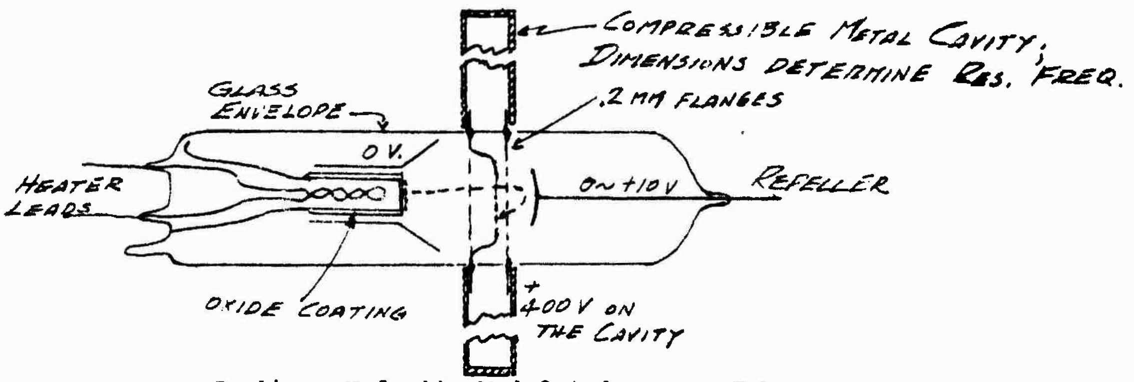
*They succeeded, however, in getting no more than about 5 kw from them.

Its chief characteristics are:

E_{plate} = 10 kv	I_f = 4.0 amp
H = 3000 gauss	λ = 5 cm
E_f = 3.5 v	Pulse Power = 1 kw

A velocity modulated tube with variable frequency was developed as a beat frequency oscillator to work in the receiver. (Attempts to produce a satisfactory controllable frequency magnetron B.F.O. were unsuccessful.) Below is a sketch of this tube which operates in the 3 to 5 cm range, giving about half as much power at the shorter wavelength. The size of the metal cavity clamped or soldered to the flanges passing through the glass envelope determines the resonating frequency. This frequency is varied up to ± 5 percent by mechanically compressing the cavity. The voltage on the repeller is varied until maximum output is obtained.



Sumitomo Velocity Modulated B.F.O. Tube.

The indicator of this set (Tachi-34) was influenced also by the captured APQ-13's. It used a PPI scope with magnetic rotating sweep coils. An A-type range scope was also provided; both had 0-50 km scales. A crystal mixer was used (tungsten needle on pyrites or silicon). The intermediate frequency was at first set at 100 MC using eight 954-type acorn tubes as I.F. amplifiers. Later this was modified to use only two 100 MC I.F. stages, with 7 more stages at 27 MC, giving more I.F. amplification (80 db) with a greater band width (± 2.5 MC).

An 80 cm parabolic antenna reflector was used fed by a wave guide transmission line through two rotating joints. The antenna was to rotate at 20-60 rpm, with elevation variable from 0° to -60°.

A variable range circle appeared on the PPI scope, and a corresponding bright spot along the axis of the A-scope. An altitude measuring circuit was incorporated, by which the sweep was delayed until the ground return circle just closed to a dot.

The one set finally constructed was delivered to Tama engineers in July 1945, who made range tests with the antenna mounted on a high promontory overlooking the sea at Ajiro (75 miles SW of Tokyo). Ranges of only 12 to 15 km on shore targets were obtained, which they considered far from satisfactory. The end of the war in August put a stop to further development.

Many additional researches were carried out at the laboratory. A list of those with possible affiliation with the radar and electronics art is given in Table 2.

Table 2. PRINCIPAL RESEARCHES CARRIED ON SINCE 1940 by Sumitomo Co.

(1) Researches on Materials:

Tungsten Wire (April 1941 to Aug. 1945)

Research was made on thoriated tungsten filament having high electron emission, produced by mixing Thorium with Tungsten powder made from Sheelite. Is in production at Takasaki Plant.

