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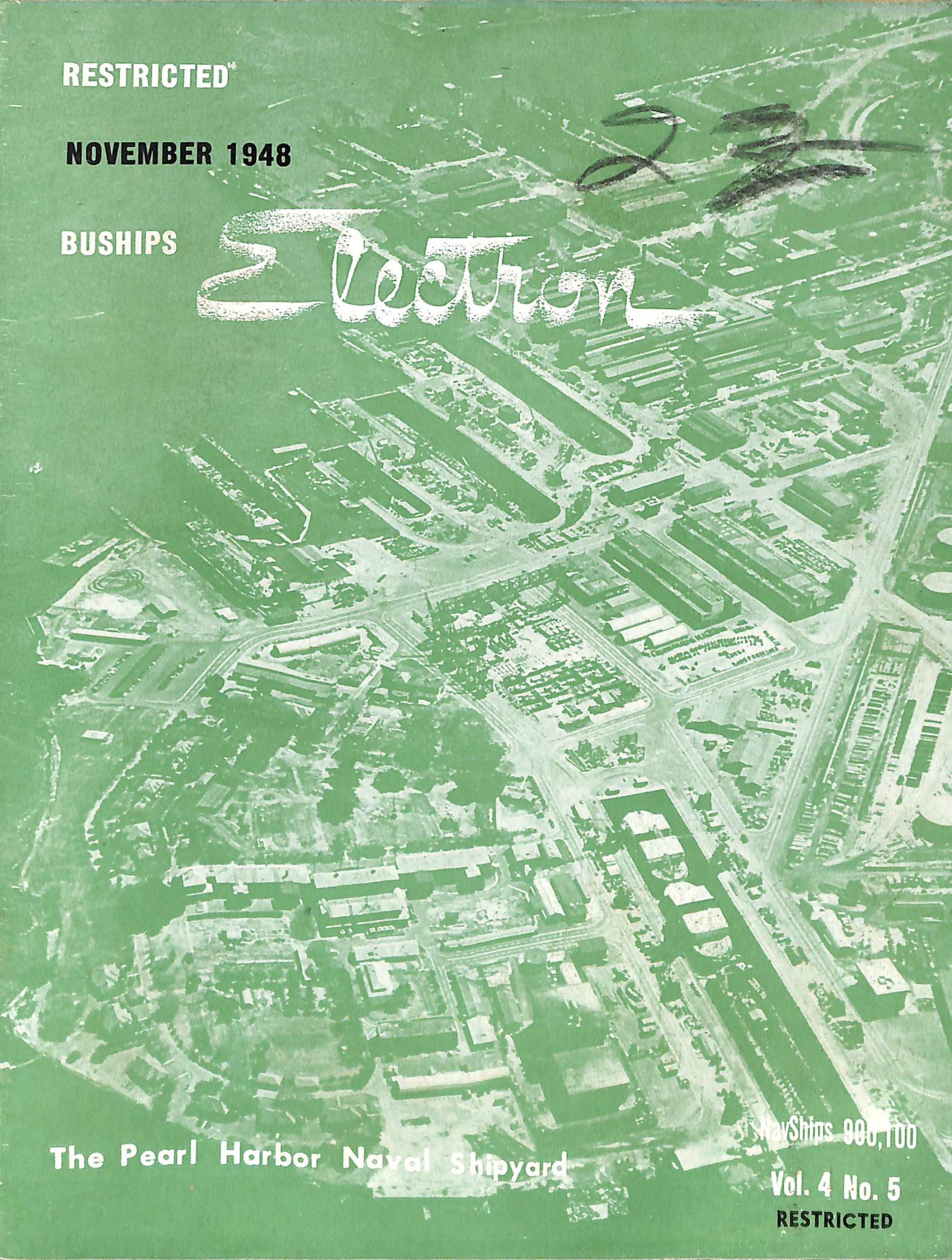
NOVEMBER 1948

BUSHIPS Electron

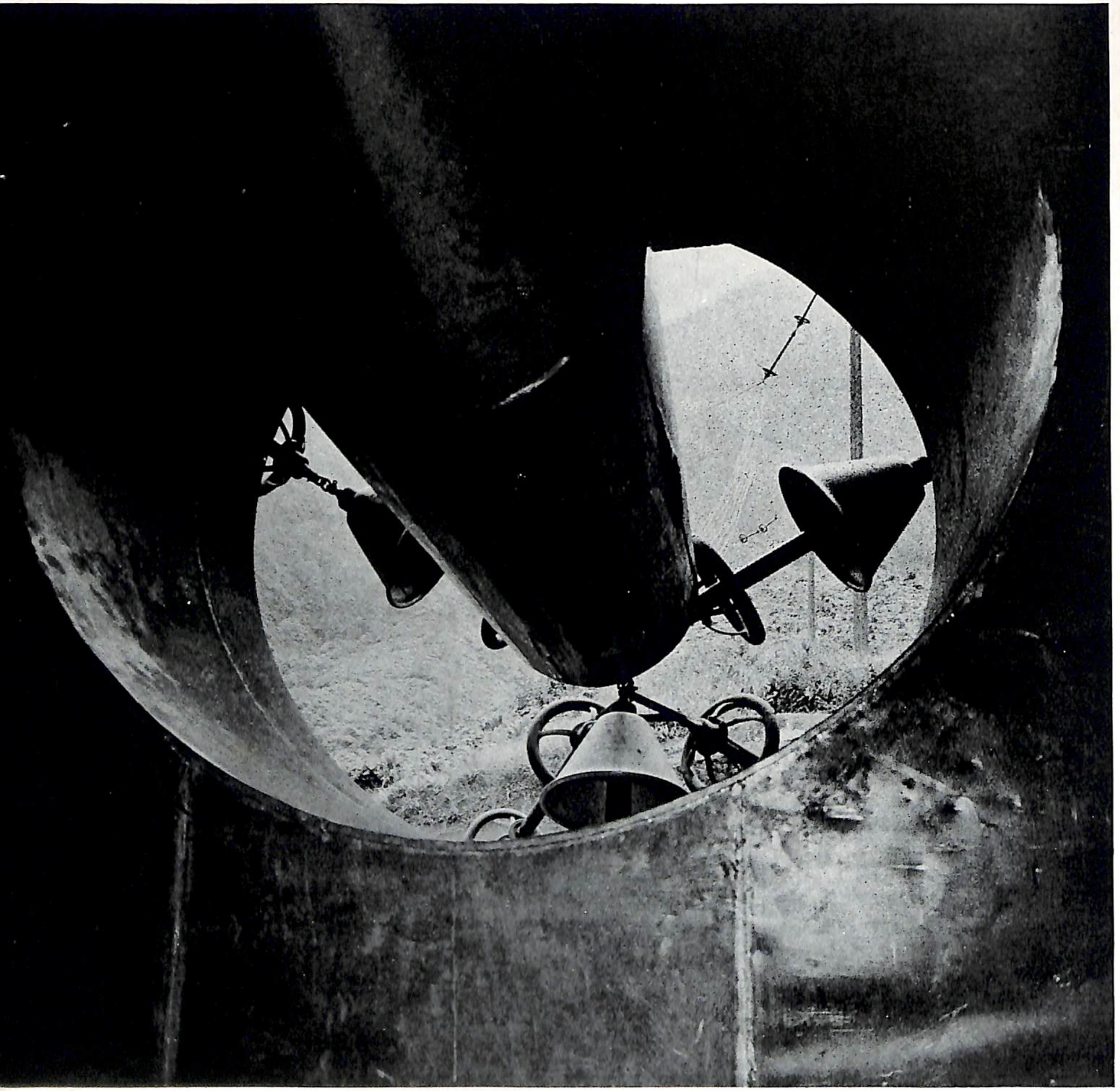


The Pearl Harbor Naval Shipyard

NavShips 900,100

Vol. 4 No. 5

RESTRICTED



Gigantic Lead-out for the Radio Transmitter at Haiku Radio Station

See Page 14

BUSHIPS Electron

A MONTHLY MAGAZINE FOR ELECTRONICS TECHNICIANS

NOVEMBER, 1948 VOLUME 4 NUMBER 5

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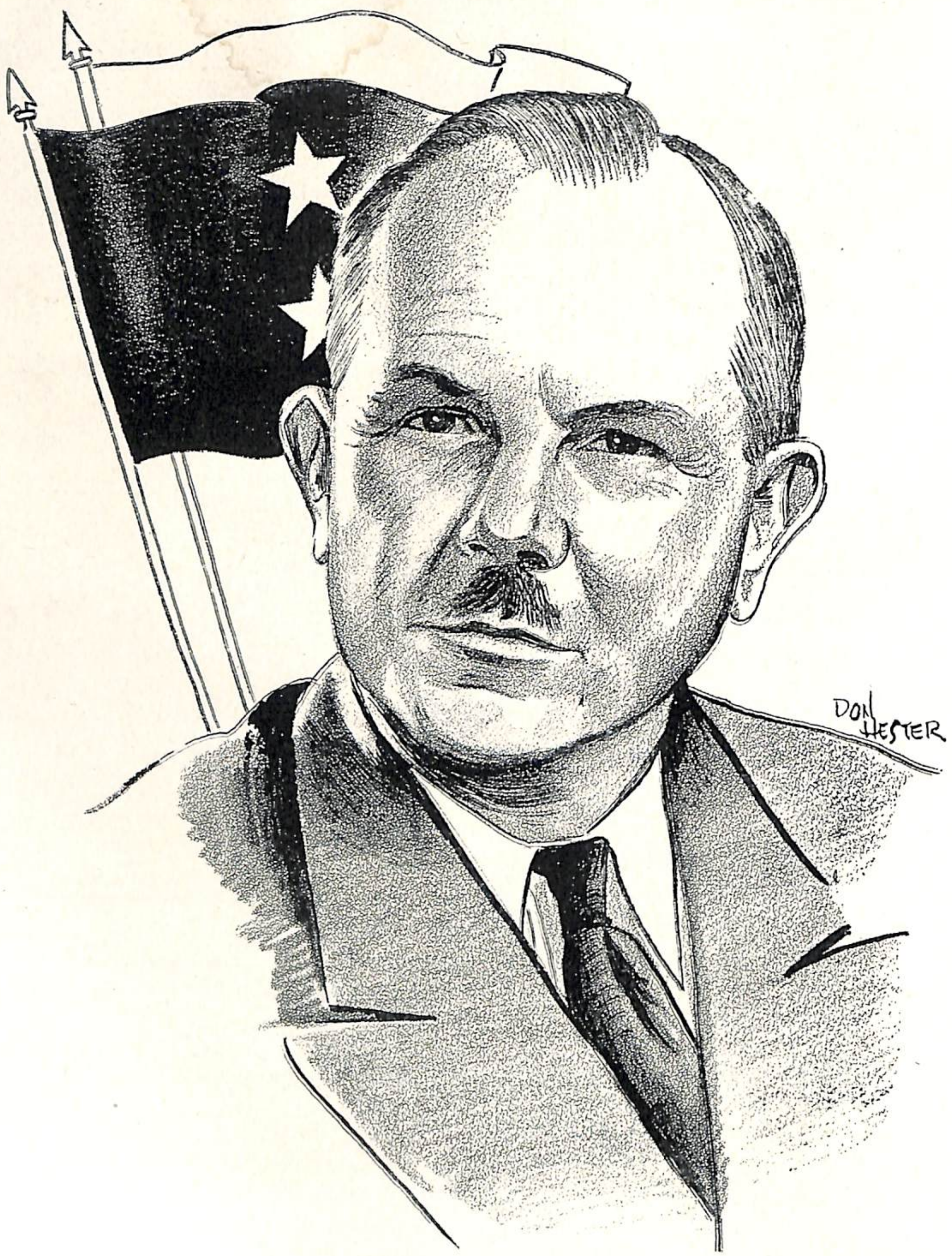


Roy T. Cowdrey
Rear Admiral, U. S. Navy

THE COMMANDER

Pearl Harbor Naval Shipyard

Rear Admiral R. T. Cowdrey was born in Milwaukee, Wisconsin on February 4, 1898. Appointed to the Naval Academy in 1916 from the second Congressional District of that state, he graduated with distinction on June 6, 1919 in the Class of 1920 and was commissioned Ensign on that date. He subsequently advanced to the rank of Rear Admiral on 1 July 1948.

Rear Admiral Cowdrey was ordered to the USS NEW HAMPSHIRE *upon graduation in 1919 and served in that battleship until September 1920. The succeeding three years he was under instruction in Naval Construction at the Post Graduate School, Annapolis, Maryland, at the Boston Navy Yard, at the Massachusetts Institute of Technology, and at the Chemical Warfare School, Edgewood Arsenal, Edgewood, Maryland. He received the degree of Bachelor of Science from the U. S. Naval Academy, and the degree of Master of Science in Warship Construction from the Massachusetts Institute of Technology in 1923.*

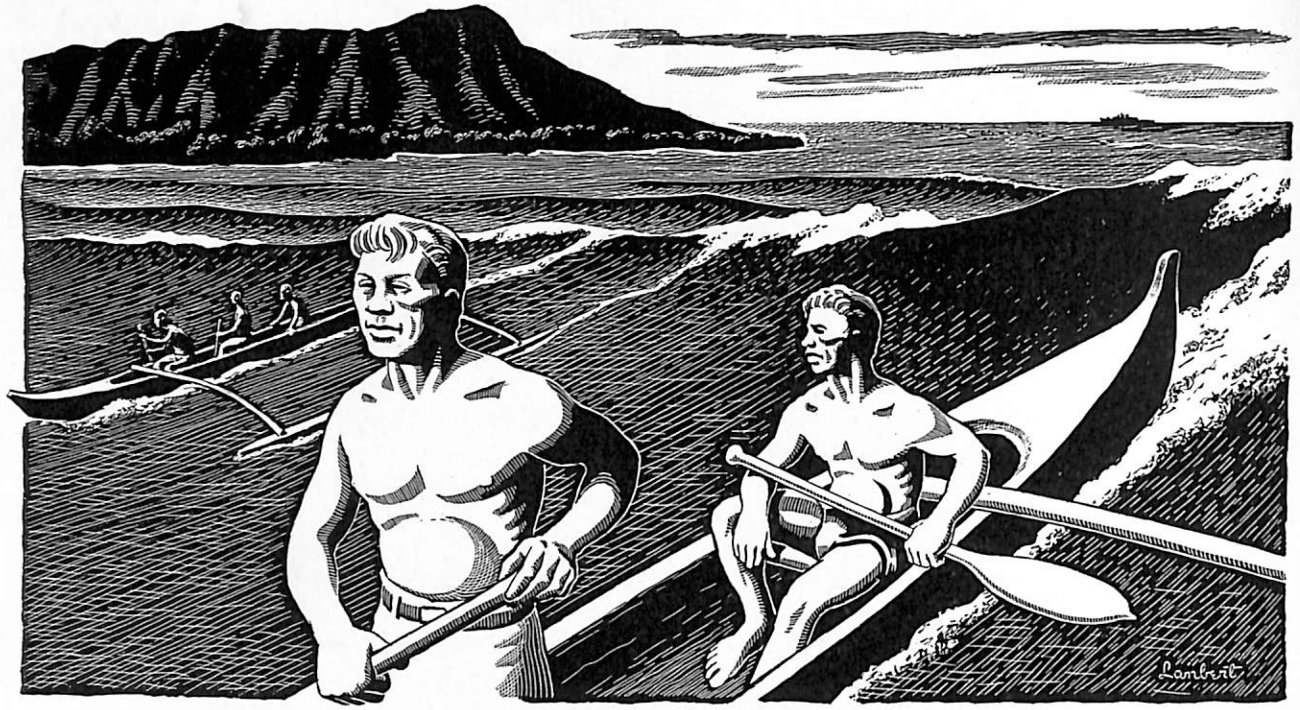
From 1923 to 1927, Rear Admiral Cowdrey was Assistant Hull Superintendent of the Philadelphia Navy Yard, after which he served as Battleship Desk Officer, Plans and Alterations Section of the Bureau of Construction and Repair, until June 1931.

Rear Admiral Cowdrey served as Assistant to the Superintendent, Mechanical Division, Panama Canal Zone, from July 1931 until June 1935. He then reported for duty at Puget Sound Navy Yard as Senior Assistant Hull Planning Officer, and Design Superintendent until July 1939. He then served in the Final Design Division of the Bureau of Ships, Navy Department, Washington, D. C., as Type Desk Officer for New Battleships and Cruisers until June 1942.

Rear Admiral Cowdrey served in the South Pacific with forces afloat from July 1942 until November 1944, first as Combat Logistics Officer and Force Maintenance Officer, Staff, Commander South Pacific Force and South Pacific Area, and finally as Force Maintenance Officer on the same staff. During this period he was awarded the Legion of Merit and two gold stars in lieu of the second and third Legions of Merit, and the Commendation Ribbon.

After about two months duty back in the Bureau of Ships, Rear Admiral Cowdrey was assigned as Commanding Officer, Industrial Command, Naval Repair Base, San Diego, California, until May 1946. He then served as Fleet Maintenance Officer, Staff, Commander Service Force, and Staff, Commander in Chief, Pacific Fleet, until July 1948.

On July 28, 1948, Rear Admiral Cowdrey assumed command of the Pearl Harbor Naval Shipyard, relieving Rear Admiral Louis Dreller, USN.



PEARL HARBOR NAVAL SHIPYARD

By LOUIS C. BUTLER

The present location of the Pearl Harbor Naval Shipyard, on the southern side of the island of Oahu known to the Hawaiians as *Wai Momi,* meaning "water of pearl," was being considered for a Naval Base for several years before the Navy Yard was started in 1908. As early as 1876 a treaty was concluded which gave the United States certain rights in Pearl Harbor in exchange for the admission of duty-free sugar, and this pact was extended in 1887, giving the United States exclusive rights to establish a coaling station for American vessels in Pearl Harbor.

In 1900, two years after the annexation of the Hawaiian Islands, the initial attempt to cut a deeper channel through the coral reef outside the harbor was made. The gunboat *Petrel* was the first vessel to enter the harbor through this channel. The establishment of a Naval station and the dredging of the channel at Pearl Harbor were authorized by Congress in 1901; in that same year the Navy acquired 800 acres of land in and around Pearl Harbor.