Tantalum Plate (April 1941 to Aug. 1945)

Research was made on production of Tantalum plate for vacuum tube anodes produced from Tantalum powder extracted from tantalite by using vacuum method, powder metallurgical process. Research on production methods has been discontinued.

Carbon Film Resistance (Aug. 1942 to Aug. 1944)

Development of carbon film resistance, with good electrical characteristic especially in humid climate as in Japan was made. Research has been completed and it has been in production at Teikoku Carbon Co.

Silicon Carbon Heater (April 1943 to Aug. 1945)

Research was made on manufacturing method of silicon carbide heater but has not been completed. Have not met success in actual production.

Fluorescent Matherials (April 1941 to Aug. 1945)

Studies were made of Zinc silicate and Zinc Sulphide for use as fluorescent materials for raun tubes. These are under production at Takasaki Plant. Research has been discontinued at present.

Glass for Vacuum Tubes (April 1945 to Aug. 1945)

Research was made of chemical composition, thermal expansion, viscosity, and electrical proerties of glasses used in manufacture of vacuum tubes. Improvements in production methods for glass were also analized.

Neon Gas (April 1942 to Aug. 1945)

Research on separation of Neon Gas by liquification of air was made and was completed in April 1943. Semi-production equipment was completed in June 1945 and has been in use. Research on separation and refining of rare gases has been continued.

Styrol Resin (Jan. 1943 to Aug. 1945)

Research on production of Styrol Resin for electrical insulation was made. Small quantity of this matter was produced in the laboratory in June 1944, but plans for industrialising this process was stopped in Aug. 1945.

Insulating Paint (April 1943 to Aug. 1945)

Research on insulating paints and insulating compounds for use in communication equipments especially for humid climate as in Japan was made. This research is still under way.

Measurement of High Frequency Characteristics Insulating Materials (Apr. 1940 to Mar. 1945)

Development work was made on method for accurate measurement of dielectri loss of insulating materials in collaboration with Nippon Gakujitsu Shinko-Kai. Reactance Variation Method, etc. was developed.

Steatite Insulating Material (April 1940 to March 1945)
Insulating material Talc-barium-clay series has been investigated with a fair degree of success and has been in production at Seto Plant.

Titan Oxide Ceramics (April 1939 to March 1945)
Titan Oxide-calcium-clay material has been investigated and has contributed to the production of small type ceramic condensers.

Temperature-proof and Moisture-proof Parts & Materials (April 1944 to Mar. 1945)
Parts and materials for use in the propics and for use in aircraft equipment for high altitude flight has been under research. Fair degree of success has been met by using various moisture-proof paints, however, further research must be made relating to the life of the material.

400 cycle Power Transformer (Jan. 1944 to Oct. 1945)
Investigation on power transformers for aircraft equipment has been made using commercial 4% silicon steel, 0.35 mm in thickness, and has resulted in 50% reduction of weight. Is under production.

Transformers for Impulse Waves (Dec. 1944 to July 1945)
Transformer for impulse wave having duration of 4 micro seconds for use in radio detectors was investigated.
Satisfactory results have been obtained using 4% silicon steel, 0.1 mm. in thickness.

Detector Crystal for Ultra Short Wave (Jan. 1945 to July 1945)
Metallic silicon detector crystals for use in radar was investigated. however, it has been found that further research must be made to further its stability.

(2) Researches on Vacuum Tubes:

Gas Discharge Tube (Jan. 1940 to Dec. 1944)
Voltage stabilizer, gas discharge tubes LS-2B, LS-4A, LS-10A were developed. Also spark modulator tube LS-110 were developed.

New Thermo-Electron Emitter (Jan. 1944 to Aug. 1945)
Thermo-electron emitter having better characteristics than the ordinary oxide cathode was investigated. Elements in Fourth Group of the Periodic Table were principally studied. Fair degree of success has been met with oxide of thorium and Zirconium. Has been used for cathode of magnetrons.