The present Pearl Harbor Naval Shipyard, which is the largest and most completely equipped industrial establishment between the West Coast of the United States and Japan, had its start in 1908 when Congress authorized the establishment of a Navy Yard and appropriated $700,000 for that purpose. That same year, Navy Department engineers surveyed the barren acres of *kiawe* stubble, burnt cane and coral which were to become the Pearl Harbor Naval Shipyard and a contract was let for the dredging of the channel. Work on Drydock #1 actually started in 1911, the same year that the first large vessel, the armored cruiser *California,* entered Pearl Harbor through the new channel. In 1913 two years of labor on Drydock #1 became a mass of wreckage when the bottom of a crib section failed, but after a year's delay work was resumed and by 1919 Drydock #1 was completed along with the 10–10 dock and a number of the present shops.

Between World War I and World War II the shipyard grew slowly. Just prior to World War II, however, a large expansion in facilities was authorized. This expansion, which included the construction of drydocks #2, #3 and #4 and the erection of many new buildings, was not yet completed when the bombs fell on Pearl Harbor on that fateful Sunday morning of December 7, 1941. From that date until the end of the war production stepped up constantly and facilities were expanded as the shipyard became the center of all major ship repair activity in the Pacific.

Employment kept pace with expansion. In 1925 there were only about 1000 workers employed in the shipyard and up to 1938 this number never exceeded 2000. As the work load increased, however, and facilities expanded, the number of employees increased. In March 1945 there were 26,000 men and women working in the shipyard. Since the war this number has shrunk to the current employment of about 6400.

The organization which was the forerunner of today's Electronics Office and Electronics Shop in the shipyard had its origin at the start of World War I, on April 6, 1917. At that time, the organization consisted of one officer known as the Radio Officer, whose headquarters were located in the Administration Building at Pearl Harbor. One half of his office was shared with a five-kilowatt spark transmitter which was used for communicating with the ships of the Navy and also for emergency communications.

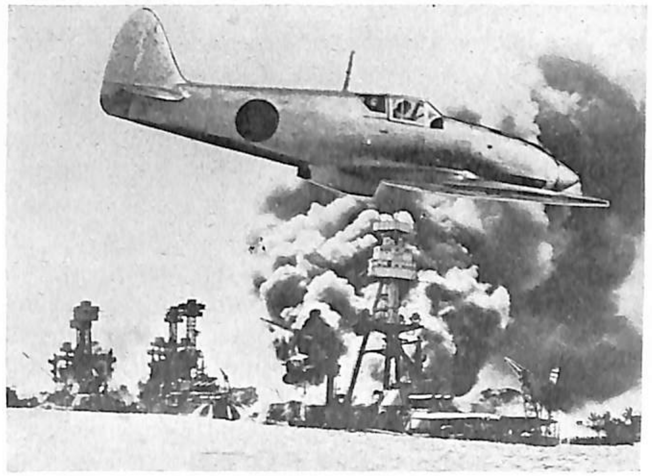
With the declaration of World War I, the communication stations belonging to the Marconi Wireless Company at Kahuku and Koko Head and the Heeia station of the old Federal Telegraph Company, all on the island of Oahu, as well as the Mutual Telephone Company stations located on the islands of Oahu, Hawaii, Kauai, Maui, and Molokai were all taken over by the Navy. They were actually manned by Naval Reserve personnel, most of whom were already employed at these stations.

Shortly after the declaration of World War I, additional officers were assigned for radio duty to handle the additional work load. At this time there were only two civilians employed in the office; one was known as the radio aide to the Radio Officer and the other was assigned as a radio draftsman. These civilian assistants helped the Radio Officer in his day-by-day work and they also assisted in the maintenance of the stations in the district taken over by the Navy at the start of the war. They acted in an advisory capacity in connection with the installation of the new Pearl Harbor high-power radio station located near Hospital Point in the shipyard.

This station was one of a chain of high-power radio stations which the Navy Department decided to establish and began building during the period from 1914 to 1917. The Pearl Harbor station was to function as a relay point between the mainland of the United States and the Orient, and between the Navy Department and the units of the fleet in the Pacific.

The transmitter was a high-powered arc transmitter rated at 500 kilowatts and was constructed for the Navy Department by the Federal Telegraph Company. It was the first super-high-power arc converter built for the Navy in the United States. The actual installation at Pearl Harbor was completed during July 1917 and was accepted by the Navy after the required tests were successfully accomplished during the last part of October 1917.

The Pearl Harbor arc converter unfortunately was a source of radio interference on various frequencies employed for communication by ships and commercial stations on the island of Oahu during the last part of its life, for the converter was not actually decommissioned until 2 January 1931. At this time all of the equipment



comprising and associated with the arc converter was removed from the station in the shipyard to make room for the new installation of the Model TAW, 300-kw tube transmitter manufactured by the General Electric Company and accepted by the Navy in January 1933.

At the close of World War I, the officer assigned to Pearl Harbor for radio duty was known as the District Radio Material Officer. He was responsible to the Pacific Coast Communication Officer in San Francisco for the proper maintenance and operation of all radio stations in the 14th Naval District. In addition to his radio aide, his office force then consisted of three civilians, one stenographer, and two radio electricians who were employed for ship inspection work and repairing radio equipment. During this period there was no shop under the District Radio Material Officer available for making radio repairs; it was necessary to set up a work bench in the Electrical Shop, Shop 51, in order to accomplish radio repairs. This same space was maintained continuously by the District Radio Material Officer in Shop 51 until 1923 when the Bureau of Engineering set up a project for the construction of a one-story wooden building to house radio inspectors and such delicate instruments as might be required for repairing and testing the various types of transmitting and receiving equipment in use. This building was designated as the Radio Laboratory and was located adjacent to the present Administration Building. It was known as Building No. 65.

Shortly after the Radio Laboratory was completed the work load started to build up, and it became necessary to employ three electricians, one rigger, and two joiners. The electricians were used in the laboratory for making repairs to radio equipment from ships and from the three radio stations in this district, namely Heeia, Wailupe, and the Pearl high-power station. The rigger and the two joiners were employed part-time in the laboratory and the balance of the time at Heeia or Wailupe. In addition to these employees in the Radio Laboratory, it was necessary to employ a force of riggers and joiners for the radio station at Heeia for the maintenance of the three wood-lattice towers, two of which were 440 feet high and built in 1912 by the Federal Telegraph Company and the other, built in 1914, 608 feet high. This extra tower was found necessary in order to carry on daylight communication between the island of Oahu and the Federal Station located in South San Francisco, Calif. These three towers were dismantled in 1933 when they were no longer required.

The Radio Laboratory continued to grow under the direct supervision of the Radio Material Officer as radio developed and increased in use aboard ship and ashore. By 1927, the technical force consisted of one associated radio engineer, one radio draftsman, and six assistant radio inspectors. The inspectors and electricians continued their work in Building 65 until 1937 when all of the personnel and equipment of the high-power radio station in the shipyard were transferred to the new station located at Lualualei, a distance of about thirty miles. By this time the organization had outgrown the Radio Laboratory and permission was obtained from the Navy Department to move all of the personnel and equipment comprising the shipyard radio organization into the buildings that formerly housed the arc transmitter and the newer electron tube transmitters of the high-power radio station adjacent to Hospital Point. This move was made during the early part of 1938, just prior to the start of the large pre-war expansion of the shipyard. In 1939 and 1940 the work load steadily increased and additional electricians and mechanics were employed to handle the ship repair work and maintenance upkeep of the stations at Lualualei, Wailupe and Heeia.

By December 7, 1941, the Radio Laboratory was well organized with a nucleus of trained civilian personnel on whom to build the large organization that was to be required to handle the terrific electronic work load which World War II placed upon the Pearl Harbor Naval Shipyard. Under the leadership of the present Assistant Chief of the Bureau of Ships for Electronics, Captain A. L. Becker, who was the Radio Material Officer of the Pearl Harbor Naval Shipyard from October 1942 until September 1944, the Electronics Organization reached its peak expansion. In addition to the manyfold increase in shipboard work as such, new fields in radar, sonar and radio countermeasures brought many new types of equipments to ships of the navy; the shore communications in the Islands, for which the Navy Yard had the maintenance responsibility, increased in magnitude. A new receiving station was completed at Wahiawa at the beginning of the war and a new v-l-f, high-power radio station was completed at Haiku during

ELECTRONICS OFFICER

Commander William I. Bull graduated from the U. S. Naval Academy in June, 1932. During his first tour of sea duty he served a year as a Communication Watch Officer with the Staff of Commander Scouting Force followed by duty in the *Barry* and *Ramapo*.

In 1939 Commander Bull was assigned to the Post Graduate School of the Naval Academy for the course in radio engineering. After two years at Annapolis he spent one year at Harvard University taking the communication engineering course, upon completion of which he received the Master of Science degree.

After completing a short course in advanced radar given by the Massachusetts Institute of Technology he was ordered to the *Semmes* as Executive Officer. In January 1943 he became Commanding Officer of the *Semmes* and served in that capacity until December 1943. During this period the ship was engaged primarily in sonar experimental work but accomplished other experimental and developmental work in radar and radio. After a year's duty as Assistant Officer in Charge of the Fleet Sonar School at Key West, Commander Bull was ordered to the Electronics Division of the Bureau of Ships. He was designated as an Engineering Duty Officer (electronics) in December 1944. In the Bureau of Ships he served as head of the Components and Standardization Section until the end of the war at which time he became head of the Equipment Branch (now the Equipment Division).

In March 1948 Commander Bull was ordered to the Pearl Harbor Naval Shipyard, where he assumed his present duties as Electronics Officer.

the war. Air stations were constructed on the islands of Hawaii, Maui, and Molokai, as well as on Oahu. Additionally the shipyard had maintenance responsibility for the shore communication stations on Kwajalein, Midway, and Johnson Islands.

To handle this wartime load at one time the organiza-

CHIEF CIVILIAN ASSISTANT

Fred L. Mason was born June 20, 1905 at Healdsburg, California. He completed his education at the University of California. He was successively employed by the Pacific Telephone and Telegraph Company, Seismograph Service Corporation, the Phillips Petroleum Company, and Western Electric Company, in different phases of electronic engineering. During the war he was in charge of Field Engineering for Western Electric Company in the Pacific Ocean Areas. In November of 1947 he left the employ of Western Electric Company to accept his present appointment with the Pearl Harbor Naval Shipyard Electronics Office.

tion had about 100 officers, 175 enlisted men, 50 contract engineers, 75 IVb engineers and clerks and 600 mechanics.

The Electronics Office of the Pearl Harbor Naval Shipyard today follows the standard shipyard organization recently placed in effect. Commander W. I. Bull, ED, U.S.N. is the Electronics Officer; Commander N. W. Gambling, ED, U.S.N. is the Assistant for Shore Electronics. The civilian organization is headed by a Chief Civilian Assistant to the Electronics Officer, Mr. Fred L. Mason. Heading up the three sections of the office are Mr. Louis C. Butler, the head of the Services Section, Mr. R. H. Worrall, head of the Ship Section and Mr. Vance Vaughan, head of the Shore Section.

The personnel of the Electronics Office carry out the technical control, inspection and final testing of all electronics work and equipment but the actual production work both at shore stations and aboard ship is accomplished by the mechanics of the Electronics Shop, Shop 67 which was established as a full-fledged shop of the shipyard on March 22, 1948. The shop is entirely housed in Building 9 and is headed up by a foreman, Mr. Paul M. Walker. The Electronics Office organization is also housed in the same building making for the closest possible cooperation between the two related organizations. The shop today has a complement of 188 mechanics but, as in many similar activities, it is a constant struggle to keep up to complement due to the heavy demand for personnel trained in electronics both by the services and industry, and the shortage of those men truly qualified in this field.

The electronics work of the post-war shipyard lacks the volume of World War II but not the variety. The different types of electronics work increase rather than decrease as the science advances.

The shore communication stations comprising the permanent communication installation are now concentrated on the Island of Oahu. It is these large naval communication stations which are our most important maintenance responsibility, for these stations are indispensable to the efficient exercise of command function in the Pacific. The stations are controlled from the communication center, located in the Administration Building of the Naval Shipyard. From this center are keyed the transmitters at Lualualei, Haiku and Heeia. Also to this center is relayed the output of the receivers from the receiving station at Wahiawa. The control and relay of information is handled by means of unattended communication control links on Mauna Kapu and Haiku Peak. Backing up these links are cables maintained by the Army Signal Corps but allocated to the Navy for this purpose. At these stations are receivers and transmitters operating on frequencies from 15 kilocycles to 400 megacycles. Most interesting and important of this equipment is the large v-l-f transmitter at Lualualei, the model TAW-a modified recently to put 565 kilowatts into the antenna, and the two 200-kilowatt Alexanderson alternators at Haiku. In addition there are more than 100 high-power, high-frequency transmitters installed at Lualualei.

The greater percentage of shipboard work performed at Pearl Harbor today is generally confined to the smaller types of ships. At this crossroads of the Pacific, however, all classes of vessels, ranging from such frequent visitors as the PCE's used for weather station vessels to such large but less-frequent visitors as the *Iowa* and the large aircraft carriers, are constantly passing through and affording an interesting if at times heavy workload for the engineers of the office and the maintenance personnel of the shop.

In such an important and expanding field as electronics the personnel are hard-put to keep up-to-date on new equipments and new techniques. A continuing training program is therefore carried on to accomplish this. From a practical standpoint, both engineers and mechanics specialize in certain fields and at the same time maintain a familiarity with all types of equipment. The shop is divided into six sections: teletype, sonar, radar, radio, internal security and shore. So today, while the enormous wartime organization has dwindled to 188 mechanics in the shop and 35 Group IVb personnel and two officers with the Electronics Officer, in these personnel the shipyard has the nucleus of a large electronics organization if the need should ever arise again for a rapid expansion in time of emergency.

ABOUT THE AUTHOR

Louis C. Butler was employed by the Federal Telegraph Company as Radio Operator at Heeia, Oahu, when World War I was declared. Being enrolled in the Naval Reserve he was called to active duty as Chief Radio Electrician and was placed in charge of the station. Upon his discharge from the Navy in 1919, he entered Civil Service at Pearl Harbor Navy Yard as radio electrician and was later promoted to Assistant Radio Inspector. He has been continuously employed in the Electronics Office up to the present time, advancing through the various grades to his present position of Administrative Officer in the Electronics Organization.

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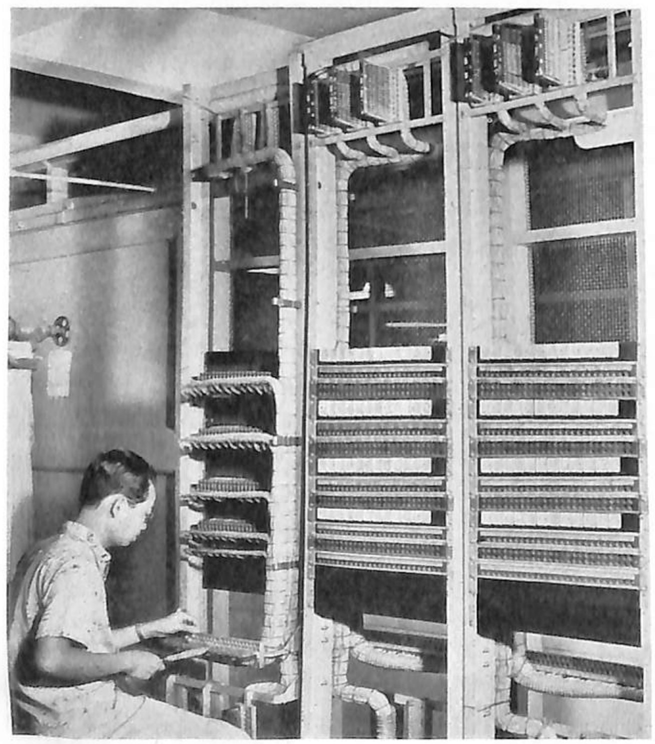
The ELECTRONICS SHOP

By P. M. WALKER

The following is quoted from a letter written by direction of the Joint Chiefs of Staff and indicates the importance of Electronics in the defense of our country.

"There is no phase of modern warfare in which electronic equipment does not play a vital role. There are certain electronic equipments without which fighting ships do not sail, aircraft do not fly and tanks do not roll in battle. They are not permitted to do so. The odds against them would be too great."



JACK PANELS being wired in the Shore Section

PEARL HARBOR NAVAL SHIPYARD

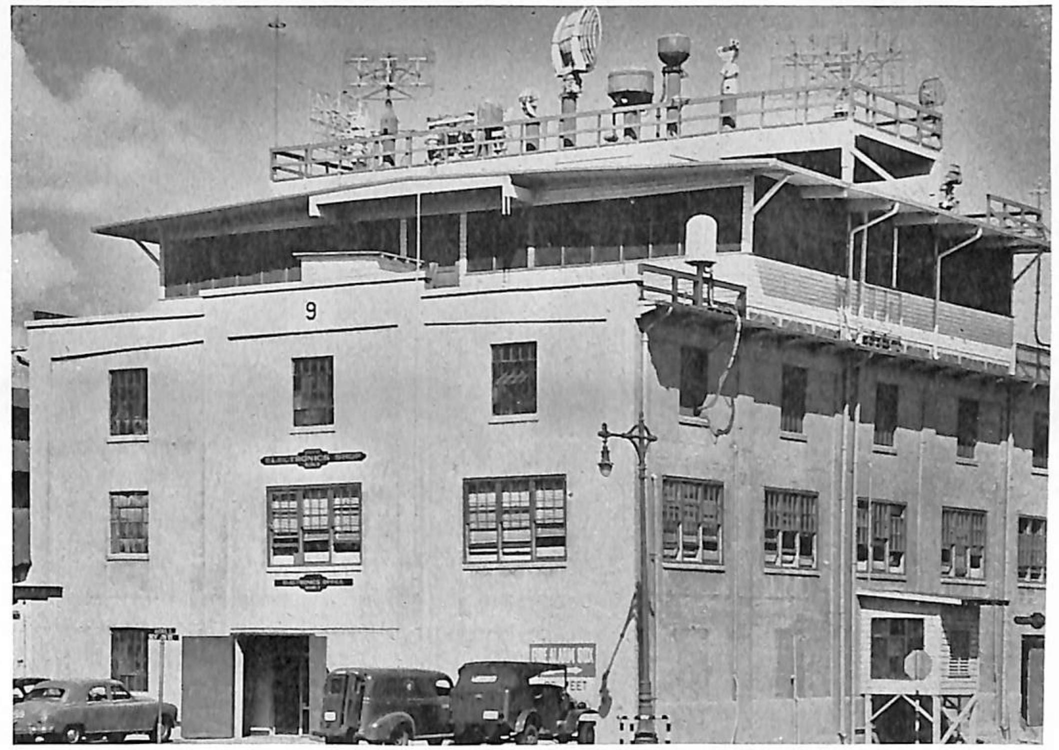
The Navy Department has been intimately associated with Electronics since 1902 when their Bureau of Equipment indicated that "Wireless Telegraph Apparatus" was to be installed on vessels of the Navy and that shore stations were to be erected in order to communicate with vessels at sea.

During the years that followed great progress was made in equipping vessels and in erecting shore stations. This work was accomplished by a hardy group of engineers, machinsts, electricians and other trades. These groups for the most part did not have permanent shop facilities and were moved from shop to shop sometimes with meager or no facilities to accomplish their difficult tasks.

This condition continued until 1935 when the Bureau of Engineering ordered the establishment of "Radio Laboratories."

At the advent of World War II in 1941 these laboratories were functioning with comparatively small organizations which had to be greatly expanded to meet the war-time requirements of new electronic equipment. The advent of radar in particular added greatly to the job to be done, and radio and sonar were greatly expanded. Teletype equipment used by the Navy also increased by leaps and bounds both on ships and in shore stations. The shore stations themselves had to be enlarged and new stations established to maintain communications with the greatly increased number of ships in operation.

As an example, the Radio Laboratory at Pearl Harbor,



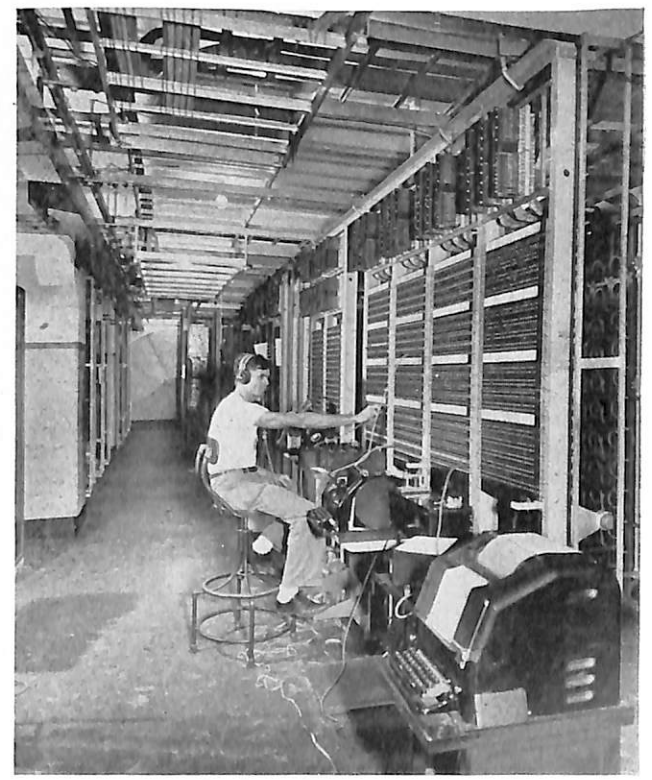
ELECTRONICS SHOP and office, showing the radar antennas mounted on the roof.

originally manned by a force of approximately 20 people, expanded to a force of approximately 1000. Working space graduated from one small building to the present large building in addition to many temporary buildings throughout the shipyard.

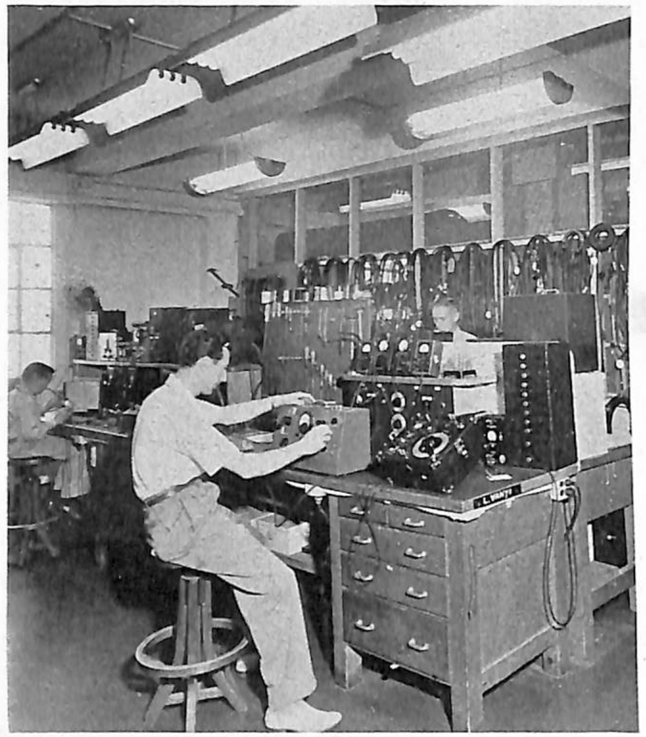
After the close of World War II this force was reduced greatly as ships went out of commission. Due to the great advances in the art made during the war, however, it was found necessary to maintain a much larger permanent group than was required previously.

An illustration of the advances made is the tremendous increase in amount of equipment required on only one ship. Before the war this would have from ten to fifteen types of transmitters of various powers and frequencies and from twenty to twenty-five receivers with customary direction finder and fathometer. A modern ship of the same type requires approximately the following equipment: 16 transmitters, 43 receivers, 1 loran, 1 fathometer, 1 direction finder, 41 radars, 21 radar remote positions, 7 types of special equipment, and many accessory items such as public address systems, remote controls for transmitters and receivers, teletype equipment both for intra-ship and ship-to-shore operation. A similar situation exists with regard to shore installations. A station which before the war had 12 transmitters now has more than 80 transmitters.

The Bureau of Ships as a result of experience during the war years found it desirable to establish permanent facilities for electronics work and established electronics shops in all Naval shipyards as production shops with the same status as other, older, established shop organi-



CIRCUIT CONTROL PANELS of a recently installed communication center made by the Pearl Harbor Naval Shipyard.



TEST EQUIPMENT Maintenance Section. Here test equipment of all descriptions is repaired and placed in good working order for forces afloat and outlying stations.

FREQUENCY MODULATED equipment mounted in a jeep.

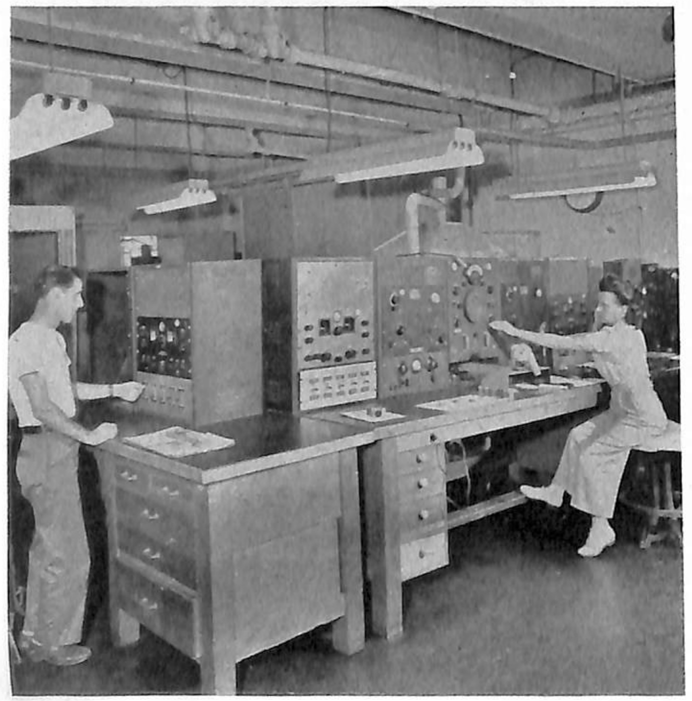
zations. This new shop is known in all shipyards as Shop 67.

On adjacent pages are pictures of this new shop at Pearl Harbor and of the work it performs.

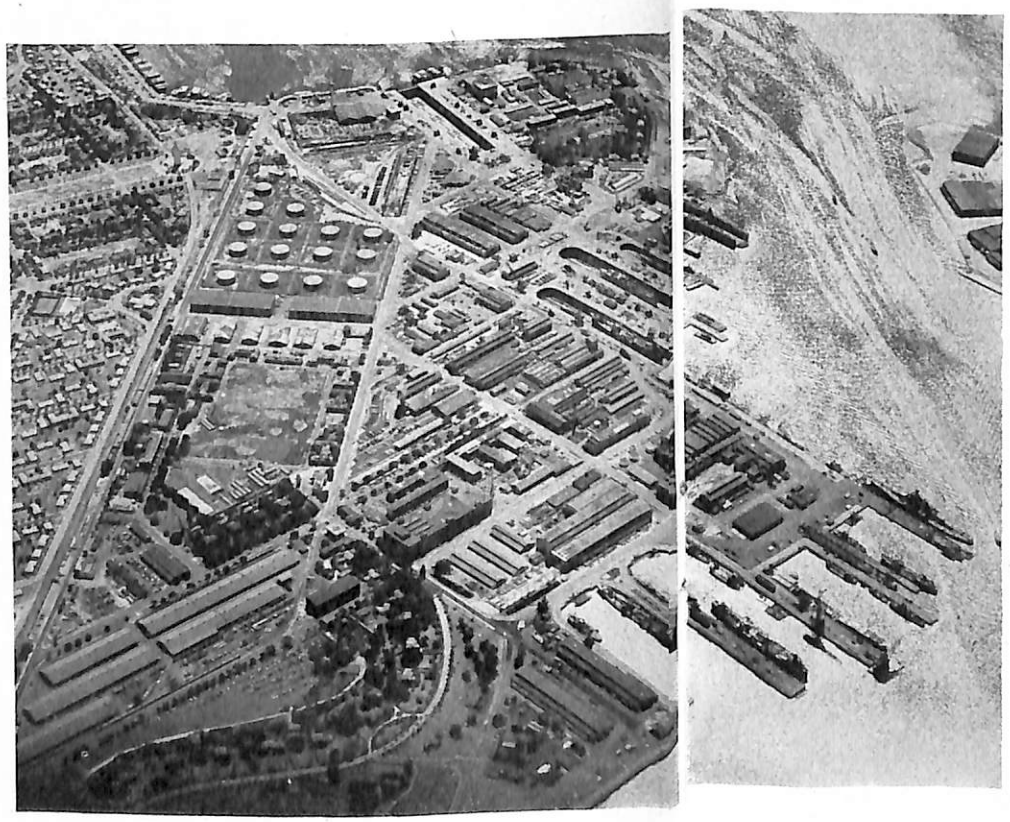
The present Shop 67 at the Pearl Harbor Naval Shipyard occupies a floor space greater in area than that of an average city block and represents an investment of several millions of dollars in plant equipment and tools of the trade. Approximately 200 people utilize this space and equipment in the performance of all types of electronics work for ships of the Navy and on Navy shore stations.

The shop is organized in sections each covering specific phases of the work such as radar, sonar, radio, teletype, and others. In the Radar Section complete equipments are set up and are in operating condition at all times. A picture of the building and the antennas mounted on the roof of the shop accompanies this article. The principal reason for having operating equipment set up is for the familiarization of the mechanics and also to provide an emergency supply of adjusted and tested equipment for ships requiring emergency repair.

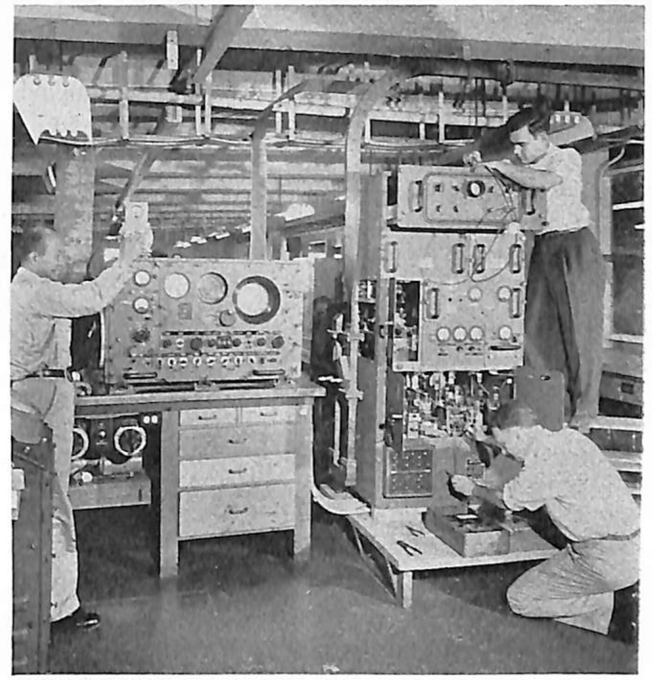
In the Radio Section a similar arrangement exists. This section handles all types of radio repair work; receivers and transmitters for operation on from 10 kc to 400 Mc at powers from a few watts to 50 kw. There is both a-m and f-m equipment; the latter is in wide use in mobile units. This section also handles radio teletype, direction finders, loran, radiosonde and other communication equipment. There is also a complete plant set-up for processing quartz crystals from the mother quartz to the finished product. Accuracy in this



QUARTZ CRYSTAL Processing Section. The primary frequency standard is located in the shielded room in the rear.



AERIAL VIEW of the shipyard, showing the repair basin in the foreground and the drydocks in the middle distance and background.

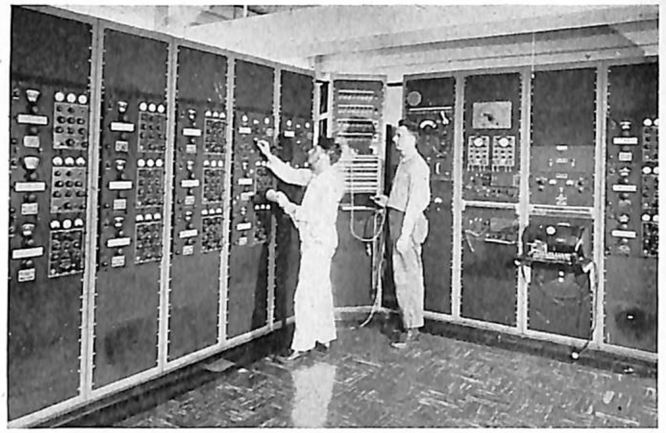


RADAR EQUIPMENT under repair in the Radar Section. Note the permanently installed wave guides.

TELETYPE REPAIR SECTION

work is checked by means of a primary frequency standard which is compared with the standard frequency transmitted by the National Bureau of Standards to maintain a frequency accuracy of less than 5 parts in 10,000,000. Some of the special equipment used in this work includes X-ray equipment for determining axis of cut; analyzers for checking of flaws; plating baths; etching baths; refrigerators and ovens for making temperature checks; oscillators for checking operation of the crystals which duplicate the actual circuit in which they are to be used.

There is also a section whose primary duty is to keep in repair and calibration all the many types of test equipment used throughout the shop. This section has a wide selection of test equipment from simple portable meters to highly precise standards and includes all types of signal generators, Q-meters, impedance bridges, micro-ohmmeters and megohmmeters, cavity oscillators,



Partial view of a recently installed COMMUNICATION BOARD made by the shipyard.

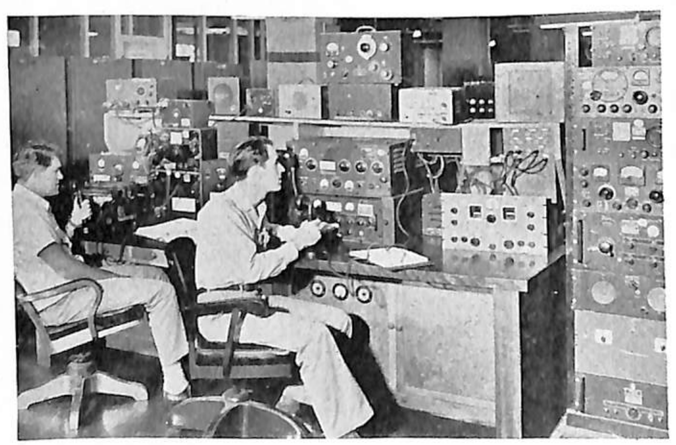
field strength measuring equipment, various types of oscilloscopes, and many others.

The teletype section repairs, overhauls and maintains some 800 units of printing telegraph equipment in the area and is equipped with an elaborate test board for making all types of tests and measurements on telegraph equipment and lines. This section not only handles ordinary page printers but also such items as perforators, reperforators, multiplex equipment, transmitter distributors, keyers, recorders, etc. Regular maintenance schedules are followed for both routine maintenance and periodic overhauls as it has been found that prevention of trouble is more economical than circuit outage and post repair.

The Shore Section has roving maintenance crews to take care of major electronic repair for all Naval activities in the 14th Naval District. Some of the equipment handled by this section are transmitters of all frequencies ranging from the very-low to the radar frequencies, and with power outputs ranging from 50 watts to 656

Portion of the TRANSDUCER REPAIR SHOP. The transducers repaired here are used on sonar equipment for underwater detection.

RADIO SECTION, showing frequency-modulated equipment under repair.



RADIO REPAIR SECTION, showing equipment being operated for test purposes.

kilowatts. It also maintains various types of Naval receivers, radio link equipment, and aircraft location equipment.

The Shore Section also has installation crews for electronics installations in the 14th Naval District covering the aforementioned equipments. The higher power transmitters in use are of the electron tube type, with the exception of a few 50 kw alternators. The antenna system of one of the higher-powered transmitters is suspended between 7,600-foot towers using 7/8-inch cable for the flat-top. Another station uses five flat-top center-fed antennas approximately 1 1/4 miles long each and suspended between two mountain peaks about 3000 feet above sea-level. [See article entitled "Haiku Catenary Antenna System" in this issue—Ed.] This section maintains several single-side-band transmitters, radio photo transmitters and receivers, large shore-based direction finders and other equipments too numerous to mention. Antennas on one station cover a 360° receiving pattern for diversity operation.

This section also maintains a shore-based under-water-sound system, operating on the triangulation principle, for location of ships at sea. One of the apexes of the triangle is located in the United States and one in Alaska. The third apex is in the 14th Naval District.

To supply the various sections with parts and material necessary in their work a complete Shop Store is maintained which carries in stock approximately 40,000 different items ranging from microscopic screws to large power transformers. An elaborate card index system is necessary to keep the large stock in order and to supply information for replenishment of stock.