Magnetron (June 1944 to Aug. 1945)
Trial production of 5 cm. wave length, transmitter tubes for radar was made. Plate voltage 6000 - 10000 volts, magnetic flux 17000 - 20000 gauss, output 1 Kw (peak value). Also trial production of 3 cm. wave length tube was made.

Noctovision Tube (Jan. 1943 to July 1945)
Experimental work has been made on Ag - Cs semi-transparent, photo-cathode for tubes 45 mm, 60 mm. and 80 mm. in diameter. Anticipated result has not been obtained.

High Mutual Conductance Receiving Tube (Jan. 1941 to Aug. 1945)

High mutual conductance video amplifier receiving tube for television was investigated and by improvement of the structure of electrodes, tube, NC-658-A, having mutual conductance of 8500 micromhos at 10 milliamperes was developed. In 1942, this tube was transfered to mass production plant. Research on this type of tube was discontinued since then, however, research on secondary emission tube has been taken up.

Circular Time Axis Cathode Ray Tube (Aug. 1941 to Sept. 1944)

Cathode ray tube using electro-magnetic deflection coil for circular time axis and using conicall, coaxial deflection plate for phenomenal deflection was investigated and was put into production with the code number, LB-2.

Ultra High Frequency Transmitting Tube for Generating Impulse Wave (Aug. 1941 to Aug. 1945)

Research was started in 1941, the first product being TR-593 for 3m. wave length and having output of 10 Kw. in 1942, TR-594 for 4m. wave length and having output of 50 Kw. was completed. In 1943, TA-1504 for 1.5m wave length and having output of 5 KW and TA-1506 for 80 cm. wave length and having output of 1 Kw were produced. Between 1943 and 1944, transmitter tube for 28 cm. wave length was investigated, resulting in the development of LD-212-C having output of 1 Kw. In 1945, by using special constructional features, tube LD-22-1B for 10 cm. wave length and having output of 1 & three-quarter Kw. was develpped, however, research has not been carried to the point of practical use. The above values for output are in peak output values.

Velocity Modulated Tube (July 1942 to Aug. 1945)

At first trial production of Klystron type, transmitting tube was made with failure. In 1944, reflecting field type velocity modulated tube for 10 centimeter local oscillator was developed, however, due to frequency drifting, difficulty was met in actual production. In 1945, by using special constractional features and by placing electrical cavity on exterior of the tube, LD-237 tube having lower frequency drifting characteristic and having easy frequency adjustment was produced. This tube can be used for oscillators down to 3 cm wave.

Cathode Ray Tube with White Fluorescent Screen (Aug. 1942 to May 1945)

White fluorescent color was obtained by mixing zinc sulphide and phosphor which produce red and blue fluorescent colors, respectively and by using red and blue filters. Fluorescent materials and filters were analized and adjusted so that the penetrating lights were of equal visual sensitivity. Braun tube using the principle is under production.

Cathode Ray Tube with Persistent Screen (Sept. 1944 to May 1945)

Experimental work was conducted on flourescent materials having special persistant property for use in radar. Cathode ray tube of this type was put into production. Mechanical and electrical requirements from this standpoint of radar were analized and Braun tube incorporating these features was produced.

Vacuum Tube for Wurzburg Radio Locator (March 1940 to Aug. 1945)

Imitations of LS-180 and LG-1 vacuum tubes and LB-1 LB-13/40 Braun tubes, produced by Telefunken Co., used in German, Wurzburg radio locator were produced. Large quantity production of these tubes has been initiated.

(3) Researches on Apparatus:

Four Meter Wave Radio Locator using Beat Method (July 1930 to May 1940)
By the direction of the Army, research was conducted on detection of aircrafts using Doppler Effect. Equipment having coutput of 100 watts and 400 watts continous wave used, however, has been discontinued.

Four Meter Wave Radio Locator using Impulse Method (May 1940 to Dec. 1941)
By the direction of the Army, research was conducted on detection of aircrafts using impulse wave. Radio Locator having peak output of 50 Kw wave length of 4 m. and detection distance of 300 KM was developed and produced.