The personnel of the shop consist of Radio Mechanics, Electronic Mechanics, Electricians, Machinists and their helpers and have been drawn not only from local island sources but from practically every part of the mainland as well. These people are highly trained and are continuously being given additional training in new developments of the electronic art. In order to maintain a future supply of trained personnel an elaborate apprentice training program is conducted. These apprentices are given a four-year course, not only in the trade, but in allied subjects as well. Included is a thorough academic education. On successful completion of these courses they become qualified journeymen mechanics.

ABOUT THE AUTHOR

Paul M. Walker has been in the communication and electronic field since 1922. He was employed by the Western Electric Company and its subsidiary Electrical Research Products, Inc., for sixteen years in various positions. Mr. Walker was first employed in Civil Service at Pearl Harbor in March 1941 as an electrician. He had charge of the Radio Laboratory from April 1943 as Quarterman Radio Mechanic and from November 1943 as Foreman Radio Mechanic. Since the establishment of Shop 67 as a separate production shop, Mr. Walker has been in charge as Foreman Electronics Mechanic.

MODEL SR-3

ANTENNA TRAIN MOTOR FAILURE

A recent letter to the Bureau of Ships from a Naval vessel reported the failure of the antenna train motor of its Model SR-3 radar. In view of the considerable difficulty experienced in locating the cause of the failure, the following information, quoted from this letter, is given. In the event that other SR-3 equipped vessels experience a similar failure, it is hoped that this information will permit it to be remedied expeditiously.

"Considerable difficulty has been encountered in the antenna drive motor of the Model SR-3 Radar Equipment installed on this vessel. On applying power, the antenna started normal rotation in automatic train, but immediately reduced to a low speed. In manual operation the same action was observed. From past experience the brushes were immediately suspected of being worn down and making poor contact. On checking they were found to be pitted but only moderately worn. On replacing them, the condition was not improved. Voltage checks were then made of the output of the train control amplifier. It was found that the voltage was far below normal. The field terminals 70 and 71 on terminal strip E-1108 showed 20 volts at 5 rpm, and the armature terminals 168 and 169 on terminal strip E-1108 showed 15 volts output. Continuity checks were made of the entire circuit but no trouble was found. The Rectox unit (CR-1102) supplying d-c voltage to the drive motor armature was suspected of causing the trouble. Considerable time was spent in checking this unit but it was found to be satisfactory. Finally the motor was removed from the pedestal and disassembled. Resistance checks of the series and shunt fields proved them normal. Upon complete cleaning of the motor it was found that one of the plastic brush holders had been considerably burned and charred. It had escaped detection because the charring had occurred inside the metal casing that surrounds the brush holder. This charring had formed a resistance path to ground. After replacement of the holder, the motor was reinstalled and satisfactory operation resulted."

The maintenance personnel of this vessel are to be congratulated on the logical and straightforward manner in which they traced down this trouble. Too much emphasis cannot be placed, however, on the importance of routine preventive maintenance and periodic checks of all antenna pedestals.

HAIKU CATENARY ANTENNA SYSTEM

By Fred L. Mason

A great many Electron readers had an active part in the installation of the catenary antenna system at N.C.S. Haiku. After more than five years in the weather this antenna is being lowered, span by span, for inspection and replacement of cable or hardware as required. It occurred to the Electronics Staff of Pearl Harbor Naval Shipyard that you might be interested in knowing how the "guinea pig" has fared in its battle with the elements.

You old-timers please bear with us while we bring the unfamiliar ones, who have little or no previous knowledge of this installation, into focus with our report.

Before World War II started it was realized by our high command that the Pacific Ocean Areas could not be adequately covered by the single very-low-frequency installation at Lualualei. Consequently, BuShips engineers were working on surveys for an additional v-l-f installation. The rugged volcanic terrain of the island of Oahu offered several possibilities for long-span antennas strung between natural support and over an open valley resulting from a long-extinct volcanic eruption. A test span was strung over one such location at Haiku Valley and excited with relatively low power. Field strength patterns produced by this "jury rig" arrangement produced amazingly good results. As result, plans went ahead and N.C.S. Haiku was born, at least on paper.

Actual construction started early in 1942 on what was to be the Navy's first station using a large and completely catenary antenna system. Plans called for five spans across Haiku Valley. Four of the spans, each with separate downlead from the center of the span, were connected in parallel and used as the radiating system for a 200-kw Alexanderson Alternator. The fifth span was connected to a 50 kw Model TCG transmitter as standby for the alternator.

Each of these spans approach 7000 feet in length, consisting of approximately 5000 feet of 1-inch copperweld cable as radiator, an insulator assembly 18 feet long on each end of the radiator, and approximately 1000 feet of galvanized wire rope pendants fastened to each of the insulators and used to secure each end of the span to its respective anchor. The downleads from the center of each span are slightly over 1300 feet long and consist of eight #8 copperweld conductors secured around brass rings six inches in diameter with a ring spacing of 20 feet for the total length of the downlead. All of this made a tremendous antenna by any standard. The individual spans are secured by anchors mounted on the crater rim. We shall not attempt to describe the anchors—the photographs do that very well. Our only comment is a note that the anchors are so constructed that the load is not a pull but is, due to the antenna sag and the mounting angle, largely compression.

ANCHORAGES (Nos. 2 and 3), showing steel walkway which provides access to them.

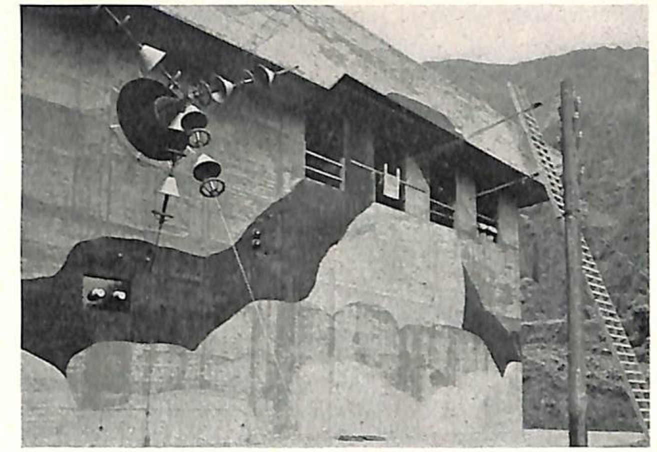
Because of the inaccessible location of the anchors it was first necessary to construct a cable lift up each side of the crater so the area could be reached and material and labor brought to the anchor site. The lifts were left in place after construction was completed to allow maintenance personnel access to the anchors. A few details on the cable car lifts may be of interest. These are the details on the short one up the south wall. The total run is slightly over 3000 feet and takes approximately 10 minutes. The cable car rides on a one-inch cable and is pulled up and down by a 200-horse-power diesel engine located on the valley floor by means of a 5/8-inch cable. The car is an eight-foot-square metal framework covered with expanded-metal sides and mounted on the rider cable with two pulley wheels. Loads around 1600 pounds can safely be hauled. I am sure a great many of you reading this will never forget your first ride up Haiku Peak, nor will you forget that first step from the car to the landing platform, with about a foot between them through which you looked straight down the 1600-odd feet to the valley floor—remember? Quite a step, wasn't it?

That is a brief background on the Haiku antenna installation. Now we will return to the subject of this article.

By viewing the downleads with field glasses from the valley floor for the past two years we have been aware that the downleads were gradually going bad. The situation became critical about a year ago when it was apparent that one of the downleads had seven strands broken in at least one spot and six strands broken in other places. Material was on order to replace the downleads and the Bureau had provided sufficient project money to accomplish the job. In August of this year the first of the spans was actually dropped to the floor of the valley. There was no way short of an inspection to determine how the spans and hardware had stood up under their more than five years of exposure to sun, rain and a more or less constant wind, at times practically saturated with sea water. The only possible means of inspection was to lower them to the valley floor.

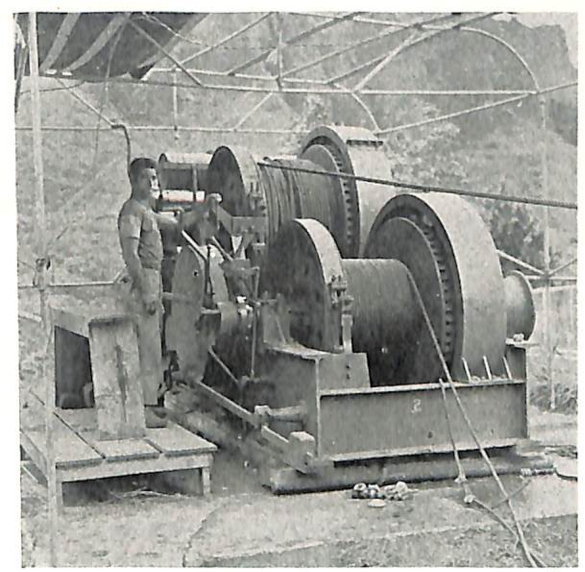
To lower the spans for inspection, a procedure similar to the method used in erecting the antenna has been adopted; that is, two winches have been located on the valley floor approximately under the center of the span, so that both ends can be lowered simultaneously. This allows the downlead to be stretched out in a prepared roadway in line with the span center as the span is lowered. Because of the lateral spacing of the spans these winches will have to be relocated at least three times to handle the five spans. Remembering our mistake in attempting to use inadequate winches when the spans were raised, this time we have obtained winches large enough for the job. As a tip to someone who may be faced with a similar problem, LST anchor winches have ample power and, in addition, have adequate drum capacity to hold sufficient cable to handle the job. The photographs show in detail the winch mountings and roadway prepared for the downlead.

It may come as a surprise to some of you that the cleared areas originally prepared when the spans were raised had grown over so completely with *hau* trees and other tropical growth that it was impossible to tell that the growth in this area had ever been disturbed. In another year the cleared area shown in these photographs will also have disappeared.

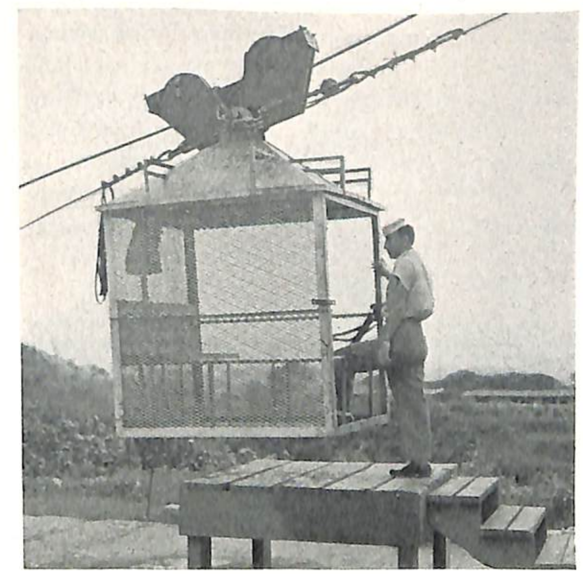


TRANSMITTER BUILDING, showing lead-in bushings for alternator and TCG.

Inspection of #5 span, the only one lowered to date, shows the effects of weather and time. The galvanized hardware used to support the downlead shows only normal weathering, and after being regalvanized will be reemployed. The hardware used to secure the downlead electrically to the radiator span shows obvious accelerated deterioration. We formerly used three bolt clamps of the familiar power-line material type at this point. To obtain the best possible electrical connection, 16-gauge sheet copper was formed around the two halves of the clamp before it was bolted in place. The sheet copper no doubt performed very well electrically, but



LST ANCHOR WINCH used to lower and raise the spans.



CABLE CAR which travels up the inside of the crater. Showing 1" rider cable and 5/8" pulling cable.

the close association of the three dissimilar metals, steel, zinc and copper, aided by a salt-laden atmosphere, set up a galvanic action which caused serious deterioration of these parts. The deterioration was so bad that the threads had completely disappeared on some of the bolts and the nuts were flaking away. These clamps will be replaced with a solid copper clamp of the type found in power sub-station material and will be hard-soldered in place.

The radiator span was in excellent condition; in fact its appearance is such that it is difficult to believe it had been in the air for five years. No replacement will be required on #5 span. The end insulators show what is considered normal weathering; after all galvanized parts are cleaned and regalvanized the whole assembly will again be reused.

The galvanized wire rope pendants used between the insulators and the anchors showed very bad deterioration. At first glance these pendants looked in about normal condition, but a close inspection revealed that the bottom side of the cable was badly corroded and not in condition for reuse. Apparently the salt from the atmosphere had collected on the bottom side of the cable and the whole bottom side showed greatly accelerated deterioration. In replacing the pendant cable we are using stainless steel cable, and we feel by so doing this corrosive effect can be avoided.

Originally these pendants were not treated with any preservative; to have used some form of cable preservative would no doubt have slowed down the weathering effects, but the effects were so severe that it was decided to use the stainless steel replacement cables. For added precaution we are treating the new cable with #506 Tectyl.

The vibration dampeners and other hardware near the cable ends showed normal weathering; these will all be regalvanized and reemployed. The metal in the anchors is in excellent condition, because they are accessible and have been kept painted and protected from weathering.

The downleads, which largely brought about the lowering of the spans, were in extremely poor condition, as we knew. On #5 span it was impossible to determine the number of breaks that existed in the downlead before lowering started, because due to their poor condition the necessary handling incident to lowering caused many more than the original number of breaks. Most of the breaks were apparently due to crystallization at the points where the individual downlead wires were fastened to the spacer rings. To dampen the movement which causes this crystallization, preformed springs of #8 copperweld wire will be used on the replacement downlead as shown in the photograph.

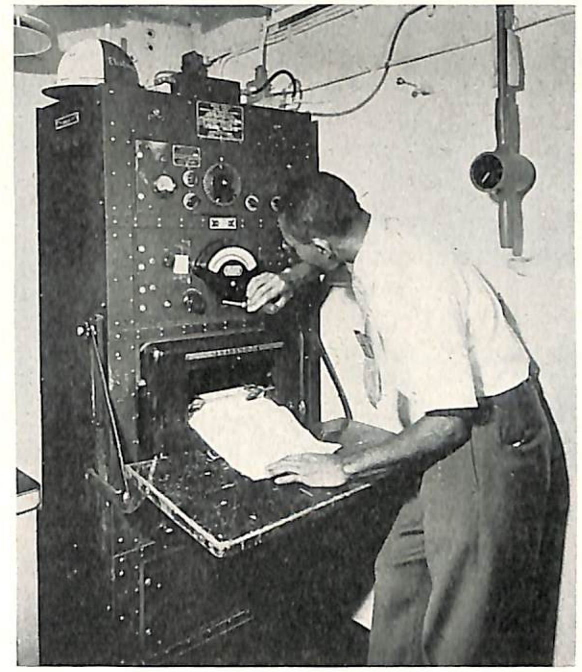
The original downleads were fabricated as the spans were raised. This method of construction caused many "nicks" and small breaks in the copper coating of the downlead wires. In order to avoid a repetition of this damage, which may have been to a large extent responsible for the rapid deterioration of the downleads, the roadway shown in the photograph was prepared and the downleads fabricated as a complete unit before erection. If experience shows that even this method has not avoided damage to the wires and rapid breakage results, the only other solution is to use the more expensive copperweld wire with a non-corrosive core for the next downlead replacement.

In conclusion we feel that the changes we are effecting in the connections between radiator and downlead and the replacement of galvanized wire rope pendants with stainless steel wire rope pendants will make the top spans well able to wage a successful battle with the elements for several years. The downleads by virtue of the new method of fabrication and the change in physical construction will be much improved; we feel another inspection in five years will provide an answer to the question regarding the possible future use of non-corrosive copperweld wire for downlead material.

CLEARED AREA into which downleads are lowered. This area is in line with the center of the spans.

DOWNLEAD CONSTRUCTION, the new method, showing preformed springs used to prevent move of downlead wires at point of attachment and resulting crystallization.

SHIPBOARD ELECTRONICS INSPECTIONS



Final adjustment of a RADIOSONDE RECEIVER.

By R. H. WORRALL
Pearl Harbor Naval Shipyard

When a ship enters the shipyard for regular overhaul, it becomes necessary to determine what service is needed on its electronic equipment. The Electronics Office, through its Ship Section, has the responsibility for obtaining information as to the condition of the electronic equipment and for recommending what steps should be taken to correct existing trouble and forestall future trouble by accomplishing preventive maintenance.

Shipboard inspections are made by the shipyard in accordance with Bureau of Ships directives contained in the following references:

1—BuShips Manual, Chapt. 67, Art. 67-82.

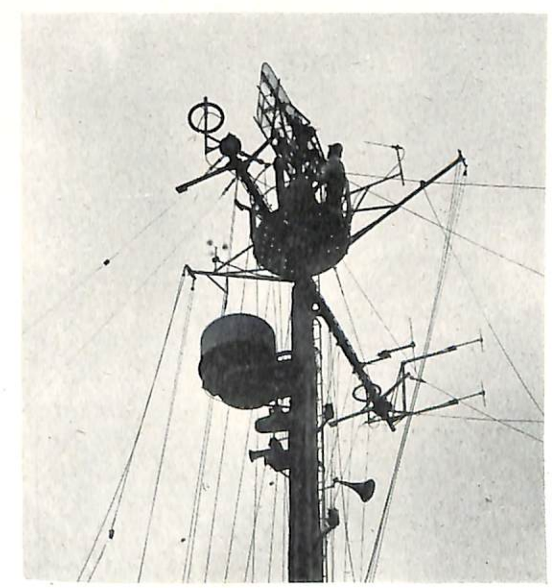
2—BuShips "Instruction for Maintaining Ship Electronic Equipment Inventory System (NavShips 900, 135).

These engineering inspections are usually conducted by the Electronics Office engineers who may be assisted by Company contract engineers.

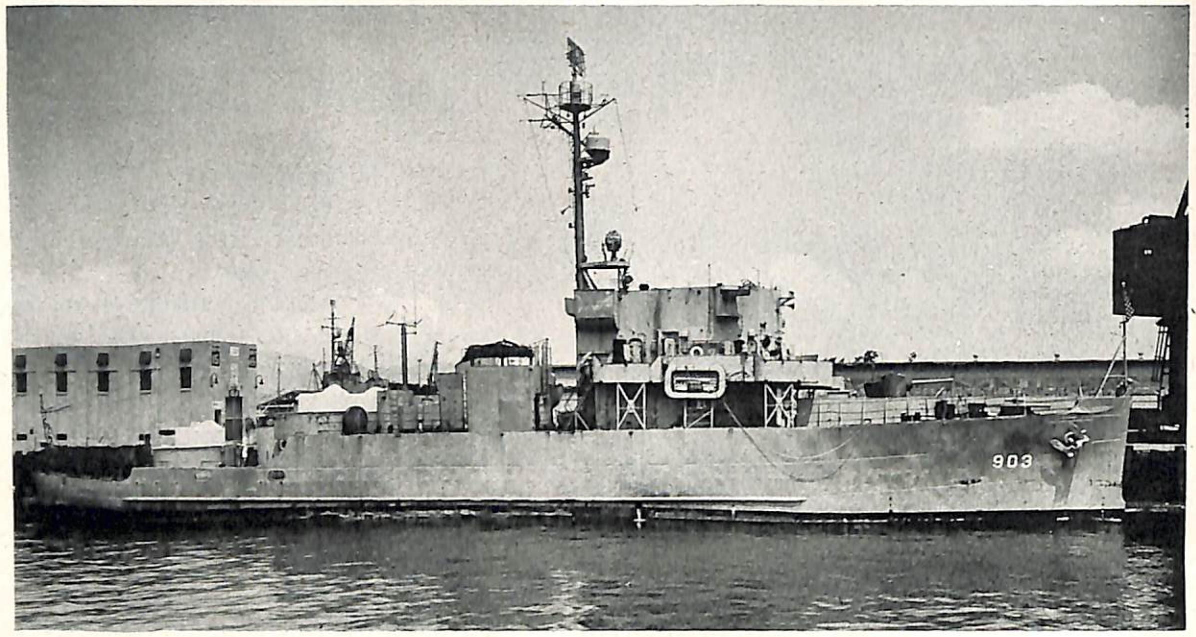
The word "inspection" is very misleading to the uninitiated. To the average person this word "inspection" simply means to glance over and if it looks all right, it is all right. One definition by Webster is, "a strict and prying examination." For shipboard electronic inspections, we think Webster very well describes what the inspectors make every effort to accomplish.

The notification sent to a ship that an electronic inspection is to take place at a certain time is the "open sesame" to a golden opportunity for the ships' force to unload all their troubles and gripes, real and imaginary. If personnel on the ships would realize that these inspections are *engineering inspections* and are made by men who are engineers and who actually have the interest of the service at heart they would probably ask for more assistance to be given them during the inspection period or overhaul. These engineering inspectors are not supermen; yet one might think so, because of the large number of complicated electronic equipments the inspectors must thoroughly understand. Nevertheless, each man is an expert on several different types and has working knowledge of many more so that their abilities overlap. They are in an excellent position to assist the ship.

One of the greatest difficulties in servicing or obtaining information leading to servicing is the attitude of the ships' personnel, who often will not admit that anything is wrong. Finally when an inspection is made and it is plainly obvious that the equipment has been defective for months (and this has been the case many times) it reflects back on the personnel worse than it would have had he admitted his lack of knowledge at the start. The best advice to the ships' force is, *Don't be afraid to confess electronic troubles or admit you don't know about the operation of some particular equipment,* if you actually don't.



VISUAL INSPECTION of radar antennas.



The WEATHER SHIP.

INSPECTION ROUTINE

As the first move, an advance notice is sent to the ship via an inspector, that an electronic inspection will be made at a specific time and date. The inspector-messenger contacts the Captain and gives him an outline of the procedure during the course of the inspection and the assistance the ship is requested to give. On the day of the inspection, one or more engineers (depending upon the type and size of the ship) are sent aboard. If required, there will be a fire control radar engineer, a search radar engineer, a sonar engineer and general radio engineer. Their routine is as follows:

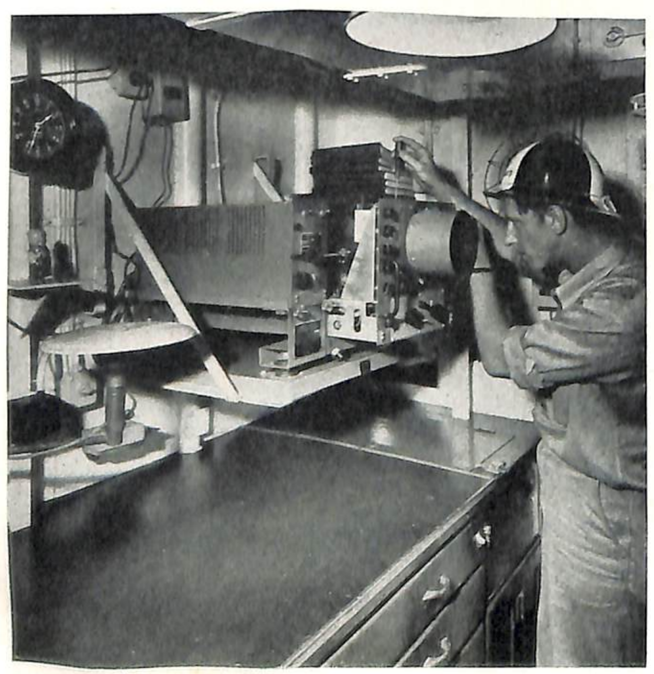
1—Make an inventory of every piece of electronic equipment under the jurisdiction of the E.O. (private and government) that is on board.

2—Operate each piece of equipment, inspect the maintenance log and ask the operators and maintenance men for details on any troubles they have had since last overhaul. Ninety percent of the time when asked how the equipment is working the answer will be, "OK I guess." If you have troubles, tell the inspector about them, for only then can he help you. In plain language, *"let the inspector have the gripes"*; it may save you a future breakdown.

3—Make a careful physical check of the equipment and make recommendations to shipyard or ships' personnel for repairs.

4—Advise ship how to word their work requests and how the shipyard electronic organization functions.

5—When time permits, instruct ship personnel in care and operation of equipment either on board or in the Electronics Shop as the case may be.



CHECKING CALIBRATION on a loran.

ASSISTANCE FURNISHED BY THE SHIP

When the inspection group arrives on board, the ship assigns technicians (through previous arrangement) to assist during the inspection period. These technicians should assist in locating all equipment which is not in plain sight. The technicians should have this equipment out and ready for inspection. They should have the machinery history records at hand to help the inspector get a better word picture as to why certain failures or troubles occurred. It should be remembered that the symptoms of some types of trouble may be apparent only when a ship is underway, hence may not be observed by a shipyard inspector. Carefully written reports of an equipment's behavior at sea will be invaluable to the inspector in such cases. The ships' technicians should operate the equipments so the inspectors can observe the method used and make suggestions as well as study the operation of this particular unit. The ship should have spare parts and replacements easily accessible for the engineers' use if needed. During the inventory the ships should take this opportunity to check their own inventory files as no copy of the inspectors' inventory will be given the ship.

It is the responsibility of the ships' personnel to acquaint the inspectors with anything and everything electronic they feel does not function at 100% efficiency. If the ships' personnel are wrong, all the more credit to them in making sure and eliminating any doubts they may have about the equipment. If you do not have full confidence in your equipment or in your ability to operate it, tell the inspector; he may find a good reason for both points.

SHIPS' RESPONSIBILITY AFTER ARRIVAL INSPECTION

Upon completion of the engineering reports resulting from the inspection, a letter is compiled and forwarded to the Commanding Officer, giving a list of all equipment found defective and making recommendation for action by the ship or the shipyard. A copy of this letter also goes to the Type Commander.

It is the ships' responsibility to make sure that:

1—Work requests are put in covering all items requiring shipyard work.

2—That the recommendations for action by ships' personnel are followed through.

3—When repairs to each piece of equipment are completed, that the equipment works to the full satisfaction of the ship. If it does not, the Electronics Officer in the shipyard should be notified at once.

The benefits which a ship derives from its overhaul period depend to a large extent on the teamwork displayed by the ship and shipyard. The security of the country may well depend upon the electronics equipment aboard ship. Such equipment must be maintained at peak efficiency, so let's all cooperate to get the most out of ship overhauls.

ABOUT THE AUTHOR

R. H. Worrall has put in more than thirty years in the Naval Service, having entered the Washington Navy Yard in 1917 from the Marconi Wireless Telegraph Company. From 1923 to 1938 he was at the Naval Research Laboratory. His major contribution while at N.R.L. was his assistance in the development of one of the early Navy primary frequency standards. He was also active in early radio direction finder work at that activity. He is a well-known inventor in many fields. He has been a member of the I.R.E., the A.I.E.E., and Chartered Institute of American Inventors, and has been listed in Who's Who in the East and Who's Who in Engineering.

CAN YOU TOP THIS?

The U.S. Marine Corps Air Station at El Toro (Santa Ana) California reports this one. The G.C.A. at the station was alerted and established contact with an F7F aircraft at 2145 on 23 June. At the time of contact, the plane reported 25 minutes of gas remaining, and was immediately brought around on downwind for a normal approach.

The aircraft was erratic on its headings downwind and crosswing, which was attributed to the pilot. When he refused to follow corrections on final, it became necessary to give him a wave-off. At this time, with an estimated 12 minutes of gas remaining aboard, an immediate P.P.I. run was commenced. This pass was successful and the aircraft landed without incident at 2208. A check with the pilot disclosed that he was newly arrived from flight school, that it was his first night hop in an F7F, that he had never flown G.C.A. before, that the plane had a defective gyro compass, and that the radio was operating intermittently!

ARCING IN THE MODEL SR-2 RADAR

The March 1947 ELECTRON carried an article on the prevention of arcing in the Model SR-2 Radar Equipment. The detailed procedure given in that article has been adopted by the Bureau of Ships and issued as "Field Change No. 3—SR-2—Prevention of Arcing." Instructions for making this field change can be obtained from the Electronics Officer at any Naval shipyard.

TEST SET FOR ALIGNMENT OF SYNCHRO UNITS

By D. L. Pang

Pearl Harbor Naval Shipyard

Synchro units connected together in a synchro system are, by their working principle, self-aligning, or to use another term, self-synchronizing. An initial alignment of the synchro units in relation to each other is necessary, however, before the system will function properly.

There are two methods by which this initial alignment could be made. Method No. 1, which is widely used, would be to have two men on a phone circuit extending from one synchro position to the other. The man at the main unit keeps the man at the secondary unit posted on the main dial reading while the secondary unit is being adjusted so that its dial reading corresponds to that of the main synchro unit.

Method No. 2 is to zero each individual unit in the synchro system using electrical zero as a reference. When this is done, the system will work properly.

Method No. 2 has the very important advantage that a zeroed synchro system can be tied in with another zeroed synchro system directly without additional alignment work. This is especially important in view of the complexity of present-day Target Designation Systems involving many different types of equipments.

Another important advantage of using Method No. 2 is that all synchro units in equipments can be zeroed in the shop during inspection of new equipment or servicing of existing equipment, thereby requiring little if any alignment work after the equipment is wired in.

Method No. 2 has the further advantage that trouble shooting in the system will be easier in that comprehensive trouble charts and table of symptoms related to faults can be prepared.

As stated above, method No. 1 is still widely used in spite of the many advantages offered by method No. 2. One reason for this is that method No. 1 is almost self-explanatory while method No. 2 involves temporary circuit changes which are by no means self-evident. Another reason is that existing units in the synchro system are not already zeroed and extensive work is required for zeroing the complete system.

It is the opinion of the author that some means to facilitate the alignment of synchro systems, when using method No. 2, should be developed in order for this method to receive universal acceptance. In line with this thought, the use of a portable test set which would simplify the procedure of zeroing the different types of synchro units has been suggested.

One device to be described is such a test set. The schematic diagram of the test set is shown in figure 1. The methods employed in using this test set for zeroing synchro units are the same as those outlined in Ordnance Pamphlet OP 1303.

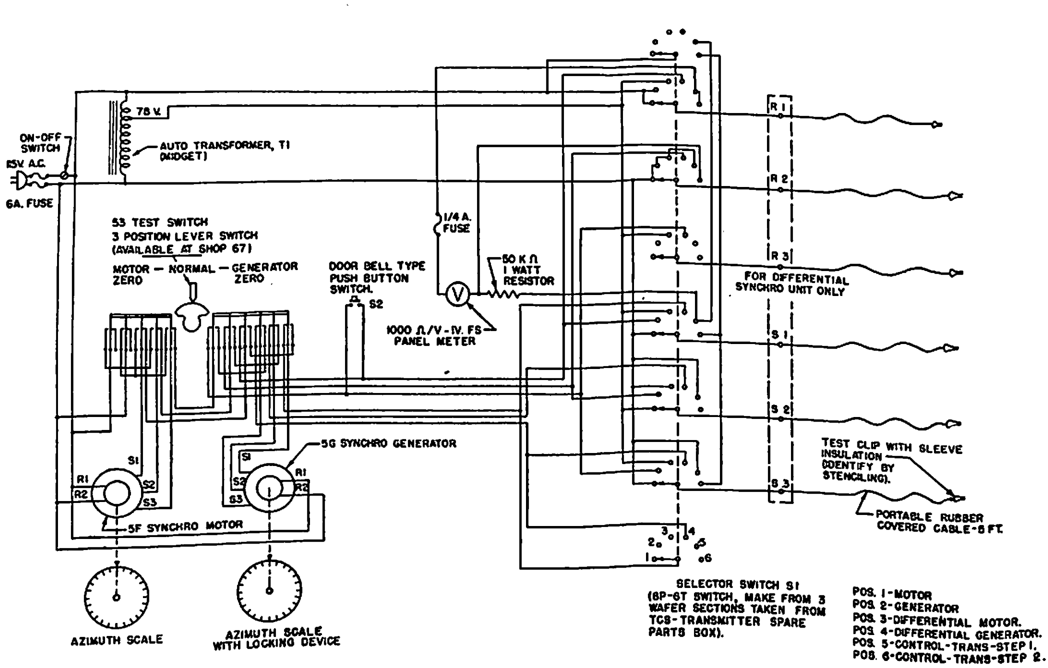


FIGURE 1—*Schematic Diagram of a device for zeroing synchro units.*

With the synchro unit which is to be electrically zeroed connected to the test set by means of the test clips, the following conditions are set up by the selector switch S1:

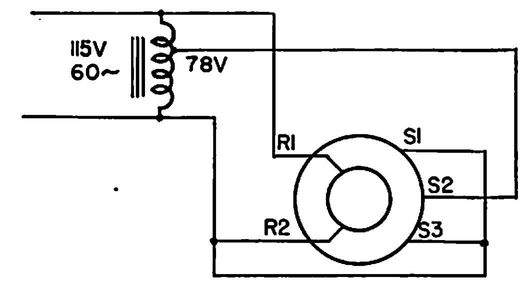


FIGURE 2—*Selector switch on Position 1 for zeroing synchro motor.*

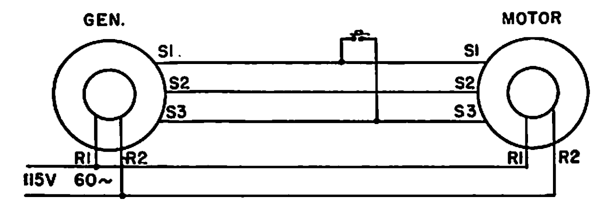


FIGURE 3—*Selector switch on position 2 for zeroing synchro generator.*

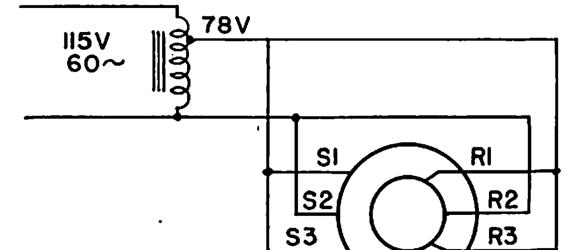


FIGURE 4—*Selector switch on position 3 for zeroing synchro differential motor.*

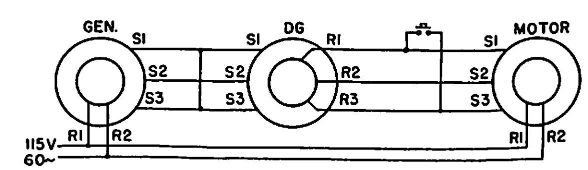


FIGURE 5—*Selector switch in position 4 for zeroing synchro differential generator.*

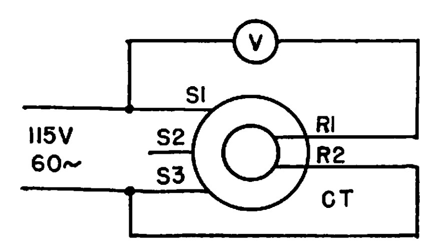


FIGURE 6—*Selector switch on position 5 for zeroing synchro control transformer—step 1.*

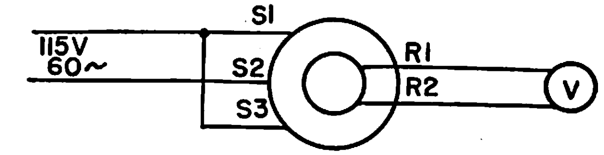


FIGURE 7—*Selector switch on position 6 for zeroing control transformer—step 2.*

Before this test set can be used as a standard for zeroing synchro units, the synchro units within it must be electrically zeroed. A test switch has to be incorporated so these units can be checked at will to see that they are electrically zeroed before the device is used. This test switch is a lever type switch with a neutral (NORMAL) position. It is left in the NORMAL position except when testing for electrical zero of the synchro units within the test set.

The following operating instructions should be attached to the underside of the cover of the apparatus. Since all connections to this test set are rather obvious and simple instructions are furnished with it, the operation of this device for electrically zeroing synchro units does not demand special training in its usage.

To zero a synchro motor:

1—Remove synchro leads from equipment circuit and clip on test leads of test set to the corresponding R and S leads of the synchro unit.

2—Set selector switch S1 to MOTOR and turn on power switch. The shaft of the synchro unit will turn definitely to zero degrees. Set the dial to its zero reading which the motor is connected this way.

To zero a generator:

1—Remove generator leads from equipment circuit and clip on test leads of test set to the corresponding R and S leads of the synchro unit.

2—Set selector switch S1 on GENERATOR and turn on power switch.

3—The standard motor in the test set as used in this test must itself be electrically zeroed. Once zeroed it will hardly require further attention but as a precaution a test switch this, throw test switch S3 to MOTOR ZERO. The motor azimuth scale should read zero degrees indicating that the motor is electrically zeroed. Return test switch to NORMAL.

4—Set the unit whose position the generator transmits, accurately in its zero position. Unclamp the generator and turn it until the motor in the test unit reads zero degrees. The generator is now approximately on zero degrees.