28 Cm. Wave Transmitting and Receiving Sets (Oct. 1943 to Nov. 1944)
By the order of the Army, researches on improvement of 50 Cm Wave transmitting set and construction of oscillators having several hundred watts output were made. Researches on superheterodyne receiving set using Kodai tube (Push - BK tube) as mixer were made.

5 Cm Wave Transmitting and Receiving Sets (Dec. 1944 to Aug. 1945)
Transmitting set using magnetron and transformer modulation method was used. Superheterodyne receiving set using crystal mixer and using magnetron or velocity modulated tube for local oscillator was used. Wave guide system was incorporated in the xxx sets.

1.5 m. Portable Radio-Locator (June 1942 to Dec. 1942)
By the direction of the Army, transmitting set using 1.5 m.wave blocking oscillator and having output of 5 Kw was produced. Receiving set using acorn tubes for high frequency amplifier and for mixer and using 4 pairs of Yagi-antennae for ehight and direction detection was developed.

4 m. Wave Radio Locator (Spet. 1942 to Aug. 1945)
By the direction of the Army, antennae system not affected by reflection from the earth, by which accurate measurement angle of height of for low altitudes, was developed.
Effective range, 40 KM; accuracy of angle of height, 1 degree; angle of direction, 0.5degree; minimum angle of height which is possible to measure over 14 degree.

Frequency Standard (Jan. 1940 to Aug. 1945)
By using Meacham's bridge stabilized feed back oscillator, frequency standard having accuracy of 10 7 second was obtained.

Aircraft Radio Locator of 80 Cm. Wave (May 1943 to Aug. 1945)
Tiodes were employed for transmitter with about 2 KW output. And Acorn tubes were employed for receiver. The antenna currents are directly introduced to mixer. Antenna are constructed of four sets of Yagi-antennae by which it is capable of locating object. The above research was completed under Army instruction and reached to production.

Four Meters Radio Detector Capable of Measuring Altitude
(Nov. 1943 to July 1944)

Research on radio detector capable of measuring altitude was conducted under Army dirction. Altitude measurement was made by means of difference in directional characteristic on vertical surfaces of the two antennae which are located at upper and lower positions, on the other hand measurement of horizontal direction was performed by horizontally sweeping directivity of antennae, said dirctivity heing composed of sum and difference of induced voltage in right and left antennae.

Hyperbolic Navigation Device of Airplane (April 1945 to Aug. 1945)

By receiving, on airplane, impulse waves from two points, position of said airplane can be set based on the fact that time difference of propagation of both impulse waves is onstant on hyperbola having said two points as foci. In order to realize means hased on above principle, device on airplane was investigated for measuring time difference, but it has not come to practical application.

Monitoring Set for Radio Detector (March 1944 to June 1944)

Supervising apparatus for operating functions of each detector at strategic point. It was completed in June 1944 under Army order.

Impulse Modulator (April 1944 to Aug. 1945)

Trial productions were made by Army order, primarily in connection with magnetron modulation system spark modulator, hard tube modulator, impulse generator circuit and impulse transformer.

Acoustic Detector (Feb. 1943 to Mar. 1944)

Research on detectors by means of sound was made by Army order, said detector being consisted of microphone, seismoscopic pick-up, amplifier etc.

Research on Special Circuit (April 1941 to Aug. 1944)

Research was made on stabilized eliminator, multivibrator, time base circuit, powerful impulse generator, phase shifter, etc. for obtaining data for designing radio locators and detectors.

e. Radars Manufactured. In Table 3 is given a list of the radars and/or components manufactured for the Japanese army and navy with the numbers made of each in the last column.