5—Check by depressing push button switch S2. If motor's shaft moves at all when S2 is depressed, the generator is not zeroed. Shift slightly and try again. When it is accurately zeroed clamp it in place.

To zero a differential motor:

1—Remove differential motor leads from equipment circuit and clip on test leads of test set to corresponding R and S leads of the motor.

2—Set selector switch S1 to DIFFERENTIAL MOTOR and turn on power switch.

3—The shaft will definitely turn to zero degrees. Set the dial to its zero reading while the motor is connected this way.

To zero a differential generator:

1—The standard motor and standard generator in this unit is used in this test. They have been electrically zeroed but as a precaution a test switch S3 is provided to check these units for electrical zero. Throw S3 first to MOTOR ZERO to check motor for electrical zero and then to GENERATOR ZERO to check generator. When the switch is in the GENERATOR ZERO position the motor dial should read zero with the generator dial set to zero.

2—Remove the differential generator leads from the equipment circuit and clip on test leads of the test set to corresponding R and S leads of the generator.

3—Set selector switch S1 to DIFFERENTIAL GENERATOR.

4—Set the dial of the generator in this device to zero degrees. Unclamp the DG and turn it until the motor in the unit reads zero degrees. The DG is now approximately on zero degrees.

5—Check by depressing pushbutton switch S2. If the motor's shaft moves at all, the DG is not on zero degrees; shift slightly and try again. When it is accurately on zero degrees clamp it in place.

To zero a control transformer:

1—Remove the control transformer leads from the equipment circuit and clip on test leads of the test set to the corresponding R and S leads of the CT.

2—Set the selector switch S1 to CONTROL TRANSFORMER —STEP 1 and turn on power switch.

3—Unclamp the CT and turn it until the voltmeter in this unit reads minimum. The CT is now approximately on zero degrees.

4—Set selector switch S1 to CONTROL TRANSFORMER—STEP 2 and again turn the CT until the meter reads minimum. When this is done clamp the CT in place.

ABOUT THE AUTHOR

D. Pang, Electronics Engineer, P-4, was born in Honolulu, T.H., December 23, 1917. He attended the University of Hawaii from which he received his B.S. degree in Mathematics and Physics.

He was with the Design Branch, Planning Division of the Pearl Harbor Naval Shipyard for four years before his transfer to the Electronics Office.

His experience with sonar and radar equipments dates back to the old stethoscope type of submarine sonar listening device and the first experimental model CXAM shipboard radar.

This is Mr. Pang's fourth year with the Electronics Office. During the first two years he was attached to the Sonar Laboratory and was directly responsible to the Electronics Officer for the proper maintenance and installation of all sonar equipment on ships and harbor defense installation.

During the past war, he directly coordinated the design of plans for the entire radio installations aboard the *Salt Lake City* and the *Pensacola* when these battle-scarred ships were being extensively refitted and modernized to do further battle with the Japs.

BASIC PHYSICS

PART 14

GENERATION OF ELECTRICAL ENERGY

This chapter will explain the theory of the more important methods of generating an electromotive force or "difference of potential."

"Generation of electrical energy" means any process whereby energy, in some form other than electrical, is converted to electrical energy. Conversion is usually accomplished by generating potential electrical energy in the form of a difference of potential and, by means of an electric circuit, this potential electrical energy is converted to kinetic energy—in which form it is used to accomplish useful work.

The meaning of electrical (potential) energy. The electrical potential at a point is said to be raised or positive when a deficiency of electrons exists. When there is an excess of electrons, the point is said to be at a low potential or negative with respect to the other point. Between these two points in an electrical circuit there will then exist a potential difference of electrical pressure. This is due to the electrostatic force that exists between charges at the two points, which will tend to move electrons from the point of excess electrons to the point of lesser quantity.

If a conducting path is provided between the two points which are at a different potential, electrons will be caused to move from the point of low potential to that of high potential: i.e. from negative to positive, until the electrostatic charges are neutralized. If, by some means, a steady potential difference is maintained between the two points in question, a steady stream of electrons will flow through the conducting path. The electrical or potential energy to maintain this potential difference may be supplied by any device capable of supplying electrons in sufficient quantity to maintain the electrostatic pressure.

An electrical generating device transforms energy in one form, whether it be thermal, chemical, or mechanical, into electrical energy by moving electrons in such a manner that a difference of potential is established.

When a force is applied to a body, the body tends to move in the same direction as the force. If the body is free and does move thus, it (or the system of which it is a part) loses potential energy. But, if the body is caused to move in the opposite direction (that is, against the force), work is done upon it and the body or system acquires potential energy. In this case the amount of potential energy gained is numerically equal to the work done upon the body. Consider the pile-driver as a practical example: when the weight is lifted from the ground against the force of gravity, it acquires potential energy; this is converted to kinetic energy when the weight is allowed to hit the piling. Now apply this same principle in the electrical field. When a negative charge (electron) is moved toward a like charge or against the electrostatic force, there is an increase in the potential energy of the system, but if the electrons move in the direction of the electrical force, from the negative to the positive side of the circuit, the potential energy is converted to kinetic energy by heating the conductor, such as in the ordinary lamp bulb. In so doing, the system loses a like amount of its potential energy.

Electromotive force. When current flows in a metallic conductor, heat is *always* developed—which means that energy is being expended. Kinetic energy is being formed from the potential energy represented by the potential difference at the terminals of the conductor.

It is obvious that a current will not continue to flow in a circuit made up entirely of metallic wires, free from outside influence. To keep the current flowing, energy equal in amount to that dissipated by the circuit must be supplied to the circuit. The amount of energy supplied in one second may be represented by the product EI, where E is the energy expended in the circuit in one second when unit current ($I = 1$) is flowing. This term E is called the electromotive force of the circuit.

Electromotive force describes the phenomenon that forces a current through a circuit. In practice, the electromotive force of a device is usually measured by determining the potential difference between the terminals of an electrical generating device. This measurement is made in terms of volts.

Forms of energy. Energy may appear in various forms, the most important of which are mechanical, thermal, chemical, electromagnetic, sonic (sound), and as visible light. In attempting to use energy in any of these forms, there is at least one method by which it may be converted to electrical energy. Of course, conversion methods which require a large quantity of available energy to obtain a relatively small amount of electrical energy are of little practical value because of their inefficiency. Yet, some of these inefficient methods are important either because of the effects they produce in an electric circuit or because they are useful in the measurement of certain physical phenomena.

Of the more practical methods, there are three in common use for supplying electrical energy to a circuit:

1—The thermal generator which transforms heat energy into electrical energy.

2—The voltaic cell which transforms chemical energy into electrical energy.

3—The dynamo or electric generator which transforms mechanical energy into electrical energy.

Each of these conversion devices succeeds in maintaining a potential difference between its terminals by moving electrons through the potential gradient until static charges accumulate. The resulting electrostatic field balances the force due to the electromotive pressure produced by the device.

In order to thoroughly understand the phenomena of generating a potential difference in an electrical generator it is necessary to study the nature of electron movement in a conducting medium.

Conduction of current in solids. An electric current in a metal wire or other solid conductor consists of a stream of electrons moving from negative to positive sources of e.m.f. When this phenomenon occurs, two effects are *always* present: the wire becomes heated and a magnetic field is present, but no chemical change takes place in the conductor. When mercury or other fluid metal is the conductor, the atoms may also move along the potential gradient, but no chemical action occurs.

It is generally believed that there are some electrons within the metal which are free to move among the molecules. These electrons are in thermal equilibrium with the molecules: that is, their average kinetic energy equals that of the molecules. The best conductors are metals such as silver, copper, nickel and various alloys, all of which have a crystalline structure. The nuclei of the atoms accompanied by the closely bound electrons are arranged in a stable lattice structure. One or two loosely bound electrons from each atom appear to be easily set free, and these move about within the conductor, but are confined to the conductor by a potential barrier at the surface, due to the total charge of the metallic atoms or molecules. Here exists a form of electrostatic equilibrium. Under the action of an electric field, such as a potential difference impressed across the ends of the conductor, the electrons will be caused to drift in a certain direction because of the electric pressure exerted by the electromotive force. This causes thermal agitation of the lattice structure because the electrons give up energy in the form of heat when they are moved against the force exerted by the electrostatic charge of the atoms or molecules. However erratic each electron's movement may be, the general drift of all the electrons within the conductor is in the same direction, from the negative source of e.m.f. to the positive.

Joule's law of heating. The quantity of heat developed by the expenditure of electrical energy depends upon three factors: the magnitude of the electron flow or current, the duration of time this current is maintained, and the resistance of the conductor. Experiments have shown that, all other factors being equal, doubling the quantity of current quadruples the heat developed, or more generally, the heat produced is proportional to the square of the current. For example, if the same current exists for equal intervals of time through pieces of wire having the same physical dimensions, one of copper and the other of iron, the iron will become hotter than the copper; consequently, the iron is said to offer more opposition to the current and to have a higher resistance than copper.

To sum it all up, *"The heat produced in a conductor is proportional to the resistance of the conductor, the square of the current, and the time of current flow."* This is commonly known as Joule's law of electric heating. The amount of energy, converted into heat in terms of joules, may be expressed:

$$W = R I^2 t$$

where R is expressed in ohms, I in amperes, and t in seconds; then the energy W will be given in joules. Joule/second is therefore the rate of expending energy in a circuit. In electrical circuits, power is expressed in watts, one watt being equivalent to a joule/second. In thermodynamics, heat energy is expressed in calories—the unit calorie being equivalent to 4.19 joules. A calorie is the heat required to cause a change of 1 degree centigrade rise in the temperature of one gram of pure water.

In accordance with Joule's Law, the rise in temperature of an electrical conductor is attributed to thermal agitation of the atomic or molecular structure of the conductor by the movements of the electrons. If this agitation be increased, by either increasing the potential difference across the terminals or increasing the resistance of the conductor, the electrons will soon acquire sufficient kinetic energy of motion to overcome the electrostatic force of the atoms and molecules as well as causing heat by giving up energy. When this occurs, the electrons actually break through the potential barrier at the surface and leave the conductor, but in so doing, their kinetic energy is expended and they are attracted back to the conductor. Under such conditions, electrons are continually leaving and returning to the surface of the conductor, effectively establishing a cloud of electrons in the immediate vicinity of the heated conductor. Usually a red or white hot temperature is required for the conductor to produce such a cloud.

The cloud of electrons constitutes a negative *"space" charge*, and if a positively charged body is brought into the vicinity, an electrostatic field will be established, causing electrons to be drawn from the "space" charge in attempting to equalize the potential difference. This current flow is known as the "Edison effect" and is the basic principle of the electron tube.

Thermal properties of metals. During the period of from 1800 to 1900 various experimenters established the fact that the potential energy gained by an electron that was caused to leave the surface of a conductor could be expressed in terms of *energy* called *electron-volts*. When used in this manner, an electron-volt represents the energy imparted to an electron in forcing it through a potential difference of one volt. One electron-volt is equal to 1.602×10^{-12} ergs of energy.

The potential barrier at the surface of a conductor prevents an electron from leaving until it has sufficient kinetic energy of motion. A convenient method commonly used is the use of heat. Each metal has a potential barrier dependent upon its atomic or molecular structure and the energy in electron-volts required to overcome the potential barrier is termed the *"work function"* of the metal.

The work function in electron-volts for three metals used as filaments in vacuum tubes are shown below with their approximate operating temperatures. This indicates that greater energy is required for metals having a greater work function.

Tungsten	4.53 electron-volts	2100° C.
Tantalum	4.07 " "	1950° C.
Thorium	3.35 " "	1500° C.

Contact potential. About 1800, Volta arrived at the conclusion that the twitch in the frog's leg in Galvani's famous experiment was due to the electric potential caused by the contact of two dissimilar metals. Later it was proven that a contact electromotive force exists between two dissimilar metals when placed in intimate contact. This is an intrinsic property of metals and the contact e.m.f. depends upon the work functions of the two metals used and the temperature of the junction.

The difference in potential resulting from contact in air between two dissimilar metals is very small, usually a few microvolts at normal temperatures. This is due to the fact that some metals have more free electrons than others; therefore, when in contact, electrons will pass from one metal to the other, thus creating an excess of electrons in one of the metals and giving it a negative charge. This contact e.m.f. is subject to considerable variation depending upon such physical factors as cleanliness of contact surfaces, temperature, humidity, pressure of contact, etc. Often, as will be seen later, contact potential is of a nuisance value in the wiring and connections in electronic circuits.

Thermoelectric potentials. A thermoelectric potential is one generated by a conversion of thermal energy to electrical energy. Figure 1 shows two dissimilar metal wires joined at two points to form a single conducting loop. A contact potential will exist at each junction, due to movement of free electrons from the copper wire to the iron wire, which charges the iron side of each junction negatively with respect to the copper side. When the temperature of junction A is the same as that of junction B, the two contact potentials will be equal, but since the potential at A is opposite to that at B, the effective potential in the entire loop will be zero.

However, if the temperature of junction B is raised as shown in figure 1 by the use of an ordinary candle, there will be an increase in electron transfer from the copper to the iron, thus raising the potential at junction B above that at junction A. The effective potential in the loop is equal to the difference in e.m.f. at each junction, and current will flow in the loop from copper to iron at the heated junction, via the iron wire to junction A, through the junction and via the copper to junction B. The quantity of thermal current established will be determined by the *difference in temperature* between the hot and cold junctions, and the direction of current flow depends upon which junction is heated.

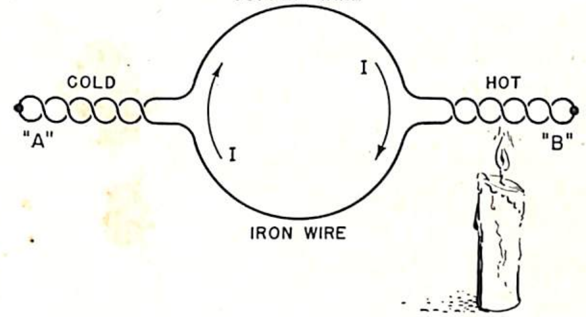


FIGURE 1—*The thermoelectric circuit.*

One theory of thermal e.m.f. is based upon the unequal quantity of free electrons per unit volume in the two dissimilar metals. Copper at normal temperatures has less electrical resistance than iron; therefore, copper is expected to have a greater number of free electrons per unit volume than iron. When the two metals are placed in contact with each other, the distribution of free electrons tends to equalize across both junctions; electrons move from copper to iron at both points of contact, which charges the copper positively, and the iron negatively. As the charge in both metals builds up it will become more and more difficult for electrons to move from copper to iron and a stabilized condition is reached when no further electrons move through the junctions. The two contact potentials are then equal but acting in opposite directions, and with no difference of temperature between the two junctions the effective e.m.f. in the loop is zero.

However, if one junction is heated, thermal agitation causes a greater transfer of free electrons from copper to iron at the heated junction. This raises the potential at the heated junction, which causes a thermal current to be established in the loop.

Since the number of free electrons in a metal does not vary directly as the temperature, the thermal e.m.f. developed across the heated junction of two dissimilar metals cannot be expected to vary directly as the temeperature. Figure 2 shows the variation of thermal e.m.f. of an iron-copper thermocouple as plotted against the difference in temperature between the two junctions. At 0° difference the thermal e.m.f. is zero, but as the temperature difference is increased by heating one junction, the thermal e.m.f. increases, first rapidly then more slowly, attaining a maximum for this particular thermocouple at approximately 275° difference. Over this range of temperature difference, the number of free electrons in the copper exceeds the number in iron. The temperature difference at which the ratio of free electrons in copper to those in the iron is maximum is called the neutral temperature of the couple and coincides with maximum thermal e.m.f.

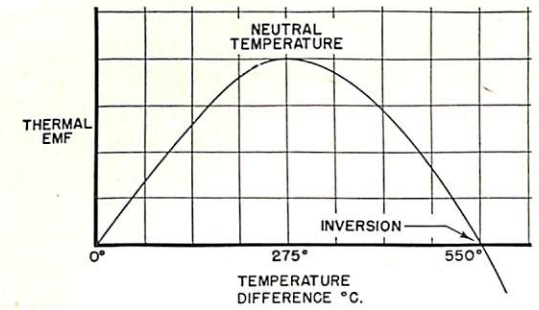


FIGURE 2—*Thermal e.m.f. diagram of a copper-iron thermocouple.*

When the temperature difference is increased above 275°, the rate at which free electrons are liberated in the iron becomes greater than the rate of increase in electrons from the copper, so that the total number of electrons transferred per unit time is reduced and causes a similar reduction in the e.m.f. At twice the neutral temperature, the number of free electrons released per unit volume for each metal is equal; therefore the thermal e.m.f. is zero. The temperature difference at which this condition is attained is called the temperature of inversion. Beyond this temperature, iron releases more free electrons than copper and causes the copper to become charged negative with respect to the iron, thus reversing the polarity of the e.m.f. across the junction.

Different combinations of metals will produce a similar-shaped curve, but of course the amplitude of e.m.f., the rate of change of e.m.f. per degree change in temperature difference and the range of temperatures over which the variation takes place will differ from figure 2. In any practical thermocouple, the variation of e.m.f. for temperature difference between zero and the neutral temperature will be of primary importance. In electrical work, the most important factor will be the rate of change of thermal e.m.f. per degree change in temperature at the hot junction. The cold junction is always assumed to be held at a fixed temperature.

Table I shows an arrangement of metals called a *thermoelectric* series. Any metal in the list is electro-positive to any metal that follows it, and electronegative to one that precedes it. For example, if nickel be placed in contact with antimony and junction heated, electrons will be transferred from nickel to antimony and the nickel becomes positively charged. Nickel is said to be electropositive to antimony. However, if bismuth is substituted for antimony, the nickel becomes electronegative, since the transfer of electrons will then be from bismuth to nickel at the heated junction.

Table I. *Thermoelectric Series.*

1. Bismuth	7. Gold
2. Nickel	8. Silver
3. Platinum	9. Copper
4. Aluminum	10. Zinc
5. Tin	11. Iron
6. Lead	12. Antimony

The above series is quite brief and can be extended considerably by the addition of a number of alloys which have marked thermal properties. A combination of pure platinum plus an alloy of 90% platinum and 10% rhodium is widely used as a thermocouple in furnace pyrometers. A thermocouple of this type in conjunction with a sensitive milliameter may be used to measure temperatures up to the order of 2000° C. Constantin, an alloy of about 60% copper and 40% nickel, is often used with iron or copper in the thermocouple-type milliameters.