Table 3 - RADAR EQUIPMENTS BUILT FOR ARMY AND NAVY BY SUMITOMO COMPANY

Type No.	Function	Wave Length (Meters)	Type of Antenna	Number Produced
		For Japanese Army		
YO-OTSU or Tachi-6	Detector 1 Transmitter 4 Receivers 4 Indicators	4.0-4.5	Transmitter: 2 sets of Beam fan-shaped fixed pattern. Receiving: Beam	288
TA-III or Tachi-3	Locator 1 Transmitter 1 Receiver and Indicator	3.84	Transmitting: broad beam. Receiving: 4 doublets.	115
		For Japanese Navy		
S-3	Locator	1.5	Beam	33
L-2	Locator	1.5	Beam	170
UF-11	(Detector) Transmitter only	3.0		260
S-24	(Locator) Transmitter only	c.a. 1.6		80
UF-21 for No. 21 set	(Detector) Receiver only	1.5		400
UF-13 for No. 13 set	Indicator	almost identical except for length of sweep		2400
M-22 for No. 22 set	Indicator	(almost identical except for length of sweep)		60

6-4195,AF

SUPPLEMENTARY

INFORMATION

DEPARTMENT OF THE AIR FORCE
AIR INTELLIGENCE AGENCY

AD-895 891

MEMORANDUM FOR DTIC-BCR

ERRATA

17 January 1994

FROM: NAIC/MSIR
4115 Hebble Creek Rd Ste 14
Wright Patterson AFB OH 45433-5618

SUBJECT: Freedom of Information Act (FOIA) Request, Case I-FASTC 93-37

1. Reference your letter 22 December 1993 and 18 October 1993 NAIC letter, same subject.

2. NAIC OPR has reviewed documents AD 895891 Volume I, AD 895892 Volume II and AD 895893 Volume III and determined that the records are fully releasable.

3. The documents identified above may be released to future Freedom of Information Act requesters.

Marlyene A. Harrison

MARLYENE A. HARRISON, GS-11, USAF
Chief, Freedom of Information
Information Management Operations

ERRATA AD-895 891

Attachment:
1. OPR Comments
2. Releasable Documents

AD 895 891
AD[redacted]
AD-[redacted]

DEPARTMENT OF THE AIR FORCE
AIR INTELLIGENCE AGENCY

ERRATA

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Marlyene A. Harrison
MARLYENE A. HARRISON, GS-11, USAF
Chief, Freedom of Information
Information Management Operations

ERRATA AD-895891

Attachment:
1. OPR Comments
2. Releasable Documents

DEPARTMENT OF THE AIR FORCE
AIR INTELLIGENCE AGENCY

MEMORANDUM FOR NAIC/DXL 6 January 1994

ERRATA

FROM: NAIC/MSIR

SUBJECT: Freedom of Information Act (FOIA) Request R-FASTC-93-37

1. The attached FOIA request is forwarded for your review and releasability.

2. It is regards to a previous request from Mr. Edward Kettler for paper copies of documents AD 895891 Volume 1, [redacted] Volume 2 and [redacted] Volume III entitled "A Short Survey of Japanese Radar." No documents were located in NAIC per telecon with DTIC, the request was forwarded to them. DTIC located the requested documents and has forwarded them to NAIC for review and release determination.

3. Please ensure the branch chief signs the 1st Ind and records the time expended on DD Form 2086. After completing the required actions on this request, please call extension 77236 for pickup.

ERRATA

JOHN A. MCGUIRE, MSgt, USAF
Asst Chief, Freedom of Information
Information Management Operations

3 Attachments
1. AD 895891 Volume 1
2. AD [redacted] Volume 2
3. AD [redacted] Volume 3

1st Ind, NAIC/DXLA DATE: 6 Jan 94

TO: NAIC/MSIR

1. The following apply:

_x_ Records are fully releasable.

Records should be:

____ Fully denied under: ____ Partially denied under:

Exemption: 1 2 3 4 5 6 7 8 9

2. Individual who worked this request/point of contact:

Name: Sherry Jennings
Office Symbol: DXLA
Phone number (black): 72435

3. Remarks:

ANITA L. MILLER, CHIEF
DOCUMENT REQUIREMENTS & ACQUISITION BRANCH