A therompile is a combination of thermocouples arranged in series so that the thermal voltages are additive. Such a device in series with a very sensitive current meter has been used to measure the heat of distant planets and to compare the temperatures of distant stars. With the thermopile placed at the focal point of an astronomical telescope, a temperature change less than one millionth of a degree Centigrade may be detected!

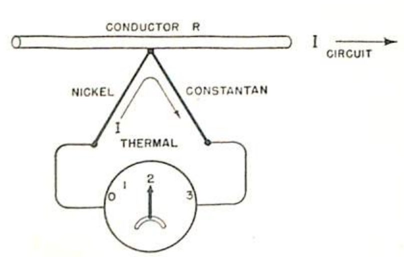


FIGURE 3—*Typical thermocouple ammeter for use on d.c. or a.c.*

The thermocouple ammeter is extensively used in high-frequency electronic circuits. Figure 3 is a typical thermo-ammeter arrangement. The resistance R is of very-small ohmic resistance and is connected in series with the circuit in which the current is to be measured. The thermocouple is mounted in direct and constant contact with R. The heating action of the current raises the temperature of the thermocouple. The thermal e.m.f. establishes a current through the sensitive meter, this current being proportional to the *heating effect* of the circuit current. According to Joule's Law of heating, the heating effect of a current varies as the square of the current value. Because heating effect varies as the square of the circuit current, the scale of the thermo-ammeter will be non-uniform, as shown in the figure.

Conduction of current in liquids. An electric current can pass in most liquids, other than molten or fluid metals, only when some of the molecules of the liquid become dissociated. The process of dissociation occurs when an inorganic salt or an acid, such as sulphuric acid, H_2SO_4, is dissolved in water. The solution is called an electrolyte, and the breaking up of molecules into atoms and groups of atoms having a positive or negative charge is called molecular dissociation. For example, consider a sulphuric acid solution, which is a common electrolyte used in storage batteries. The dissociation of each molecule of H_2SO_4 produces three charged particles: two positively charged hydrogen atoms (each deficient of one electron), and one SO_4 group of atoms carrying a double negative charge, thus

$$H_2SO_4 \rightleftarrows H^+ + H^+ + SO_4^{--}$$

This process is reversible and may proceed in either direction, as indicated by the arrows in formula above, until equilibrium is reached for the solution.

These charged atoms or groups of atoms are called *ions.* An ion has entirely different characteristics from those of the corresponding neutral atom or group. An ion will remain charged either positively or negatively until the charge carried is neutralized by an opposite charge that may be supplied by an external source of e.m.f., or by another ion of opposite polarity.

Electrolytic conduction is the term applied to the passage of current through a solution of this kind, although the current does not consist of a drift of electrons as in a solid conductor. In electrolytic conduction, the ions are the carriers of the electric charge. The number of electrons in excess or deficiency in an ion is equal to the chemical valence of the atom or group. (See *Basic Physics,* part 6, December 1947 issue, ELECTRON.) Within the solution, the current equals the sum of the charges carried through any cross section in one second by the two streams of ions: one, moving toward the anode and the other, toward the cathode. The anode is the conductor, or plate, from which the current enters the electrolyte, and the cathode is the conductor or plate where the current leaves the electrolyte.

Electrolysis and Faraday's Laws. In studying the conduction of current through solids, you learned that two effects are always present: a magnetic effect and a heating effect. In electrolytic conduction, there are also two effects: a chemical decomposition of the solution or the electrodes, and a heating effect. Chemical decomposition resulting from electric current supplied from an external e.m.f. is called *electrolysis.*

The dissociation of a metallic salt in a solution, such as silver nitrate, results in positively charged silver atoms and negatively charged nitrate groups in solution. When an external source of voltage is applied to electrodes placed in the solution, the negative terminal or cathode will attract the positive silver atoms which are deposited on the cathode when their charge is neutralized. Such a process—depositing of metal on an electrode—is called electroplating.

As the result of a long series of experiments Faraday evolved the following laws of electrolysis:

1—The mass of a substance liberated by electrolysis is proportional to the quantity of electric current which passes through the solution.

2—The mass of a substance liberated by a given quantity of current is proportional to its chemical equivalent: that is, the ratio of its atomic weight to its valence.

These two laws may be combined into one working statement: Liberated mass is equal to the electro-chemical equivalent times quantity of current, where the electro-chemical equivalent of any substance is defined as the mass of that substance which is liberated electrolytically by one coulomb of electricity.

In practice, the mass of a metal deposited on a cathode can be determined with greater accuracy than the volume of a gas formed by a similar process. The deposit of silver from a solution of silver nitrate has been carefully measured by various observers with results which differ only very slightly from 0.0011181 gram per coulomb. This mass is called the electrochemical equivalent of silver. It should be noted that the International Standard for the quantity of electricity called the coulomb is 0.0011181 grams of silver, since the known physical standard for this comparison was the Standard Kilogram (See, however, ELECTRON, Dec. 1947, page 16).

Electrochemical potentials. The contact potential which results when dissimilar metals are placed in certain electrolytes, either acid or alkaline, are of much greater magnitude than those obtained between the same metals in air. Table II, below, shows the contact potentials for a few of the more important elements when immersed in a normal electrolyte. The potentials listed in this table are not to be considered exact; they are simply given to indicate the general magnitude. The potentials will vary to some extent with temperature and purity of the metals and only slightly with the strength of the electrolyte.

Table II. *Electrochemical Series*

Element	*Contact potential and polarity when referred to hydrogen*
Potassium	—3.20 volts.
Sodium	—2.72 "
Aluminum	—1.82 "
Zinc	—0.77 "
Iron	—0.46 "
Cadmium	—0.42 "
Nickel	—0.25 "
Lead	—0.12 "
Hydrogen	00.00
Copper	0.33 "
Mercury	0.60 "
Silver	0.79 "
Carbon	0.83 "
Gold	1.08 "
Lead peroxide (approx.)	1.98 "

In any electrolytic solution, chemical reaction tends to dissociate some of the neutral molecules into positive and negative ions, the usual process by which chemical energy is converted to electrical energy. The negative ions are chemically active; that is they are the ions that will eventually cause chemical decomposition of one of the metal plates or electrodes in a battery.

Electrolytic and voltaic cells. You have just learned that when a current is passed through an acid or alkaline solution called an electrolyte, chemical decomposition takes place and a metal or gas is liberated. This process was termed electrolysis. The apparatus used is known as an electrolytic cell, and the electrical energy, supplied by an outside source, serves to produce the chemical changes involved, a small part being wasted as heat.

Cells which themselves supply electrical energy, due to the chemical reactions that occur when they contain metals immersed in an electrolyte, are called voltaic cells. In this type of cell, chemical energy within the cell is transformed into electrical energy, which is supplied to some exterior point with, of course, loss of part of the energy as heat. Voltaic cells are called primary cells when the electrodes must be replaced after use, and secondary, or storage cells, when the electrodes can be restored to their initial condition by a process called "recharging."

The chemical action within a primary cell. All elements have a chemical affinity for negative ions, the actual magnitude of the attraction for the ions being determined by the nature of the element. This may be observed from the series in table II. To avoid confusion, make a closer study of the table. Note that the contact potential is that which exists between the metal and a hydrogen reference electrode. However, a gas makes a poor electrical connection. For that reason, a second metallic electrode is required for electrical connection with an external circuit. With regard to the potential difference available to a circuit, another metal on the list is chosen for the other electrode. The actual transformation of chemical energy to electrical energy takes place at the negative electrode where the negative ions in the electrolyte give up their negative charge, or charges upon contacting the metal electrode, and in this chemical process an atom of metal is detached from the electrode and goes into the solution. The charge is built up in the negative electrode until it just counterbalances the chemical affinity for the ions by the electrode.

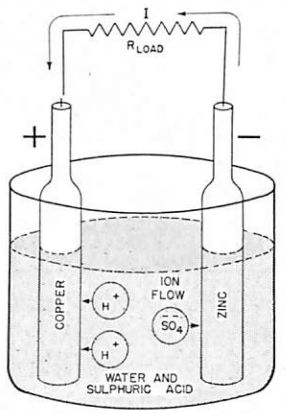


FIGURE 4—*Simple voltaic cell.*

Figure 4 shows the primary type of copper-zinc cell with an electrolyte composed of a solution of sulphuric acid and water—dissociation causing the sulphuric acid to break into plus hydrogen ions and negative So_4 (sulphate) ions. The negative ions migrate toward the zinc electrode, due to its chemical attraction, and give up their charges on contact. The chemical reaction sets a neutral zinc atom free which goes into the solution. The reaction is at equilibrium when the repulsive force of the negative charge built up on the zinc electrode is equal to the attraction the latter has for the negative ions. The same action takes place at the copper electrode, but since it has less chemical affinity for the negative ions than zinc, equilibrium is reached with less chemical reaction. Between the two electrodes will exist a potential difference due to the transformation of chemical energy to electrical energy. This potential may be determined from the series in table II by taking the algebraic difference that exists between the two elements in the series.

Polarization. Given the primary cell just described: If a metallic conductor is now connected between the exposed ends of the zinc and the copper (see figure 4), a current will flow through the wire from the zinc or negative electrode to the copper or positive electrode. These electrons stop the chemical action at the copper electrode within the solution, and the negative charge then attracts the positive hydrogen ions. Upon contact, the charge of the hydrogen ions is neutralized by picking up electrons from the copper, and when neutralized, the hydrogen ions form molecules of gas which cling to the surface of the copper electrode. The flow of electrons in the external circuit reduces the charge on the negative zinc electrode, thus permitting further chemical reaction and conversion from chemical to electrical energy. However, the formation of hydrogen gas on the copper electrode reduces the activity of the cell by making it more difficult for the positive ions to reach the surface of the copper and remove electrons. This in effect results in a zinc-hydrogen cell which is of lower potential difference than a zinc-copper cell. The reduction of cell activity by formation of hydrogen gas about the positive electrode is called *polarization.*

To eliminate polarization it is necessary to replace the hydrogen deposit at the electrode by something which is not a gas, preferably by the element of the electrode itself. In this type cell, copper sulphate is used in close contact with the copper electrode. The resulting chemical action causes the hydrogen ions to form sulphuric acid and release a positive copper ion. This in turn combines with the copper electrode, when it removes a negative electron in neutralizing its charge; thus the conductivity of the electrode remains the same. Such an agent is called a *depolarizer.*

Primary cells in common use. Primary cells differ according to the particular materials used for the electrode, the electrolyte, and the depolarizer. High electromotive force and low internal resistance are desirable, but durability and cost of materials are the controlling factors.

The so-called gravity (copper-zinc) cell previously described is one type of primary cell in common use where long unattended service is required, such as railroad switches etc. It is necessary, however, to replace the zinc electrode and the depolarizer at certain intervals. This type of cell is designed for continuous service, but becomes temporarily useless if left long on open circuit. The e.m.f. produced is about 1.08 volts and the resistance in ordinary sizes ranges from 1 to 6 ohms.

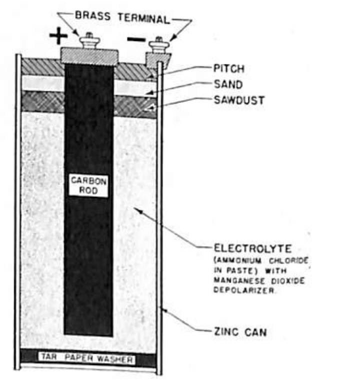


FIGURE 5—*The common dry-cell in cross section.*

The ordinary dry cell is the most common type of primary cell. It is usually discarded when used up because it is uneconomical to replace the chemically decomposed electrode.

This type of cell is not "dry" in the true sense of the word, since the electrolyte consists of a moist paste instead of a liquid, thus making it portable. Figure 5 is a cross-sectional view of the cell. The container is a zinc cylinder which also serves as the negative electrode. The positive pole is the carbon rod. The electrolyte is a solution of water and ammonium chloride, NH_4Cl. The zinc container is lined with thick blotting paper which is saturated with the electrolyte. The space between the lining and the carbon rod is packed with granulated carbon and manganese peroxide mixed in a paste wet with the electrolyte. The manganese peroxide is the depolarizer. The chemical action is as follows: dissociation of the ammonium chloride produces positive NH_4^+ ions and negative Cl^- ions. The transformation of chemical to electrical energy takes place at the zinc electrode where the negative Cl^- ions migrate and give up their charge, at the same time detaching neutral zinc that goes into the solution. The positive NH_4^+ ions take up electrons from the positive carbon rod and, in the process of doing so, break down chemically to ammonia, NH_3, and hydrogen gas. The action of the depolarizer is to remove the hydrogen gas by supplying oxygen to form water and manganese oxide. The ammonia does not materially affect the chemical transformation of energy. Whenever the external circuit is completed, the above chemical reaction takes place and current is supplied at the expense of the zinc electrode which is gradually decomposed.

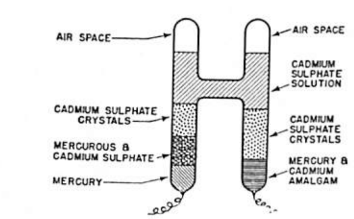


FIGURE 6—*The Weston Standard Cadmium Cell.*

The electromotive force of a new dry cell is about 1.6 volts and the resistance less than 0.1 ohm. The current on short circuit may be in the vicinity of 25 amperes. On open circuit the cell deteriorates very slowly and polarizes rapidly when a heavy current is drawn, but recovers in a short time when the current is stopped. Dry batteries are universally used in equipment requiring relatively low current for short periods, or low current alternately with large currents, such as in portable radios, door bells, flashlights etc.

Standard or Weston Cell. A standard cell is of simple design so that it can be used as a standard of electromotive force which remains constant over a long period of time. It is not intended to supply current, so it should be used in series with a high resistance in order to avoid injury from short circuits. The Weston Cadmium Cell is now used almost universally as the standard of electromotive force. The electromotive force is about 1.0188 absolute volts at 20° C. Its variation with temperature can be accurately calculated.

Figure 6 shows the simple construction of the Weston Standard Cadmium Cell. The cell is made of glass tubing in the form of the letter *H*. Platinum wires sealed in the bottom of each leg serve as terminals. Mercury and an amalgam of mercury and 12½% cadmium serve as electrodes (the same as copper and zinc, respectively, in the cell described previously). The mercurous sulphate is the depolarizer and the electrolyte is composed of a solution of cadmium sulphate. The air space at the top of each leg provides for expansion of the materials under temperature changes. The entire cell is sealed and is usually mounted inside a case in an upright position with the terminals at the bottom, so that the temperature may be measured quite accurately. Since cell e.m.f. varies exactly with temperature, exact calculations of e.m.f. can be made.

Secondary or storage cells. The discussion up to this point has centered on primary cells in which the transformation of chemical energy to electrical energy has been effected at the expense of chemical decomposition of one of the electrodes. This characteristic of a primary cell limits its use to low-current requirements. For economical reasons, therefore, it cannot be used where the current requirements are of large magnitude or of long duration.

For purposes requiring steady currents larger than can be supplied by primary cells, storage batteries are used. Batteries are combinations of secondary cells in groups that are either in series or parallel and containing a sufficient number of workable units to meet the requirements of current and voltage. Typical applications include storage batteries offering standby service in power substations to supply the load for short periods in the event of power failure of the regular generators, service as a source of power for submarines and for electric trucks, and service as independent batteries for energizing the starting and lighting circuits in automobiles.

You have previously noted that the electrodes in a primary cell cannot be chemically restored to their original form by the application of an external source of e.m.f. The construction of the secondary type cell overcomes this defect by utilizing electrode materials which can be restored by an external source of e.m.f. during a process called charging.

There are two types of secondary or storage cells used commercially; the nickel-iron or Edison cell, and the lead-lead peroxide cell. Since the lead cell is more often encountered, its operation will be briefly explained here (see figure 7). The lead battery has as its positive electrode a plate (or plates) of lead peroxide pressed firmly into a supporting grid of lead. The negative electrode consists of plates composed of pure spongy lead to provide as much surface as possible. The electrolyte is dilute sulphuric acid with a specific gravity of 1.150 to 1.300. The chemical action proceeds in much the same fashion as that of the primary cell. Dissociation of the acid in the water produces positive H^+ ions and negative SO_4^{--} ions. When the latter give up their charge at the spongy lead or negative electrode, a lead atom is dislodged, which combines with a sulphate ion to form insoluble lead sulphate. This is deposited on the plate. The positive

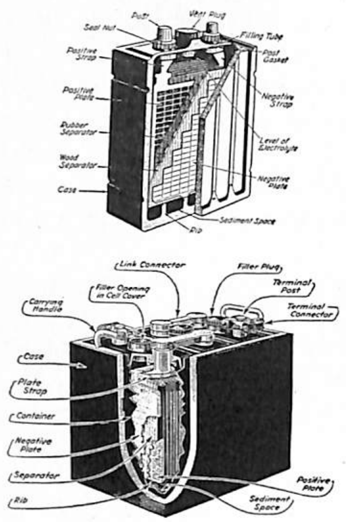


FIGURE 7—*The secondary or storage cell in cross section and when used in groups to form a storage battery.*

H^+ ions that are neutralized by taking a charge from the positive lead peroxide plate reduce it to lead oxide and oxygen. Then the neutral H atoms unite with oxygen to form water. The lead oxide, however, is unstable, and immediately combines with the acid in the electrolyte to form more water and deposits lead sulphate on the positive electrode. This is the chemical reaction that takes place when the cell is delivering current to an external source connected between the terminals. This evolution of chemical energy to electrical energy is termed the *discharge* of the cell and is accompanied by a gradual reduction of the activity of the electrolyte as evidenced by a decrease in the specific gravity. At the same time that the strength of the electrolyte is being reduced, the plates of each electrode become coated more and more with the insoluble lead sulphate which increases the internal resistance of the cell and, hence, the current delivered to the external source is decreased.

By causing current from an external source to flow through the cell in the opposite direction to which the cell supplied current, it is possible to reverse the chemical process described above and restore the electrodes and electrolyte to their original form. This charging process consists of supplying an excess of electrons to the negative electrode of the cell, which causes the coating of lead sulphate to dissociate or break down into spongy lead (left deposited on the plate) and into sulphate ions with a negative charge which are returned to the solution.

The chemical action at the positive electrode is more complex, however, since several chemical changes take place simultaneously when energy is removed from that electrode by the external source. The coating of lead sulphate combines with water in the electrolyte under these circumstances, and the sulphate ions are released from the lead sulphate, while water is separated into H^+ ions and O^{--} ions. The oxygen combines with the lead to form lead peroxide, the original composition of the electrode, and the hydrogen combines with the sulphate ions, as well as with those liberated at the negative electrode, to form sulphuric acid. The formation of acid increases the specific gravity of the electrolyte which provides a very reliable indicator as to the state of charge in the lead acid type of battery.

If the cell is overcharged or charged at too high a rate, all of the hydrogen and oxygen gas liberated will not unite with the ions of lead and sulphate. This gas escapes in the form of tiny bubbles and the effect is known as "gassing." An excess of it indicates the completion of "charge." With regard to an automobile battery, the specific gravity of the electrolyte is 1.285 when the battery is fully charged; when discharged it may fall as low as 1.150. During the charging process, a small amount of water is lost due to electrolysis and the escape of gasses formed, otherwise the processes of charge and discharge are very efficient. An efficiency of 90% is possible, but this depends greatly upon the condition of the battery, its electrodes and electrolyte, the temperature and the rate of charge and discharge.

The dynamo or electric generator. The dynamo or electric generator is a device that is used to transform mechanical energy to electrical energy, through the medium of the magnetic field. The process of transformation is easy to understand when you consider the relationship that exists between magnetic flux and directions of current and motion.

Referring back to part 13 which explained magnetic lines of force, a generalization was made to the effect that an electric current always establishes lines of force around it. The natural question that arises is whether this phenomenon can be reversed: i.e., can a current be produced in a circuit through the use of a magnetic field? Experiments conducted by Faraday in 1831, along these lines, proved that an e.m.f. could be induced in an electric circuit by a *relative motion* between the circuit and a magnetic field. These experiments lead to the conclusion that an e.m.f. will be induced in a coil or wire whenever there is a *change* in the magnetic flux *linked* with it.

Figure 8 is a simple and direct method of illustrating how an e.m.f. is induced in a conductor which is part of an electrical circuit. In the interest of simplification a horseshoe magnet is shown with one line of force. The direction of the flux line is from the N-pole to the S-pole. The conductor, shown as a heavy circle within

the area of the magnet, represents the portion of the electrical circuit within the influence of the magnetic field. The direction of motion of the conductor, in the sequence, is to the right. B, C, D, E represent the inter-

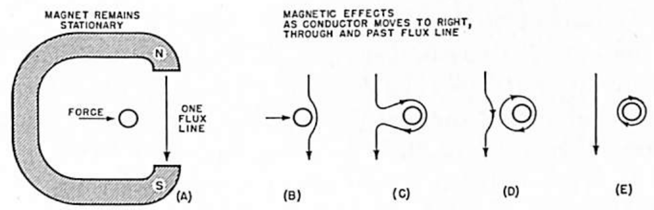


FIGURE 8—*The generation of e.m.f. by induction.*

action of the conductor and the line of flux at later intervals of time without showing the actual magnet in each case. As the conductor is moved to the right, the flux line is distorted B, and as the conductor is moved still farther the flux line extends around both sides of the conductor C, where the opposite sides of the flux line begin to attract each other because they are oppositely directed. Due to this mutual attraction they draw together as the conductor is moved farther to the right until they touch, and because of their opposite direction at this point cancellation results, as shown in D. The flux line immediately returns to its direct path between the N-pole and S-pole of the magnet while the loop that had been formed about the conductor is collapsing into the wire.

In parts 12 and 13 of this course it was shown that the magnetic field about a conductor was proportional to the current flow, therefore when a portion of the flux line is detached in the manner shown in figure 8 it will represent a certain finite magnetic field. Since a current cannot flow without its attendant magnetic field, the converse may be also taken as true; and a *changing* magnetic field, however minute, will cause a certain amount of current flow. The magnetic field produced about the conductor when it passed through the line of flux between the poles of the magnet immediately collapsed after it was formed, but in doing so, caused a minute current to flow while it was collapsing. The production of current in this manner is called *induction,* and the e.m.f. resulting from the collapsing magnetic field is called an *induced e.m.f.*

Quantitative experiments have shown that an e.m.f. of one absolute volt (electromagnetic unit) is generated when a conductor 1 cm in length cuts a magnetic field at the rate of one flux line per second. This is a very small quantity, 10^8 abvolts being equal to one practical volt. It can be stated:

$$e = B\,L\,v\ (10^{-8})\ \text{practical volts.}$$

where e represents the induced e.m.f. in volts, B is the flux density, L the active length of the conductor in centimeters and v is the velocity in cm/sec.

From the above it can be readily seen that the voltage may be increased by any one or a combination of three ways; the flux may be increased, more conductors may be used, or the speed at which the flux change is effected may be increased.

The above formula applies only when the conductor is cutting the flux lines at right angles, but when the angle between the flux lines and the direction of motion is any angle other than 90° the induced e.m.f. may be stated as:

$$e = B\,L\,v \sin\theta \times 10^{-8}\ \text{volts.}$$

Direction of induced e.m.f. and Lenz's Law. Lenz's Law in a generalization of findings from experiments on induced e.m.f. It states in effect that, *whenever a current is set up by a change of flux through a circuit, its direction will be such as to oppose the act that caused it.* This may sound confusing at first, but consider the basic laws of physics concerning energy. Energy may neither be created nor destroyed, but it may be converted from one form to another with varying degrees of efficiency. Since this is true, every force will have an equal and opposite force or reaction, which means an energy change of some kind.

In figure 8 the force which caused the induced e.m.f. was the action of moving the conductor to the right across the line of flux. The small loop about the conductor that produced the induced e.m.f. (and hence the current) is noted to be of such a direction that the current is coming out of the page. Note that in figure 8 (D) the direction of the flux line and the loop about the conductor is opposite. Therefore there is an attraction between the flux lines at this point or a force that opposes the movement of the conductor. If another flux line were placed to the right of the conductor in figure 8 (E) the lines would be of the same direction thus further opposing the movement of the wire.

In the previous chapter the behavior of a current-carrying wire in a magnetic field was shown and the force acting on the wire was found to be proportional to the flux density, the current, the active length of the conductor, and the sine of the angle between the flux direction and the direction of the conductor movement. Now, considering these two cases, it may be seen that when a conductor is moved across lines of flux, the induced e.m.f. causes a current to flow in the conductor whose magnetic field is of such a direction that the force developed is in opposition to the original force causing movement of the conductor. This conforms to all the laws regarding conservation of energy.

The electrical generator. The transformation of mechanical to electrical energy is accomplished by moving a number of conductors across magnetic flux lines. A simple generator, consisting of a single-turn loop and a two-pole permanent magnet, is shown in graphic steps in figure 9. The magnetic field between the pole faces consists of parallel lines. The single-turn loop is con-

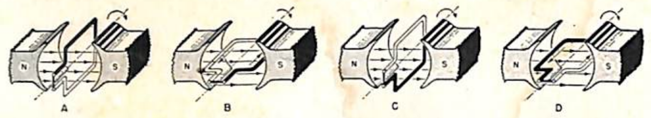


FIGURE 9—*Successive positions in generating an e.m.f. by the use of a rotating conductor in a fixed magnetic field.*

structed so that each conductor is parallel to the pole faces, and rotates about an axis that is the center of the area between the magnetic poles. The conductors of the loop rotate so as to cut the lines of force, but will cut through the lines of force perpendicularly only at two points which are opposite the center of each pole face. At all other points of rotation the angle between the line of force and the direction of conductor movement will be an angle less than 90°.

At position A, neither conductor will be cutting or passing through a line of flux. Therefore the induced e.m.f. will be zero, but as the rotation is continued, each conductor will be passing at right angles through the flux lines opposite the center of each pole face, as shown in B. The induced e.m.f. at this instant causes a current flow out of the page in the conductor opposite the N-pole and into the page in the conductor opposite the S-pole. Each conductor has opposite current direction but since the conductors are connected as shown, the induced current is in one direction. The magnitude of the induced e.m.f. and hence the current flow is maximum at this instant of rotation.

When the conductors have rotated to a position shown at C, the e.m.f. and current are again zero. Let us consider what has actually happened between positions A and C. The rotation has been at a constant rate, the flux existing between the pole faces has been constant, but the angle at which each conductor was cutting the lines of force has changed. From position A where the conductors were moving parallel to the lines of force to position B where each conductor was moving exactly at right angles, the angle of cutting lines of force has varied from zero to 90°, hence the function of the sine of the angle has varied, from zero to one. Between position B and position C the sine function of the angle of cutting has varied from one to zero, just the reverse. Since the induced e.m.f. varies as the sine function of the cutting angle, figure 10 may be used to illustrate the variation in the amplitude of induced e.m.f. versus angle of rotation. The corresponding position of the rotating element is also shown for clarity. During this half revolution, the current and induced e.m.f. have varied from zero to maximum (at 90°) and back to zero again.

As rotation is continued, at a constant rate, from C to D, the angle of cutting increases from zero to 90° again. Each conductor is now cutting flux lines in the same manner as previously explained, but the direction of the flux lines with respect to each individual conductor has reversed. From A to C the current was flowing out of the page in the black conductor and into the page in the white conductor, but now the positions of the conductors have been reversed. The field direction, however, has remained unchanged; therefore, the direction of current flow in the loop is reversed. The variation of current through the loop is again from zero to maximum at D, and back to zero at the original position A. This variation of current is plotted in figure 10 below the central line to indicate magnitude opposite to that of the first half-rotation.

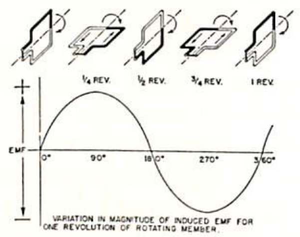


FIGURE 10—*Graph of induced e.m.f. versus position of rotor.*

Subsequent revolutions at a constant rate will produce exact replicas of the action shown in figure 9 and plotted in figure 10. This explanation describes how mechanical energy may be converted to electrical energy. The mechanical force exerted on the rotating member causes the conductor to cut the lines of force in the magnetic field which induces an e.m.f. in the circuit. The current caused to flow as a result of this induced e.m.f. is of such a direction that its magnetic field produces a force opposing the original force acting on the rotary element. When the conducting loop is complete as in this example, there is a small loss in energy in the form of heat due to the current passage through the loop, and also an amount of mechanical heat loss from the friction encountered in rotating the element.

The mechanical energy supplied plus that lost in overcoming friction is equaled by the energy from the counter force due to induced e.m.f. and current flow plus the energy lost in heating the conductors.

Utilization of this electrical energy takes many forms depending upon the application and is beyond the scope of a basic course, but will be taken up in later assignments on electrical machinery.

ANSWERS TO QUESTIONS IN PART 13

1. 11/15 dine per unit pole.
2. Two.
3. 900 to 1000 lbs. depending upon flatness of surface.
4. 4.25 amperes and using #3 AWG wire.
5. 200 grams of force per centimeter of length. Force exerted is proportional to length; therefore 20 conductors would experience a force of 2 kg.

MODEL TDH SWITCH FAILURES

During a recent field trip, a representative of the Bureau of Ships received a complaint about repeated failures of the contacts on inductance switch S-111 of the Model TDH Radio Transmitting Equipment. These failures can best be prevented by proper tuning of the balanced network used to feed the Model TDH transmission lines.

In this particular instance, by corrective tuning, the circulating tank current was reduced from approximately 60 to 21 amperes at a frequency of 8190 kc. This value compares favorably with the tank current of the Model TDH-4 Radio Transmitting Equipment which has a circulating current of 24 amperes at 8190 kc.

PORTABLE COVERPLATES FOR SONAR SEACHEST

It has come to the attention of the Bureau of Ships that various vessels having sonar sounding equipment installed are not initially provided with portable coverplates, and that in many cases the coverplates are not carried on board even though they were supplied. Attention is invited to BuShips letter S68-(1) (983) EN28/A2-11, Serial R-366, Paragraph 6, which states in part "In all cases, a portable coverplate should be prepared and fitted to the outer opening of the seachest, and then removed when the projector is in place."

Type plans based on BuShips drawings RE 78F 113, RE 78F 134 and RE 78J 136 cover fabrication of watertight coverplates for sonar sounding transducer seachests. These coverplates are bolted over the external opening of the seachests prior to the removal of the transducers, when the vessel is waterborne. A bolting ring, flush with the hull of the vessel, is provided when the seachests are built into the hull. The bolting holes are stopped-off with headless flush bolts when the coverplate is removed.

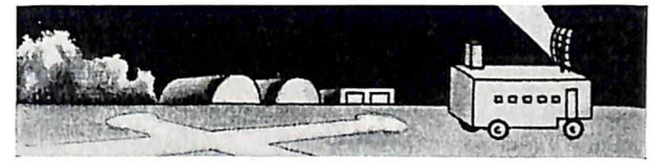
Based on a beneficial suggestion submitted by Mr. Lawrence E. James of the Mare Island Naval Shipyard, it is recommended that a nameplate be affixed to each coverplate to facilitate identification aboard ship and to prevent loss or misplacement. Action will be required as follows:

1—Weld a 3 x 5 corrosion-resistant steel nameplate to each coverplate.

2—Engrave on this nameplate in ½-inch letters "Coverplate for sonar seachest, Frame No. ———, for Model ———." (Model letters of the particular sounding equipment concerned should be used.) Also engrave "Do not destroy—for emergency use only."

3—Mount each complete coverplate by means of studs and wing nuts on a bulkhead near the seachest for which it is intended.

Type of Approach	Last Month	To Date
Practice Landings	9,647	151,700
Landings Under Instrument Conditions	199	6,576



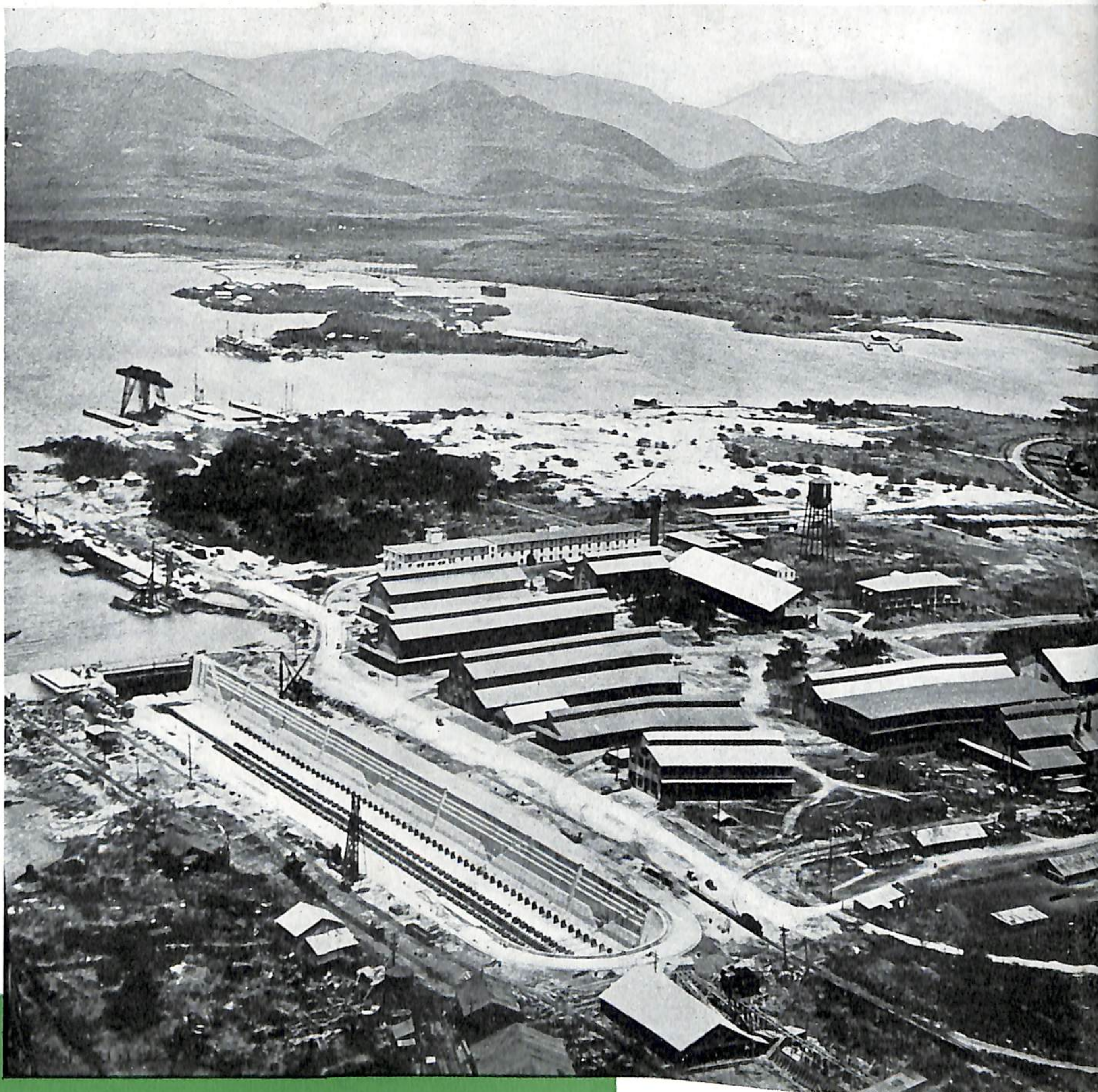
OVERHAULING TYPE CG-66ABH ANTENNAS

The Boston Naval Shipyard reports that a Type CG-66ABH Antenna Assembly of a Model SK-2 Radar Equipment was recently removed from a CVE of the Atlantic Reserve Fleet and overhauled at the shipyard. During the overhaul, the framework of the antenna was carefully wire-brushed and repainted.

After the overhaul had been completed, it became necessary to remove the upper framework of the antenna assembly in order to facilitate stowage on the hanger deck of the vessel. Upon disassembly of the I.F.F. reflector framework from the radar reflector framework it was found that the two adjoining metal surfaces were almost completely rusted away. Apparently this condition was caused by the condensation of moisture within the rectangular framework. Due to the excessive deterioration of the surfaces between the I.F.F. and radar reflector frameworks, the shipyard found it necessary to rebuild this section of the antenna.

In view of the fact that this deterioration was not detected during the regular overhaul of the antenna, the above information is brought to the attention of all overhauling activities, so that the condition described can be detected and eliminated during future antenna overhauls.

The Pearl Harbor Naval Shipyard



as it appeared in 1917